U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Geologic Map of the Cascade Head Area, Northwestern Oregon Coast Range (Neskowin, Nestucca Bay, Hebo, and Dolph 7.5 minute Quadrangles)

by

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Open File Report 96-0534

1996

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INTRODUCTION

The geology of the Cascade Head area bridges the geology in the Tillamook Highlands to the north (Wells and others, 1994; 1995) with that of the Newport Embayment on the south (Snavely and others, 1976 a,b,c). The four 7.5-minute quadrangles (Neskowin, Nestucca Bay, Hebo, and Dolph) which comprise the Cascade Head area include significant stratigraphic, structural, and igneous data that are essential in unraveling the geology of the northern and central part of the Oregon Coast Range and of the adjacent continental shelf.

Earlier studies (Snavely and Vokes, 1949) were of a broad reconnaissance nature because of limited access in this rugged, densely forested part of the Siuslaw National Forest. Also, numerous thick sills of late middle Eocene diabase and middle Miocene basalt mask the Eocene stratigraphic relationships. Previous mapping was hampered by a lack of precise biostratigraphic data. However, recent advances in biostratigraphy and radiometric age dating and geochemistry have provided the necessary tools to decipher stratigraphic and structural relationships in the Eocene sedimentary and volcanic rock sequences (W.W. Rau, personal communication, 1978 to 1988; Bukry and Snavely, 1988).

Many important stratigraphic and igneous relationships are displayed within the Casacde Head area:

(1) turbidite sandstone of the middle Eocene Tyee Formation, which is widespread in the central and southern part of the Oregon Coast Range (Snavely and others, 1964), was not deposited in the western part of the Cascade Head, and is of limited extent north of the map area (Wells and others, 1994);

(2) the late middle Eocene Yamhill Formation, which crops out along the west and east flank of the Oregon Coast Range, overlaps older strata and overlies an erosional unconformity on the lower Eocene Siletz River Volcanics (Snavely and others, 1990; 1991);

(3) thick sills of late middle Eocene diabase (43 Ma) are widespread in the Cascade Head area and also form much of the eastern flank of the Tillamook Highlands (Wells and others, 1994), but are rare south of the map area;

(4) Cascade Head is the northernmost eruptive center of late Eocene alkalic basalts--85 km north of the eruptive center of correlative alkalic flows of the

Yachats Basalt in the Newport Embayment (Snavely and Vokes, 1949; Snavely and others, 1990; Barnes and Barnes, 1992; Davis and others, 1995);

(5) early Oligocene (33 Ma) sills and dikes of nepheline syenite and camptonite present in the Newport Embayment (Snavely and Wagner, 1961) are not found in the Cascade Head area;

(6) extensive middle Oligocene (30 Ma) granophyric gabbro sills that are widespread in the central part of the Oregon Coast Range (Snavely and Wagner, 1961; MacLeod, 1969) are not present in the Cascade Head area.

The Cascade Head area is the last segment of the Oregon Coast to receive detailed geologic mapping. Increased logging operations in the 1970's and 1980's created numerous new roadcut exposures and access to exposures in stream beds. More importantly, microfossil biostratigraphic control, available since 1970, based upon foraminifer determinations by W.W. Rau and nannofossil determinations by David Bukry provided critical information on stratigraphic succession as well as on depositional environments of the deep water (bathyal) siltstone units present in much of the Cascade Head area. These paleontologic data also permitted correlations with other sedimentary sequences mapped in the Newport Embayment and in the Tillamook Highlands as well as in western Washington.

New 7.5-minute topographic maps and aerial photographs which became available in the late 1980's provided detailed topography which can be related to the distribution of thick sills and broad landslide areas, as well as a precise geographic relationship of geologic observations in this densely forested and brush-covered terrain.

New geographic information systems (GIS) technology has produced a digitized color map of the Cascade Head area that combines the four 7.5-minute quadrangles that previously were open-filed as separate black and white 7.5-minute quadrangles (Snavely and others, 1990; 1990a; 1991; 1993).

The tectonic framework and stratigraphic architecture presented on the map of the Cascade Head area was obtained by classic geologic field methods. This information could have been obtained only through detailed observation and sampling along stream beds, road cuts, and outcrops. Remote sensing techniques were of minor help in unraveling the geology in this poorly exposed and complex terrain, a terrain that characterizes much of the Oregon and Washington Coast Ranges.

GEOLOGIC SKETCH

The Cascade Head area lies astride the north-trending faulted asymmetric Salmon River arch[1] that is cored by lower Eocene oceanic basalt and volcaniclastic rocks which include the Siletz River Volcanics (Tsr) (Snavely and others, 1968) and the Salmon River Formation (Tsar) (Snavely, 1991a), and is overlain unconformably by lower and middle Eocene marine sedimentary rocks. The steep west flank of the arch consists of marine sedimentary rocks that range in age from upper Eocene to middle Miocene with a thick prism of upper Eocene alkalic basalt flows and breccia (Snavely and others, 1990a; 1991). The east flank consists chiefly

[1] Cross-hatched stripes on the geologic map show the inferred crest of the Salmon River arch.

of late middle Eocene siltstone of the Yamhill Formation (Ty) intruded by extensive diabase sills (Tid) near the base of the siltstone sequence. In the northern part of the Cascade Head area thick, widespread sills of middle Miocene basalt (Tidb) cap the arch and form the high upland areas.

A family of northwest-trending sinistral high-angle faults, linked by northeast-trending normal and oblique slip dextral faults, form a conjugate strike-slip pattern in the northern and central parts of the map area. Both the northwest- and northeast-trending faults are intruded in places by diabase dikes (Tid) (43 ± 1.8 Ma), indicating that the faulting occurred soon after the deposition of the late middle Eocene Yamhill Formation. A pop-up block of Tyee Formation (Tt) within the Yamhill Formation in the north central part of the Dolph quadrangle is bounded by two major northwest trending sinistral faults. The Tyee crustal block is segmented into rhombohedral blocks by the northeast normal and oblique slip dextral faults. The uplift of this Tyee pop-up is most likely the result of underplating and uplift due to the emplacement of thick diabase sill or sills related to the diabase dikes that occur along the margin of the pop-up block.

Since faulting, igneous activity, and the regional unconformity at the base of the Yamhill Formation are essentially contemporaneous, these events probably are related to the major plate reorganization in the Cascade forearc at about 43 Ma (Snavely, 1987). Intrusion of diabase along the northwest sinistral faults indicates a pre-43 Ma period of major faulting; however, in the western part of the Cascade Head area some northwest-trending faults offset strata as young as Oligocene (e.g., Alsea Formation (Tal) as well as middle Miocene basalt sills (Tidb)), indicating that renewed movement occurred along these northwest faults.

The structural style differs in the south part of the Cascade Head area, and extends further southward into the adjacent Euchre Mountain quadrangle (Snavely and others, 1976). Here northeast-trending normal and reverse faults interleave Siletz River Volcanics and intensely deformed basaltic sedimentary rocks of the lower Eocene Salmon River Formation (Bukry and Snavely, 1988). This family of faults is overlapped by the early middle Eocene (CP12) basaltic sandstone beds of Otis Junction (Tobs) (Snavely and others, 1990), strata correlative with the Tyee Formation. Although the major offset on these northeast-trending reverse faults was in the early Eocene, renewed movement occurred in the late Eocene as these faults offset strata in the Nestucca Formation in the Euchre Mountain quadrangle south of the map area (Snavely and others, 1976).

The oldest rocks in the Cascade Head area, the Siletz River Volcanics (Snavely and others, 1968), are seamounts which are largely pillow lava and breccia with minor basaltic sandstone and siltstone interbeds. Some basalt formed oceanic islands in the northern part of the Euchre Mountain quadrangle at Ball Mountain, just south of the area. In the map area, coccolith flora from siltstone interbeds in the Siletz River Volcanics indicate an early Eocene age (zones CP10 and 11, Bukry and Snavely, 1988).

The overlying lower Eocene (CP11) Salmon River Formation (Snavely, 1991a) consists of basaltic sandstone and conglomerate derived from erosion of the Siletz River volcanic islands. These shallow-water deposits form thick aprons adjacent to the islands. Basalt dikes and minor interbeds and pillow lavas (Tb) reflect the last vestiges of Siletz River volcanism.

Middle Eocene (CP12a and 12b) turbidite sandstone and bathyal siltstone of the Tyee Formation are widespread in the Oregon coast range south of the map area, but are restricted to the east flank of the Salmon River arch and are poorly developed to the north in the Tillamook Highlands (Wells and others, 1994). In the Cascade Head area Tyee turbidites crop out only in the east flank of the constructional volcanic high formed by the Siletz River Volcanics and Salmon River Formation (Snavely and others, 1990). The middle Eocene Basaltic sandstone of Otis Junction (Bukry and Snavely, 1988) that crops out on the west flank of the high is equivalent in age (CP12a) to the Tyee Formation.

A poorly exposed unit of basalt and well-indurated basaltic sedimentary rock and tuff crops out along Three Rivers in the central part of the Hebo quadrangle. This unit, informally referred to as basalt and sedimentary rock of Three Rivers (Ttr), may be interbedded in places with the lowermost part of the middle Eocene Yamhill Formation. The Three Rivers unit consists of columnar jointed basalt, vesicular pillow lava, black well-indurated siltstone, and white tuff beds. Filled lava tubes and invasive flows that occur locally contain abundant secondary minerals including pyrite, chalcopyrite, calcite, and zeolite. In places these flows have baked intensively the interbedded sedimentary rocks. Sparse coccolith flora in the Three Rivers basalt are assigned to the middle Eocene zone CP13 by Bukry (written communication, 1985) and may correlate with basalt and sedimentary rocks assigned to the lower part of the Tillamook Volcanics (Wells and others, 1994) in the Tillamook area.

Sills of diabase (Tid) 10-150 m thick, the most widespread intrusive rock in the Cascade Head area, commonly occur near, or at the base of, the Yamhill Formation. The thickest and most extensive sills crop out in the southeastern part of the Cascade Head area along the uplands at Saddle Bag Mountain. Here the sill (or composite sills) are more than 150 m thick and extend eastward beyond the map area into the Spirit Mountain quadrangle (MacLeod, 1969). A 500-m-thick vertical dike of diabase that was intruded along a pre-existing fault in the Yamhill Formation crops out near the southeast boundary of the Dolph quadrangle and extends eastward for more than 14 km into the adjacent Spirit Mountain quadrangle. This dike most likely was the feeder to the sills in the Saddle Bag area. Correlative diabase sills, similar to those east of the Tillamook structural arch described by Wells and others (1994), are widespread north of the map area along the east flank of the Oregon Coast Range and extend northward into southwest Washington. Sills in these two regions also were intruded into the lower part of the late middle Eocene strata.

The most widespread formation in the Cascade Head area, the late middle Eocene Yamhill Formation (CP13 to CP14a,b) (Bukry and Snavely, 1988), crops out across the broad arch extending from near the coast to the Willamette Valley (Wells and others, 1994). In the map area the Yamhill mudstone is a transgressive unit that overlaps older middle Eocene units and rests in places on the lower Eocene Siletz River Volcanics (Snavely and others, 1990; 1991). Most of the Yamhill Formation is concretionary bathyal massive and finely micaceous mudstone with an upper and lower basaltic sandstone (Tybs) and arkosic sandstone sequence. Tongues of pillow basalt flows and breccia from volcanic centers to the north in the Tillamook Highlands (Wells and others, 1995) intertongue with the Yamhill Formation (Tylt, breccia member of the Yamhill

Formation) in the northeast part of the Cascade Head area (Snavely and others, 1994). A K/Ar age on the plagioclase from a diabase sill near Castle Rock in the Hebo quadrangle is 43.2 $\pm$ 1.8 Ma (Leda Beth Pickthorn, written communication, 1987), which is in agreement with the geologic setting. Near the base of the Yamhill Formation in the northern part of the Dolph quadrangle a 10-30 m interbed of dacitic volcanic tuff contains a few small mollusks and spheres of accretionary lapilli. A correlative tuff bed occurs locally near the base of the Yamhill Formation as far south as the Heceta Head quadrangle, about 100 km south of the Cascade Head area (unpublished mapping by Snavely).

A regional unconformity of late Eocene age separates the Yamhill Formation from thin-bedded tuffaceous siltstone and silicic tuff of the upper Eocene Nestucca Formation (Tn). This marine siltstone intertongues with a lenticular wedge of the Cascade Head alkalic basalt and breccia (Tchb). The upper Eocene sequence is overlain unconformably by the Alsea Formation (Tal), a massive to thick-bedded basaltic sandstone and tuffaceous mudstone unit of latest Eocene to Oligocene age. The influx of silicic ash and pyroclastic debris on the inner and outer shelves reflects the inception of widespread volcanism in the western Cascade arc to the east. Thick (1-3 m) silicic tuff beds exposed along the north side of Nestucca Bay in the Nestucca Formation suggest that a major drainage system (e.g., the ancestral Nestucca River) was a major western drainage for volcanic debris from the western Cascade arc to this part of the forearc.

The Astoria Formation at Cape Kiwanda is the youngest marine sedimentary sequence exposed in the Cascade Head area. A regional unconformity at the base of the middle Miocene shallow water bioturbated to hummocky bedded fossiliferous micaceous arkosic sandstone of the Astoria Formation (Ta) overlaps Refugian and Zemorrian strata of the Alsea Formation. Pholad and *Thalassinoides* burrows through the unconformity indicate a semi-consolidated substrata. Burrows of the *Cruziana* facies and hummocky bedding suggest a storm-wave-dominated shelfal environment marginal to a major ancestral delta of the Columbia River to the north (Niem, 1976; Parker, 1990; Cooper, 1981). Local basaltic sandstone channels (Tabs) composed of upper Eocene volcanic detritus imply some local uplift, downcutting, and filling during a low-stand. Depoe Bay Basalt was intruded as sills (e.g., Mt. Hebo) during the middle Miocene. These basalts are petrologically identical to the Grande Ronde Basalts of the Columbia River Basalt Group (Snavely and others, 1973) and may be invasive (Niem and Niem, 1985; Niem and others, 1994).

In the late middle Miocene, the Oregon and Washington Coast Ranges along with the adjacent inner continental shelf were uplifted most likely due to the underplating of an accretionary wedge of middle Miocene to Eocene sedimentary rocks (Snavely, 1991). Although strata younger than Oligocene are not preserved along the crest of the Salmon River arch in the map area, sills (10-100 m thick) of middle Miocene basalt have been folded broadly across the arch. During the Coast Range uplift, late Miocene, Pliocene, and Quaternary strata were deposited in basins on the inner shelf (Snavely and Wells, 1991).

Interpretation of seismic-reflection profiles across the shelf of northwest Oregon (Snavely, in Niem and others, 1992) indicates that a major decollement is present on the outer continental shelf, forming the contact between complexly folded and faulted late Miocene and Pliocene strata and late Oligocene and older rocks of an accretionary prism. Regional uplift in the Oregon Coast Range may have been in response to an episode of underplating along this shallow east-dipping decollement.

The early to middle Miocene Astoria Formation at Cape Kiwanda is the youngest marine sequence exposed in the Cascade Head area. This shallow-water strata is overlapped unconformably by a thick sequence of late Miocene and Pliocene strata on the adjacent inner shelf (Snavely and Wells, 1991).

Quaternary landslides (Qls) are numerous in the Cascade Head area, most commonly in areas underlain by siltstone of the Yamhill Formation. Major landslides occur where the Yamhill Formation is overlain by thick sills of Depoe Bay Basalt, as for example along the southwest flank of Mount Hebo. Here a logging road cut exposed landslide deposits separated by three paleosoil zones, suggesting repeated mass wasting in the Quaternary. On the north slopes of Saddle Bag Mountain channelized debris-flow deposits (Qc) consist of cobbles and boulders of diabase derived from Eocene sills.

In response to both tectonic and eustatic change in relative sea level, the configuration of the coastline has undergone significant change. During the late Pleistocene low stand, the Nestucca River formed an incised valley fill (Qfc) in the Quaternary coastal plain sediment north of Cape Kiwanda. This valley, which was more than 55 m deep, was backfilled with carbonaceous silt and sand and thick beds of plant debris during the eustatic rise in sea level (Snavely, 1948). Southward-directed longshore currents shifted the mouth of the Nestucca River southward and developed an extensive spit (Qbs, Qds) extending about 7km south of Cape Kiwanda to the present mouth. Clayey estuarine deposits just seaward of the shoreline indicate that these deposits, which underlie the lower reaches of Nestucca Bay, extended beyond the present strandline.

Downwarping along the strandline is documented by a drowned forest of Sitka spruce (C14 date 1730 ± 160BP) exposed south of Proposal Rock near the coastal village of Neskowin. More than 100 tree trunks standing upright are exposed during low tide. Although the drowned forest and Quaternary terrace deposits (Qtc) on Cape Kiwanda and Cascade Head could record several glacial and interglacial high and low stands of sea level, tectonic deformation of the coastal zone is also likely. Seismic-reflection profiles offshore of Cascade Head show faults that, in places, deform the sea floor sediments (Snavely, 1987).

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Qal **Alluvial deposits (Holocene)**—Silt, sand, and basalt gravel along rivers and streams; locally includes low-lying river terrace gravels and thick colluvium; also includes estuarine and lagoonal mud, silt, and sand marginal to Nestucca Bay and the lower reaches of the Salmon River; in places unmapped Tertiary bedrock is exposed in river beds

Qbs **Beach and spit sands (Holocene)**—Beach sand and minor gravel, and spit sands; Tertiary bedrock is locally exposed at low tide along beach in winter and spring; patterned area on beach south of Neskowin is location of drowned Sitka spruce forest, C14 date 1,730 ± 160 years (Rubin and Alexander, 1958)

Qds **Dune sands (Holocene and Pleistocene)**—Active and stabilized dunes with thin paleosoil on the Nestucca River spit, adjacent to Kiwanda Beach north of Neskowin, and in the Pacific City-Cape Kiwanda area; thin veneer of eolian sand on bedrock in coastal area not mapped

Qls **Landslide debris (Holocene and Pleistocene)**—Poorly sorted angular to subrounded bedrock clasts in weathered muddy matrix, forming hummocky topography with closed depressions; mapped where deposits are readily apparent or inferred from topographic expression on maps or aerial photographs; thin colluvial deposits and small soil or rock failures not shown; landslides are pervasive, but of greatest areal extent marginal to areas capped by basalt sills, as along the southwest side of Mount Hebo, and areas underlain by siltstone along the lower reaches of the Nestucca and Salmon Rivers; half arrows show direction of movement

Qtr **River terrace deposits (Pleistocene)**—Sand and gravel; includes uplifted river deposits and estuarine deposits of carbonaceous sand and silt adjacent to Nestucca Bay and lower Salmon River; modified in places by landslide or colluvial deposits

Qc **Colluvial deposits (Pleistocene)**—Poorly sorted angular to rounded debris of diabase that form broad aprons or filled-channel deposits along the north side of Saddle Bag Mountain; commonly 2 m to 10 m thick; mapped only where deposits obscure bedrock over large areas; deposits modified in places by terraces along the Salmon River

Qtc **Coastal terrace deposits (Pleistocene)**—Thick- to thin-bedded planar to cross-bedded, fine- to medium-grained sand with minor interbeds of carbonaceous silt; well-rounded basalt cobble and pebble gravel and carbonized wood deposited locally at contact with Tertiary bedrock

Qfc **Fluvial channel deposits (Pleistocene)**—Semi-consolidated medium-bedded cross-stratified poorly sorted coarse-grained sand with interbeds of basalt gravel, massive carbonaceous silt and clay with large fragments of carbonized wood; unit contains 1 to 1.5 m bed of blocky weathering peat and lignite with thin sand and silt interbeds; peat bed is overlain by light-gray blocky-weathering tuffaceous(?) clay; unit exposed in sea cliff 350 m north of Cape Kiwanda is approximately 10 m thick, but a water well drilled near the village of Woods, 4 km southeast of the sea cliff outcrop, penetrated 55 m of correlative channel fill deposits (Snavely, 1948)

BEDROCK UNITS
Sedimentary and Volcanic Rocks

Ta **Astoria Formation (middle Miocene)**—Massive to cross-bedded and medium- to thin-bedded fine- to medium-grained micaceous, carbonaceous, arkosic to lithic sandstone, thin-bedded sandy carbonaceous siltstone and rare conglomerate beds composed of clasts of igneous and metamorphic rock types; sandstone beds exhibit planar and trough cross-bedding and large scale convolute bedding and slump structures occur locally near the unconformable contact with underlying Alsea Formation; Astoria strata are highly bioturbated and contain abundant trace fossils and thin beds of siltstone conglomerate; on north side of Cape Kiwanda glauconite, fish vertebrae, and shark teeth are concentrated along unconformable contact with the Alsea Formation; sandstone-filled burrows of Astoria sandstone extend 10 to 15 cm into the underlying Alsea mudstone; in places contain concretions and concretionary ledges, poorly preserved mollusks, and a few lenses of pebble to boulder conglomerate composed chiefly of basalt clasts; iron-oxide-stained calcareous concretions, iron sulfide nodules, and carbonized wood fragments are common; unit crops out onshore only at Cape Kiwanda where it is intruded by a 1.5 m basalt dike of middle Miocene Depoe Bay Basalt (Tidb) petrographic type (Snavely and others, 1973); offshore the basalt forms seastack at Haystock rock; mollusks indicate a correlation with the middle Miocene Astoria Formation at Newport, Oregon (Snavely and Vokes, 1949); foraminifers from the Astoria Formation at Newport are assigned to the Miocene Saucesian Stage (Snavely and others, 1976)

Tabs **Basaltic sandstone member of the Astoria Formation**—Filled-channel deposits of massive and trough cross-bedded medium-grained concretionary sandstone that contains slump structures and thin irregular siltstone beds into underlying Astoria sandstone; irregular basal contact of channel has up to 4 m of relief; sandstone composed of grains of pilotaxitic basalt derived from upper Eocene volcanic units together with minor quartz and plagioclase set in a calcite cement; unit crops out only on westernmost part of the southern headland at Cape Kiwanda

Tal **Alsea Formation (Oligocene)**—Massive to thin-bedded, blocky- and concoidal-weathering tuffaceous siltstone and claystone with minor interbeds of arkosic and basaltic fine-grained sandstone; thin tuff beds, calcareous concretions, and ledges of calcareous sandstone occur locally; minor amounts of carbonaceous plant debris present in sandy siltstone; sparse foraminifers assigned to the Refugian and Zemorrian Stages by W.W. Rau (written commun., 1983);

abundant redeposited diatoms assigned a middle Eocene to early Oligocene age by John Barron (written commun., 1989)

Talbs **Basaltic sandstone member of the Alsea Formation**—Massive to thick-bedded and trough cross-bedded basaltic grit to fine-grained concretionary sandstone with minor pebble conglomerate and siltstone; unit consists in part of broad overlapping packets of trough cross-bedded sandstone with thin-bedded carbonaceous siltstone partings; iron oxide-stained marcasite concretions occur locally; hackly-weathering sandstone contains brick-red scoria clasts and small scour and fill channels rich in shell debris; near the planar unconformable contact with the underlying sedimentary member of the Cannery Hill sequence (unit Tcsbs) along the south side of Nestucca Bay, unit Talbs consists of medium-bedded fine- to very-fine-grained fossiliferous basaltic sandstone with discontinuous calcareous ledges up to 0.3 m thick separated by tuffaceous siltstone partings; the base of the unit is marked by a 0.5 m calcareous ledge with abundant large pectens and other mollusks; this basal ledge overlaps the underlying Cannery Hill unit Tcsbs and rests upon basalt flows and breccia of unit Tcsbv; foraminifers assigned to the Refugian Stage by W.W. Rau (written commun., 1964); coccoliths assigned to the lower Oligocene CP16c(?) Subzone by D. Bukry (personal commun., 1989)

Tcsb **Sedimentary rocks and basalt of Cannery Hill (upper Eocene)**—A sequence that includes four units from youngest to oldest, (1) thin-bedded siltstone with lithic sandstone interbeds, (2) basalt flows and breccia, (3) massive tuffaceous mudstone, (4) basalt conglomerate and sandstone

Tcsbs **Siltstone and sandstone**—Thin-bedded carbonaceous tuffaceous siltstone and silty fine-grained sandstone with 2 to 3 cm thick tuff beds, and 0.3 m thick beds of flaggy dark-gray siltstone with thin-shelled mollusks; contains ledge-forming irregular and cross-bedded calcareous basaltic sandstone, light-gray tuffaceous sandstone, and a l-m thick laminated dark-gray fine-grained basaltic sandstone and light-gray laminae rich in foraminifers and shell fragments; contains channelized massive to thick-bedded pebbly and gritty basaltic sandstone with mollusk-rich beds that include large pectens, and calcareous concretions and marcasite nodules; foraminifers assigned to the lower part of the Refugian Stage by W.W. Rau (written commun., 1983); coccolith flora assigned to the late Eocene Subzone CPl5a by D. Bukry (written commun., 1989)

Tcsbv **Basalt**—Platy basalt flows, pillow lavas, lapilli tuff, and mudflow breccia with blocks of dense basalt up to 0.5 m in length; in places basalt is vesicular and scoriaceous; cut by feeder dikes and a small plug-like basalt body; red oxidized scoriaceous basalt breccia with rare volcanic bombs probably represent subaerial near vent eruptions; contains channel-fill deposits of basaltic sandstone and boulder and cobble conglomerate; the chemistry of these basalts differ from the underlying Basalt of Cascade Head, notably by their higher TiO_2 content (Davis and others, 1995)

Tcsbm **Mudstone and siltstone**—Massive, blocky weathering siliceous mudstone and siltstone with channel-fill deposits of basaltic sandstone and minor beds of fine-grained sandstone and tuff; contains numerous light-gray siliceous concretions up to 1.5 m in diameter; sparse diatoms, the only microfossils found in siltstone, suggest a latest Eocene or early Oligocene (J. Barron, written commun., 1988)

Tcsbc **Conglomerate and sandstone**—Cobble and boulder basalt conglomerate overlain by massive- to thick-bedded and cross-bedded fossiliferous coarse- to medium-grained basaltic sandstone; contains grains of red scoria and a 2 to 5 cm zone of shell hash; these basaltic sedimentary rocks eroded off upper Eocene Balsalt of Cascade Head

Tchb **Basalt of Cascade Head (upper Eocene)**—Subaerial flows of massive to platy, spheroidal-weathering porphyritic olivine-augite basalt, plagioclase-phyric basalt and aphanitic basalt (Snavely and Vokes, 1949); most basalts are alkalic (Snavely and others 1990, Davis and others, 1995); flows commonly have red scoriaceous upper surfaces; locally basalt is very vesicular, rarely pillowed, and commonly veined with calcite; includes interbeds of fine to lapilli subaqueous tuff, tuffaceous siltstone, and flow breccia; intruded by numerous feeder dikes of aphanitic basalt, olivine-augite porphyritic basalt and plagioclase-rich basalt (not differentiated on map), and several hornblende-bearing dacite dikes (mapped as Tihd); siltstone clasts and calcareous bearing concretions derived from underlying Nestucca Formation are commonly associated with breccias in lower part of sequence. The basalt of Cascade Head thins northward and grades laterally into marine tuffaceous siltstone and sandstone with subaqueous lapilli tuff interbeds assigned to the Nestucca Formation (Tn); the basalt of Cascade Head correlates with the upper Eocene Yachats Basalt of Snavely and MacLeod (1974) Davis and others, 1995; unit yields anomously young (~30 Ma) K/AR ages, but is late Eocene age on basis of microfossils above and below unit

Tchbb **Basalt breccia member**--Mudflow breccia, massive to well-bedded poorly sorted subaqueous lapilli tuff with scattered volcanic bombs and siltstone clasts; also includes irregular pod-shaped masses of lapilli-tuff that have loaded, intruded and penecontemporaneously deformed siltstone of the Nestucca Formation. Lapilli tuff represents basalt magma extruded into water-saturated sediments of the Nestucca Formation with attendant steam explosion and autobrecciation; includes peperite, mudflow breccias (lahars) with blocks of dense basalt up to 2 m in diameter set in a silty basaltic sandstone matrix; breccia commonly laced with calcite veins and in places intruded by comagmatic dense to vesicular basalt dikes. Tchbb member is differentiated only where well exposed along the coast from Roads End northward to the mouth of the Salmon River and in most places is in fault contact with siltstone of Nestucca Formation

Tn **Nestucca Formation (upper Eocene)**—Medium- to thin-bedded tuffaceous siltstone with a few interbeds of fine-grained micaceous arkosic and basaltic sandstone up to 0.5 m thick; contains abundant 0.2 to 1 m-thick tuff beds and calcareous concretions; in places sandstone is irregularly bedded, glauconitic, and fossiliferous; locally the siltstone beds are bioturbated and fissile; north of Nestucca Bay contains thick (1-1.5 m) interbeds of light gray tuff and marine tuffaceous siltstone cut by dikes and sills of iron-stained lapills tuff. The high percentages of volcanic ash in the sequence north of Cascade Head suggest a major river-transported silicic ash from vents in the Western Cascade Range to the coast; foraminifers are assigned to the upper Eocene Narizian Stage by W.W. Rau (written commun., 1979); coccoliths in the Nestucca Formation in the Neskowin quadrangle are assigned to the late Eocene CP15a Subzone (Bukry and Snavely, 1988)

Ty **Yamhill Formation (middle Eocene)**—Massive to thin-bedded concretionary finely micaceous medium to light gray siltstone with minor interbeds of thin- to medium-bedded micaceous arkosic and lithic sandstone; contains thick- to medium-bedded basaltic sandstone with thin siltstone interbeds and siltstone rip-ups; basaltic sandstone is flaggy and contains red scoria fragments and shell hash; tuff beds up to 0.5 m thick occur locally; in the Hebo and Neskowin quadrangles foraminiferal assemblages assigned to the upper Ulatisian Stage and to the lower to middle part of the Narizian Stage by W.W. Rau (written commun., 1986); coccolith flora assigned to the middle Eocene Subzones CP13c and CP14a (Bukry and Snavely, 1988); a zeolitized diabase sill 50 m thick intrudes the basal part of the Yamhill Formation on Three Rivers in the Hebo quadrangle, and has a K/Ar age of 43.2 ± 1.8 Ma (LedaBeth Pickthorn, written commun., 1987); north of the map area the Yamhill Formation intertongues with tuff-breccia, basaltic sandstone and siltstone, and basalt flows of the Tillamook Volcanics (Wells and others, 1994); a regional unconformity is present at the base of the Yamhill Formation and it onlaps rocks as old as lower Eocene

Tybs **Sandstone and tuff member**—Thick- to medium-bedded dark-gray basaltic sandstone and lapilli tuff with interbeds of well indurated dark-gray platy and nodular basaltic siltstone; analcime forms cement in some beds; calcareous concretions locally abundant; lapilli and tuff breccia contain fragments of augite crystals and are zeolite cemented; upper part of unit contains interbeds of arkosic and lithic sandstone; tuff breccia and basaltic strata represent detrital material derived from the middle Eocene Tillamook Volcanics (Wells and others, 1994) that crop out to the north; siltstone contains foraminifers assigned to late middle or early late Eocene by W.W. Rau (written commun., 1964); coccoliths are assigned to middle Eocene Subzone CP14a by D. Bukry (written commun.,1988)

Tylt **Lapilli-tuff (middle Eocene)**—Spheroidal-weathering massive to thick-bedded, zeolite- and calcite-cemented basaltic lapilli-tuff with minor interbeds of tuffaceous siltstone, and light-gray fine- to medium-grained tuff of the Yamhill Formation; irregular intrusive bodies of lapilli-tuff with blocks of baked siltstone occur north of the Little Nestucca River; some lapilli-tuff interbedded with the Yamhill siltstone may have been eroded off lenticular-shaped extrusive basalt highs; a distinctive 30-m-thick light-gray fine- to medium-grained silicic tuff bed, which contains accretionary lapilli(?) and a few thin-shelled mollusks, is present near the base of the lapilli-tuff unit

Ttr **Basalt and sedimentary Rocks of Three Rivers (middle Eocene)**—Generally poorly exposed pillow basalt and columnar-jointed basalt, lapilli tuff and breccia; minor poorly sorted basaltic sandstone and grit composed of broken grains of plagioclase feldspar and angular to subrounded fragments of basalt, basaltic andesite and felsite of the Tillamook Volcanics (with pilotaxitic flow texture composed of plagioclase and ilmenite microlites); massive to thick-bedded sandstones that are well-cemented by yellowish-brown clay minerals; most pillows are less than 1 m in diameter and very vesicular; interbedded well-indurated dark gray, finely micaceous siltstone and white tuff beds are penecontemporaneously deformed along base of invasive(?) flows and columnar-jointed filled lava tubes; abundant secondary minerals include pyrite, chalcopyrite, calcite and zeolite minerals; flows have intensely baked the adjacent sedimentary rocks; upper part of unit contains coccolith flora assigned to the CP13 Zone (Bukry, written commun., 1985); this sequence most likely correlates with basalt and sedimentary rocks assigned to the Basalt of Hembre Ridge (Wells and others, 1994) in the Tillamook Highlands north of the map area

Tt **Tyee Formation (middle Eocene)**—Well-bedded sequences of medium to thick bedded medium- and fine-grained micaceous, lithic, arkosic sandstone and micaceous carbonaceous siltstone form graded beds 1/2 to 3 m thick of turbidite origin (Snavely and others, 1964); groove and flute casts occur on the soles of beds; a 2-m-thick thin-bedded siltstone and sandstone unit is present at the base of the Tyee Formation along the Salmon River where it unconformably overlies the Siletz River Volcanics. The siltstone is overlain by 30-cm-thick Tyee turbidites with calcareous concretions 25 cm in diameter; deposition of Tyee turbidites was restricted to the east side of volcanic highs formed by the lower Eocene Siletz River Volcanics as correlative strata on the west side are the basaltic sandstone of Otis Junction (Bukry and Snavely, 1988; Snavely and others, 1990a). Foraminifers from hemipelagic claystone laminae along the top of some turbidite beds are referred to the Ulatisian Stage by W.W. Rau, written commun., 1976). Coccoliths from these claystone laminae in the Euchre Mountain quadrangle immediately south of the map area and from a 50-m-thick siltstone unit (Tts) that overlies the Tyee turbidites in the north-central part of the Dolph quadrangle are assigned to Subzone CP12b of early middle Eocene age (Bukry and Snavely, 1988; Bukry, written commun., 1989)

Tts **Siltstone member (middle Eocene)**—Thin- to medium-bedded fissile siltstone with minor 1 m thick interbeds of spheroidal-weathering gritty lithic sandstone cemented with calcite in the upper part of the Tyee Formation, mostly in the northern part of the Dolph quadrangle. Coccoliths assigned to Subzone CP12b of early middle Eocene age by D. Bukry (written commun., 1989)

Tobs **Basaltic sandstone of Otis Junction (middle Eocene)**—Medium- to thin-bedded basaltic sandstone and siltstone with beds rich in shell debris, calcareous algae, and carbonaceous material; includes several punky limy beds rich in weathered *Discocyclina*; unit onlaps a pillow basalt flow in the Salmon River Formation with low angle unconformity; coccoliths from calcareous siltstone beds assigned to Subzone CP12b of lower middle Eocene age (Bukry and Snavely, 1988). Unit is unconformably overlapped by the Yamhill Formation north of Salmon River. Unit Tobs correlates in age with the Tyee Formation and probably was deposited only west of oceanic islands formed by the Siletz River Volcanics

Tsar **Salmon River Formation (lower Eocene)**—Thick- to medium-bedded, coarse- to fine-grained basaltic sandstone and siltstone with calcareous ledges and concretions; thin- to medium-bedded siltstone and calcareous sandstone and platy siltstone with shell hash occur locally; contains minor interbeds of basalt cobble and pebble conglomerate; in the southwestern part of the Dolph quadrangle the unit contains thick interbeds of massive- to medium-bedded zeolitized lapilli-tuff and an amygdaloidal pillow basalt flow (Tb); pyrite-rich calcareous nodules occur in siltstone; near the lower contact with the Siletz River Volcanics the unit consists of massive to thick-bedded filled channel deposits of boulder and cobble conglomerate composed of well-rounded zeolitized basalt, pillow rinds, and diabase which are set in a matrix of gritty basaltic sandstone; irregular basalt dikes less than 0.5-m-thick that locally cut unit are feeder dikes to sparse flows in sequence; unit mostly represents basaltic debris eroded off Siletz River oceanic islands and deposited chiefly in a shallow-water environment (Snavely, 1991); coccoliths assigned to Subzone CP11 of early Eocene age (Bukry and Snavely, 1988)

Tsr **Siletz River Volcanics (lower Eocene)**—Pillow lava, flow breccia, tuff-breccia, and lapilli-tuff of tholeiitic and alkalic basalt with minor interbeds of marine basaltic sandstone, siltstone, and conglomerate; close-packed pillows range in diameter from 0.5 to 2 m (average 1 m), have radiating columnar joints, are pervasively zeolitized and veined with calcite and zeolite minerals, and are commonly amygdaloidal; basalt is aphanitic to porphyritic with phenocrysts of plagioclase and augite (Snavely and others, 1968); contains minor 1 to 2-m-thick beds of massive to graded and cross-bedded basaltic sandstone with siltstone rip-up clasts. Unit is entirely of submarine origin in the area but locally includes subaerial flows in adjacent Euchre Mountain quadrangle to the south (Snavely and others, 1976); foraminifers assigned by W.W. Rau (written commun., 1976) to the Penutian Stage; coccoliths from siltstone interbeds along the Little Nestucca River in the Nestucca Bay quadrangle are assigned to Zone CP10 of early Eocene age (Bukry and Snavely, 1988; Snavely and others, 1990b). These oceanic basalts, which in places formed islands and seamounts, are interpreted to have formed *in situ* during oblique rifting and extension of the continental margin (Snavely, 1984, 1987; Wells and others, 1984)

Intrusive Rocks

Tidb **Depoe Bay Basalt (middle Miocene)**—Dikes and sills of massive and columnar jointed fine-grained equigranular basalt; extensive sills up to 200 m thick cap Mount Hebo and Mt. Gauldy; a K/Ar age of 15.1 ± 0.4 thick was obtained from the basalt dike on Cascade Head (LedaBeth Pickthorn, written commun., 1983); petrochemically similar to the Grande Ronde Basalt of the Columbia River Basalt Group and the Depoe Bay Basalt in the central Oregon Coast Range (Snavely and others, 1973)

Tiao **Olivine-augite-phyric basalt (upper Eocene)**—Sills and minor dikes that intrude the Nestucca and Yamhill formations; characterized by abundant olivine, augite, and plagioclase phenocrysts commonly 2 to 10 mm in diameter; rocks with similar composition and age occur as flows in the basalt of Cascade Head (unit Tchb); similar thick sill-like bodies are widespread east of Cascade Head extending into the southeastern part of the Dolph quadrangle, these bodies most likely are invasive flows from the volcanic center at Cascade Head

Tip **Peperite dikes (upper Eocene)**—Peperite dikes consisting of sedimentary and juvenile volcanic clasts; grains ranging in size from medium- to some of pebble-size; intrudes siltstone and sandstone of the Nestucca formation near contacts with basalt breccia member of the basalt of Cascade Head (Tchbb); probably a consequence of steam-injection of basaltic magma into water saturated semiconsolidated sediment

Tipb **Plagioclase-phyric basalt and basaltic andesite dikes (upper Eocene)**—Plagioclase-phenocryst-bearing basalt dikes 0.5 to 3 m in width and less common small sills that intrude the Nestucca and Yamhill formations and the basalt of Cascade Head; dikes are not mapped in basalt of Cascade Head unit

Tihd **Hornblende dacite dikes (upper Eocene?)**—Porphyritic hornblende dacite dikes 1 to 2 m thick, intrudes basalt of Cascade Head east of the village of Neskowin; contains prismatic hornblende phenocrysts 1.5 cm to 3 cm in length together with zoned plagioclase; K/Ar ages of 33.6 ± 1.3 and 34.0 ± 1.0 Ma determined on hornblende and whole rock respectively (LedaBeth Pickthorn, written commun., 1986); however, this is probably a minimum age as the stratigraphic position of basalt of Cascade Head indicates these rocks are of late Eocene age

Titb **Basalt sill (upper Eocene)**—Basalt characterized by markedly trachytic fine-grained basalt composed of needle-shaped microlites of plagioclase in a groundmass augite, olivine, altered glass, and opaque minerals; sill intrudes Yamhill Formation; basalt with similar texture occurs as flows in the upper Eocene basalt of Cascade Head in Neskowin quadrangle.

Tid **Diabase sills (middle Eocene)**—Sills of fine- to coarse-crystalline equigranular to porphyritic diabase 10 to 150 m thick; commonly albitized and laumontized; basalt at chilled margins has pilotaxitic texture and in places is vesicular or amygdaloidal; a 60 m-thick sill near Castle Rock in the Hebo quadrangle has a K/Ar plagioclase age of 43.2 ± 1.8 Ma (LedaBeth Pickthorn, written commun., 1987)

Tiu **Basaltic intrusive rocks, undivided (middle Miocene and Eocene)**—Sills and dikes of basalt, diabase, and fine-grained gabbro

ACKNOWLEDGMENTS

The authors gratefully acknowledge age assignments based upon foraminifers by W.W. Rau and upon coccoliths by D. Bukry. Their biostratigraphic studies improved the quality of both the stratigraphic and tectonic framework of the area. Rau's assignments of the foraminiferal assemblages are to the Eocene Stages of Mallory (1959). The authors also thank Diane Minasian, Dan Hafley, and Mike Smith who assisted in geologic field studies. Wendy Niem ably assisted in the preparation of the geologic map, and Diana Collins and Anne Gartner carefully typed the manuscript. We thank Ray Wells for sharing his geologic knowledge of the Oregon and Washington Coast Ranges and for many insightful discussions of the tectonic history of the Cascadia forearc. His careful review of the map is gratefully acknowledged.

REFERENCES CITED

Barnes, M.A., and Barnes, C.G., 1992, Petrology of Late Eocene basaltic lava at Cascade Head, Oregon Coast Range: J. Volcan. Geotherm. Res., v. 52, p. 157-170.

Bukry, David, and Snavely, P.D., Jr., 1988, Coccolith zonation for Paleogene strata in the Oregon Coast Range, *in* Filewicz, M.V., and Squires, R.L., eds., Paleogene Stratigraphy, West Coast of North America: Pacific Section, Society of Economic Paleontologists and Mineralogists, West Coast Paleogene Symposium Volume 58, p. 251-263.

Callender, A.D., Jr., 1977, Middle and upper Eocene biostratigraphy (Foraminifera) of the Cascade Head area, Lincoln and Tillamook Counties, Oregon: Portland, Oregon, Portland State University unpublished M.S. thesis, 212 p.

Davis, A.S., P.D. Snavely, Jr., L.B. Gray, and D.L. Minasian, Petrology of Late Eocene lavas erupted in the forearc of central Oregon: Open-File Report 95-40.

Kleinpell, R.M., 1938, Miocene stratigraphy of California: Tulsa, Oklahoma, American Association of Petroleum Geologists, 450 p.

MacLeod, N.S., 1969, Geology and igneous petrology of the Saddleback area, central Oregon Coast Range: Santa Barbara, California, University of California, Ph.D Dissertation, 205 p., unpublished.

Mallory, V.S., 1959, Lower Tertiary biostratigraphy of the California Coast Ranges: Tulsa, Oklahoma, American Association of Petroleum Geologists, 416 p.

Rubin, M., and Alexander, C., 1958, USGS Radiocarbon dates IV: Science, v. 127, no. 3313, p. 1476-1487.

Schenck, H.G., and Kleinpell, R.M., 1936, Refugian stage of the Pacific coast Tertiary: American Association of Petroleum Geologists Bulletin, v. 20, no. 2, p. 215-225.

Snavely, P.D., Jr., 1948, Coquille formation in the Nestucca Bay Quadrangle, Oregon: Geological Society of Oregon, Geological News Letter, v. 14, no. 2, p. 11-12.

Snavely, P.D., Jr., 1984, Sixty million years of growth along the Oregon continental margin, *in* Clarke, S.H., ed., U.S. Geological Survey, Highlights in marine research: U.S. Geological Survey Circular 938, p. 9-18.

Snavely, P.D., Jr., 1987, Tertiary geologic framework, neotectonics, and petroleum potential of the Oregon-Washington

Continental Margin, *in* Scholl, D.W., Grantz, A., and Vedder, J.G., compilers and editors, Geology and resource potential of the continental margin of western North America and adjacent ocean basins--Beaufort Sea to Baja California: Houston, Texas, Circum-Pacific Council for Energy and Mineral Resources Earth Science Series, v. 6, p. 305-335.

Snavely, P.D., Jr., 1991, Cenozoic geologic history of the Oregon and Washington continental margin: Proceedings of the Exclusive Economic Zone (EEZ) Symposium on Mapping and Research: U.S. Geological Survey Circular 1092, p. 30-36.

Snavely, P.D., Jr., 1991a, The Salmon River Formation--A lower Eocene sequence in the central Oregon Coast Range: U.S. Geological Survey Bulletin 1935, Changes in Stratigraphic Nomenclatures by the USGS, p.1-4.

Snavely, P.D., Jr., Bukry, David, and Wells, R.E., 1993, Coccolith-bearing late middle Eocene kerogen shale, Tillamook Highlands, Northwest Oregon Coast Range: U.S. Geological Survey Open-File Report 93-623.

Snavely, P.D., Jr., and MacLeod, N.S., 1974, Yachats Basalt--an upper Eocene differentiated volcanic sequence in the Oregon Coast Range: U.S. Geological Survey Journal of Research, v. 2, no. 4, p. 395-403.

Snavely, P.D., Jr., and Vokes, H.E., 1949, Geology of the coastal area between Cape Kiwanda and Cape Foulweather, Oregon: U.S. Geological Survey Oil and Gas Investigations Preliminary Map 97, scale 1:62,500.

Snavely, P.D., Jr., and Wells, R.E., 1991, Cenozoic evolution of the continental margin of Oregon and Washington, *in* Rogers, A.M., and Walsh, T.J., eds., Assessing and reducing earthquake hazards in the Pacific Northwest: U.S. Geological Survey Open-file report 91-441-B.

Snavely, P.D., Jr., MacLeod, N.S., and Minasian, D.L., 1990, Preliminary geologic map of the Nestucca Bay quadrangle, Tillamook County, Oregon: U.S. Geological Survey Open-File Report 90-202, scale 1:24,000.

Snavely, P.D., Jr., MacLeod, N.S., and Minasian, D.L., 1990a, Preliminary geologic map of the Neskowin quadrangle, Lincoln and Tillamook Counties, Oregon: U.S. Geological Survey Open-File Report 90-413, scale 1:24,000.

Snavely, P.D., Jr., MacLeod, N.S., and Minasian, D.L., 1991, Preliminary geologic map of the Dolph quadrangle, Lincoln, Tillamook, and Yamhill Counties, Oregon: U.S. Geological Survey Open-File Report 91-277.

Snavely, P.D., Jr., MacLeod, N.S., and Minasian, D.L., 1993, Preliminary geologic map of the Hebo quadrangle, Tillamook, and Yamhill Counties, Oregon: U.S. Geological Survey Open-File Report 93-302, scale 1:24,000.

Snavely, P.D., Jr., MacLeod, N.S., and Wagner, H.C., 1968, Tholeiitic and alkalic basalts of the Eocene Siletz River Volcanics, Oregon Coast Range: American Journal of Science, v. 266, p. 454-481.

Snavely, P.D., Jr., MacLeod, N.S., and Wagner, H.C., 1973, Miocene tholeiitic basalts of coastal Oregon and Washington and their relations to coevalbasalts of the Columbia Plateau: Geological Society of America Bulletin, v. 85, p. 387-424.

Snavely, P.D., Jr., MacLeod, N.S., Wagner, H.C., and Rau, W.W., 1976, Geologic map of the Cape Foulweather and Euchre Mountain quadrangles, Lincoln County, Oregon: U.S. Geological Survey Miscellaneous Investigations Map I-868, scale 1:62,500.

Snavely, P.D., Jr., MacLeod, N.S., Wagner, H.C., and Rau, W.W., 1976, Geologic map of the Yaquina and Toledo quadrangles, Lincoln County, Oregon: U.S. Geological Survey Miscellaneous Investigations Series Map I-867, scale 1:62,500.

Snavely, P.D., Jr., Wagner, H.C., and MacLeod, N.S., 1964, Rhythmic-bedded eugeosynclinal deposits of the Tyee Formation, Oregon Coast Range: Kansas Geological Survey Bulletin 169, v. 2, p. 461-480.

Wells, R.E., Engebretson, D.C., Snavely, P.D., Jr., and Coe, R.S., 1984, Cenozoic plate motion and volcano-tectonic evolution of western Oregon and Washington: Tectonics, v. 3, no. 2, p. 275-294.

Wells, R.E., Snavely, P.D., Jr., MacLeod, N.S., Bukry, D., and Kelley, M., 1994, Geologic map of the Tillamook Highlands, Northwest Oregon Coast Range, Tillamook County, Oregon: U.S. Geological Survey Open-File Report 94-21, scale 1:62,500.