



Lidar-Revised Geologic Map of the Uncas 7.5' Quadrangle, Clallam and Jefferson Counties, Washington

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Pamphlet to accompany
Scientific Investigations Map 3160

2011

**U.S. Department of the Interior
U.S. Geological Survey**

U.S. Department of the Interior
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Suggested citation:

Tabor, R.W., Haeussler, P.J., Haugerud, R.A., and Wells, R.E., 2011, Lidar-revised geologic map of the Uncas 7.5' quadrangle, Clallam and Jefferson Counties, Washington: U.S. Geological Survey Scientific Investigations Map 3160, 25 p., scale 1:250,000 [<http://pubs.usgs.gov/sim/3160/>].

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About Revision from Lidar Topography

In 2000 and 2001, the Puget Sound Lidar Consortium obtained 1 pulse/m² lidar data for about 65 percent of the Uncas 7.5' quadrangle. For a brief description of LIDAR (Light Detection And Ranging) and this data acquisition program, see Haugerud and others (2003). This map combines geologic interpretation (mostly by Haugerud and Tabor) of the 6-ft (2-m) lidar-derived digital elevation model (DEM) with the geology depicted on the Preliminary Geologic Map of the Uncas 7.5' Quadrangle, Clallam and Jefferson Counties, Washington, by Peter J. Haeussler, and others (1999).

Interpretation of the lidar DEM began with a geomorphic interpretation following the methods outlined by Haugerud (2009). We did no additional field work to make this map, and, although the lidar DEM provides little insight to the bedrock geology, we revised the extent of bedrock outcrops based on geomorphic interpretation of the DEM.

We also revised the stratigraphy of the Tertiary bedrock units to conform to changes in the Eocene time scale (Gradstein and others, 2005) and revised the interpretation of some structure and identification of a major outcrop area. We also smoothed a few lengthy buried faults and moved them slightly to accommodate changes in the revised bedrock extent. We added a cross section to illustrate the revised structural interpretation.

The absolute positions of geographic features in Haeussler and others (1999), based on the 1953 (revised 1973) 1:24,000-scale topographic map, do not match well with the lidar DEM. For this reason, contacts adopted directly from the original map are shown as approximately located. We reproduced structural data directly from Haeussler and others (1999) but moved a few features slightly to accommodate the revised base. For instance, a bedding attitude that is west of a creek on the old map might plot east of the creek on the new base; we have moved it to the west side.

Landforms revealed by lidar for most of the Uncas quadrangle are different in character than those portrayed on the 1953 topographic map. Alluvial flats—both Holocene and late Pleistocene—are easily distinguished from the fluted, rolling glaciated terrain of most of the quadrangle. Most stream valleys are steep-sided canyons with a distinct break in slope to more gentle terrain of the interfluves. This canyon form is depicted on the 1953 topographic map for Snow Creek and the lower ends of major drainages but not for other valleys.

Much of the text, especially in the descriptions of materials, in this revision has been taken verbatim from Haeussler and others (1999) with only minor editing.

There are no digital representations of drainage or road networks that are sufficiently accurate to match the lidar DEM. We have digitized both from the DEM. Many logging roads are apparent on the DEM that are not shown on other large-scale road maps. These roads may not be maintained, and we referred to 1:24,000-scale road depictions on the 1953 topographic map and Google Earth to select the roads we digitized. We selected streams to digitize based on 1:24,000-scale drainage depictions.

Acknowledgments

We benefited greatly from reviews by Dori Kovanen and Russell Evarts. The metadata accompanying this report was much improved by Karen Wheeler.

Geologic Summary

Introduction

The Uncas quadrangle in the northeastern Olympic Peninsula covers the transition from the accreted terranes of the Olympic Mountains on the west to the Tertiary and Quaternary basin fills of the Puget Lowland to the east. Elevations in the map area range from sea level at Port Discovery to 4,116 ft (1,255 m) on the flank of the Olympic Mountains to the southwest. Previous geologic mapping within and marginal to the Uncas quadrangle includes reports by Cady and others (1972), Brown and others (1960), Tabor and Cady (1978a), Yount and Gower (1991), and Yount and others (1993). Paleontologic and stratigraphic investigations by University of Washington graduate students (Allison, 1959; Thoms, 1959; Sherman, 1960; Hamlin, 1962; Spencer, 1984) also encompass parts of the Uncas quadrangle. Haeussler and Wells mapped in February 1998, following preliminary mapping by Yount and Gower in 1976 and 1979. The description of surficial map units follows Yount and others (1993) and Booth and Waldron (2004). Bedrock map units are modified from Yount and Gower (1991) and Spencer (1984). We used the geologic time scale of Gradstein and others (2005).

The Uncas quadrangle lies in the forearc of the Cascadia subduction zone, about 6.25 mi (10 km) east of the Cascadia accretionary complex exposed in the core of the Olympic Mountains (Tabor and Cady, 1978b). Underthrusting of the accretionary complex beneath the forearc uplifted and tilted eastward the Coast Range basalt basement and overlying marginal basin strata, which comprise most of the rocks of the Uncas quadrangle. The Eocene submarine and subaerial tholeiitic basalt of the Crescent Formation on the Olympic Peninsula is thought to be the exposed mafic basement of the Coast Range, which was considered by Snavely and others (1968) to be an oceanic terrane accreted to the margin in Eocene time. In this interpretation, the Coast Range basalt terrane may have originated as an oceanic plateau or by oblique marginal rifting, but its subsequent emplacement history was complex (Wells and others, 1984). Babcock and others (1992) and Haeussler and others (2003) favor the interpretation that the basalts were the product of an oceanic spreading center interacting with the continental margin. Regardless of their origin, onlapping strata in southern Oregon indicate that the Coast Range basalts were attached to North America by 50 Ma; but on southern Vancouver Island, where the terrane-bounding Leech River Fault is exposed, Brandon and Vance (1992) concluded that suturing to North America occurred in the broad interval between 42 and 24 Ma. After emplacement of the Coast Range basalt terrane, the Cascadia accretionary wedge developed by frontal accretion

and underplating (Tabor and Cady, 1978b; Clowes and others, 1987). Domal uplift of the part of the accretionary complex beneath the Olympic Mountains occurred after ~18 Ma (Brandon and others, 1998). Continental and alpine glaciation during Quaternary time reshaped the uplifted rocks of the Olympic Mountains.

Stratigraphy

Bedrock

The oldest rocks in the quadrangle belong to the lower(?), middle, and late(?) Eocene Crescent Formation, which consists of submarine and subaerial basalt flows, breccia, and interbedded sedimentary rocks. Pillow lavas, pillow and lapilli breccia, amygdaloidal lava flows, dark-gray calcareous mudstone, basaltic siltstone, and sandstone make up the lower submarine unit (unit Tcs) exposed in the southwest corner of the quadrangle. Calcareous nannoplankton from interbedded turbidite siltstone and sandstone at the top of the submarine unit at Bon Jon Pass, 1 km west of the quadrangle, are referred to the CP 11 zone, or early Eocene (about 50 Ma), by D. Bukry (written commun., 1998). Most of the upper part of the Crescent Formation consists of amygdaloidal basaltic flows and breccia (units Tcf, Tcb, Tcfb, and Tcs). The breccia is monolithologic, and the flows in some places have rubbly reddish weathering surfaces that indicate subaerial eruption. However, about 9 mi (14.4 km) south of the map area on the west shore of Quilcene Bay, Spencer (1984) noted massive basaltic flows interbedded with pillow lavas, indicating complex depositional environments typical of oceanic islands. No ages have been determined from the subaerial part of the Crescent Formation within the quadrangle. In the Bremerton area, 25 mi (40 km) to the south, Duncan (1982) reported an $^{40}\text{Ar}/^{39}\text{Ar}$ age of 55.3 ± 3.1 Ma, and Babcock and others (1992) report an $^{40}\text{Ar}/^{39}\text{Ar}$ age of 50.3 ± 1.5 Ma. East of the quadrangle, Yount and Gower (1991) report foraminifera referable to the Ulatisian benthic foraminiferal stage (early middle Eocene) within marine siltstones and sandstones of the Crescent Formation.

Marine basaltic conglomerate, sandstone, and mudstone (unit Tebs) overlie the basaltic flows and breccia of the Crescent Formation. These basaltic sediments are found in the northeastern part of the quadrangle along the Salmon Creek drainage and along Highway 101 on the west side of Port Discovery. Spencer (1984) measured the section in Salmon Creek as more than 232 m thick and argued that its rocks are sourced from the Crescent Formation. Spencer (1984) found that the contact with the underlying basalt was irregular and undulatory, with limestone pods in basaltic breccia at the base of the section, suggesting some erosion between deposition of the two units. Subaerial basalt flows and breccia stratigraphically beneath the marine basaltic sandstones indicate subsidence following the end of basaltic volcanism. The basaltic sediments contain upper Ulatisian to lower Narizian benthic foraminiferal stage taxa and mollusks indicative of middle Eocene age. Macrofossils, microfossils, and trace fossils indicate subtropical to temperate water temperatures at neritic water depths <200 m (Spencer, 1984). Based on fossils, Tabor and Cady (1978a) cite a late Eocene age

for basaltic sandstones now included in this unit, but subsequent revision of the time scale makes the age more likely middle Eocene (Gradstein and others, 2005).

The middle and late Eocene Aldwell Formation (unit Ta) crops out in the southeastern part of the quadrangle, near the Snow Creek road. Regionally, the Aldwell Formation consists of thin-bedded slope mudstone and thin-bedded turbidite sandstone (Tabor and Cady, 1978a). Massive to well-bedded basaltic conglomerate and lithic sandstone occur locally. Along Quilcene Bay, south of the map area, basal Aldwell Formation interfingers with basaltic sedimentary rocks (Tebs?), and the contact is placed where coarse, massive to thick-bedded volcanoclastic rocks give way to the more thinly bedded sandstone and siltstone of the Aldwell (Spencer, 1984, p. 24–25). The upper contact of the Aldwell Formation is not exposed in the map area, but it may be unconformable based on relations with the overlying Lyre Formation elsewhere on the Olympic Peninsula. Foraminifera from the Aldwell Formation are referable to the lower Narizian or upper Ulatisian benthic foraminiferal stages. At Quilcene Bay, south of the map area, calcareous nannoplankton from the Aldwell are referable to calcareous nannofossil CP 14a zone (upper middle Eocene, about 42–40 Ma; D. Bukry, written commun., 1998). These fossil data indicate that the Aldwell Formation is coeval with the middle Eocene basaltic sedimentary rocks (Tebs) described above. The paleoecology of faunas collected from the Aldwell Formation indicates cool to cold water temperatures at bathyal depths (Spencer, 1984), which is quite different from the neritic water depths and warm temperatures during deposition of basaltic sedimentary rocks overlying the Crescent Formation.

The upper Eocene Lyre Formation (unit Tl) is about 300 m thick in the map area (Spencer, 1984) and consists mostly of conglomerate, with some interbedded andesite tuff and breccia (unit Tlav). Locally, the conglomerates are either clast or matrix supported. Commonly there is no preferred orientation for the clasts, which suggests deposition by debris flows in a submarine fan environment. In the southern part of the Uncas quadrangle, the Lyre Formation lies on the Aldwell Formation. Along the west edge of the quadrangle and northeast of the quadrangle, the Lyre Formation lies directly on the Crescent Formation. Spencer (1984) observed the contact in the upper part of the Snow Creek drainage and described it as irregular and undulatory. Near the contact northeast of the quadrangle, the formation contains basaltic cobble and boulder conglomerate. From these observations, Spencer (1984) inferred that there was considerable relief on the surface beneath the Lyre Formation. Spencer (1984) measured 418 paleocurrent indicators in the Lyre Formation and found a consistent south-southwest direction of transport. The base of the section has a higher percentage of basaltic clasts, which indicates erosion of the underlying Crescent Formation. Chert and phyllite clasts are also common in the conglomerates (units Tllc and Tluc), and Snively and others (1993) and Garver and Brandon (1994) concluded that similar clasts in the Lyre Formation at the northwest tip of the Olympic Peninsula were derived from Mesozoic sediments on southern Vancouver Island.

There is no direct fossil control on the age of the Lyre Formation in the map area, but to the west it contains foraminifera referable to the upper benthic foraminiferal Narizian stage

(Snively and others, 1993). The interbedded andesitic volcanic rocks (unit **Tlav**), near the bottom of the unit on Mount Zion, just west of the quadrangle, may represent post-Crescent Formation rejuvenation of Coast Range volcanism or may represent the distal parts of the earliest lavas derived from the Cascade Volcanic Arc. Hornblende separates from an andesite boulder in this unit collected just west of the quadrangle boundary, near the summit of Mount Zion and near the bottom of the Lyre Formation, yielded K-Ar ages of 36.4 ± 1.3 and 42.1 ± 6.9 Ma (Engels and others, 1976; ages corrected for new constants). Although Spencer's (1984) biostratigraphic reasoning indicates that the unit is middle Eocene in age, the analytically more secure isotopic age of about 36 Ma suggests that the Lyre Formation in the Uncas quadrangle is mostly late Eocene. Possibly correlative silicic volcanic rocks have been described in the Sequim quadrangle to the northwest, where they were included in the Crescent Formation by Schasse and Logan (1998).

Silty sandstone and sandstone turbidites in the Snow Creek drainage form the sandstone of Snow Creek. Spencer first used the informal name "sandstone of Snow Creek" and we follow his usage. The section in the upper Snow Creek drainage is 567 m thick; foraminifera are referable to the upper Narizian stage and are "indicative of cool to cold water temperatures and water depths in the lower bathyal zone" (Spencer, 1984, p. 135). Sandstone grains are predominantly chert and lesser quartz (Spencer, 1984). Spencer (1984) notes that the sandstone of Snow Creek (**Tss**) and the Lyre Formation are related because of a conformable contact and because there is an abundance of chert and metamorphic clasts in both units, which indicates a similar source area. The sandstone of Snow Creek, at least locally, overlies conglomerates of the Lyre Formation, but the upper Narizian benthic foraminiferal stage age suggests that it is in part contemporaneous with the Lyre Formation. Deposition of the sandstone of Snow Creek appears to be localized, because it is not found northeast of the quadrangle, where the Townsend Shale lies unconformably on the Lyre Formation (Thoms, 1959).

Yount and Gower (1991) and Tabor and Cady (1978a) map the Snow Creek unit as the Twin River Formation of Brown and Gower (1958), and Spencer (1984) considers it to be a member of the Lyre Formation. We prefer to map it as a separate unit. We thus avoid expanding the Lyre Formation, and we avoid using the term "Twin River," which has been used as a Group name to refer to several formations that range in age from uppermost middle Eocene (upper Narizian) to Miocene time (for example, Garver and Brandon, 1994).

The stratigraphic position of the Eocene(?) micaceous sedimentary rocks on the north side of Big Skidder Hill (unit **Tems**) is problematic, because there are no ages from this unit and contacts with the adjacent Lyre and Crescent Formations are not clear. Massive micaceous siltstone and fine sandstone predominate. They could represent one of three known micaceous sequences in the forearc: Eocene Tyee Formation equivalents (Sandstone of Scow Bay, Armentrout and Berta, 1977); middle and late Eocene Puget Group; or late Oligocene and early Miocene Pysht Formation and the early Miocene Clallam Formation (Garver and Brandon, 1994). Because the micaceous sedimentary rocks apparently rest on Crescent Formation and are in an

upthrown block against the Lyre Formation on Big Skidder Hill, they may be one of the pre-Lyre Formation units.

Consolidated Deposits

Overlying all of the Tertiary units are surficial deposits related to the Vashon Stade of the Fraser Glaciation of Armstrong and others (1965). The only surficial deposits that we found that may predate this stade are indurated colluvial deposits on the flank of the Olympic Mountains in the southwestern part of the map area (unit **Qci**) and possibly deposits represented by lidar-mapped pre-Vashon stade till (unit **prevt**). The colluvial deposits lie directly on bedrock. They contain locally derived clasts only and, thus, predate the culmination of the Vashon-age ice, which delivered considerable amounts of foreign debris to all the deposits of its time period.

Unconsolidated Deposits

During the Vashon stade advance, the Vashon ice sheet bifurcated northeast of the map area into the Puget lobe, which occupied the Puget Lowland, and the Juan de Fuca lobe, which occupied the Strait of Juan de Fuca (Waitt and Thorson, 1983). The Puget lobe blocked northward drainage from the Puget Lowland and formed proglacial lakes that drained southward to the Chehalis River valley and thence to the Pacific Ocean. The Juan de Fuca lobe presumably blocked drainage of Port Discovery (Discovery Bay) before occupying it. Pebbly and stony silts (unit **Qval**) near Port Discovery are interpreted as deposits of these proglacial lakes. These sediments are overlain by gravel-dominated recessional outwash (unit **Qvrg**) that was deposited by streams and rivers issuing from the front of the retreating ice sheet. The ice sheet first covered the map area around 18,000–17,500 cal yr B.P., reached its maximum extent in southern Puget Sound around 16,950 cal yr B.P. (Porter and Swanson, 1998), and covered the region with as much as 1,500 m of ice (Booth, 1987). Till (unit **Qvt**) marks the presence of the ice sheet in the map area and mantles most surfaces. Abundant granitic clasts within the till attest to a northern source, either Vancouver Island or the Coast Mountains of British Columbia.

The canyon topography revealed by the lidar DEM suggest that the bottom of the thick Vashon stade till blanketing much of the terrain should be exposed on the steep canyon walls. Assuming that the till is no more than 10–15 m thick, we have mapped a lower contact in most deep canyons and depicted an unknown pre-Vashon stade till unit (**prevt**). In some parts of the canyons, this contact is characterized by a break in slope from the erosionally resistant till above more friable sands and gravels. Most likely the underlying deposits are advance outwash such as **Qvas** and (or) **Qval**.

The Puget lobe rapidly retreated from its maximum extent and a series of proglacial lakes formed. Initially, the lakes drained south to the Chehalis River. The lowermost, and largest, of these lakes is known as "Lake Russell" (Bretz, 1910; Thorson, 1989). When the ice front retreated to the latitude of the map area around 16,500 cal yr B.P. (Porter and Swanson, 1998), a new, lower-elevation outlet to the Strait of Juan de Fuca

was opened. Thorson (1979, 1980) named the younger, north-draining lake "Lake Bretz". Thorson (1979, 1980) and Waitt and Thorson (1983) interpreted the Port Discovery-Crocker Lake-Leland Lake valley on the east side of the Uncas quadrangle to be the Lake Bretz outlet. Lidar topography does not support this interpretation; although such evidence might be covered by younger deposits, this valley shows no sign of through-going, large-discharge subaerial flow. The Chimacum Valley, about 10 km east of the Uncas quadrangle, was the outlet of Lake Bretz (Haugerud, 2009).

Extensive high alluvial terraces (units **Qa1** and **Qa2**) revealed by the lidar DEM probably formed originally by ice-marginal drainage flowing south into glacial Lake Russell. Most sediment in these terraces was derived from bedrock along the mountain front to the west. When the ice retreated enough to open drainage to the north and through the Strait of Juan de Fuca, the lateral system was disrupted as streams from the mountains drained eastward into Snow Creek valley and Port Discovery. The major east-draining streams, Salmon Creek, Snow Creek, and Andrews Creek, cut canyons through the lateral stream deposits, Vashon Stade till (**Qvt**) that blanketed the area, and older outwash deposits and bedrock. The youngest terraces (**Qa3** and **Qa4**) may record stages of falling base level during late- and post-glacial isostatic rebound.

Details of this terrace history are elusive within the map area, but significant isostatic rebound is required to explain the presence of glaciomarine deposits at elevations above sea level (Thorson, 1989; Dethier and others, 1995). Around Port Discovery and in the lower Snow Creek valley, we mapped a subtle maximum-elevation, late-glacial marine shoreline at elevations of about 121 ft (37 m) to 141 ft (43 m). Thorson (1989) observed the late-glacial marine shoreline at an elevation of 131 ft (40 m) at Gardiner, about 2 mi (3.2 km) north of the map area on the west shore of Discovery Bay, and added 328 ft (100 m) of global sea level rise since the Late Pleistocene to obtain an estimate of 459 ft (140 m) of total isostatic rebound at this locale.

The lidar DEM reveals multiple episodes of alluvial fan construction, shown by map units **Qf1**, **Qf3**, **Qf4**, and **Qf5**. These deposits may reflect the same changes in base level responsible for the terrace development described above, but exact correlation, as implied by the numbers in unit labels, with the terraces is uncertain. Where the change from a sloping fan to an alluvial flat is gradual, the contact between the two deposits is somewhat arbitrary, and we give the units the same number unless other evidence, such as a local scarp, indicates a greater age difference.

Following Vashon stade glaciation, landslides developed on some steep hillsides (unit **Qls**). Perhaps the most interesting of these is a landslide about 2.2 mi (3.5 km) south of the head of Port Discovery, where a massive jumble of Lyre Formation conglomerate, with blocks as large as houses, slumped off the east-facing hillside. As a result, the landslide deflected Snow Creek eastward. The modern depositional environment includes alluvium (unit **Qa**) and alluvial fan deposits (unit **Qf**) along modern streams and beach deposits (unit **Qb**) along the shores of Port Discovery. Human modification of the land surface is mostly seen as artificial fill (unit **af**) along Highway 101.

Structural History

The structure of the Uncas quadrangle is difficult to interpret, because faults strike north, east, northeast, and northwest. Overall, the area has been tilted eastward on the flank of the growing Olympic uplift, which was accompanied by folding and faulting of the bedrock strata into an eastward-plunging synclinorium. Although attitudes in the Crescent Formation are similar to those in the Lyre Formation, an unconformable contact is inferred from the general absence of the Aldwell Formation and the deposition of Lyre Formation conglomerate directly on the Crescent Formation. This suggests deformation began in late middle Eocene time. In the Cape Flattery area, at the northwest tip of the Olympic Peninsula, the Lyre Formation overlies the main thrust at the base of the Crescent Formation, suggesting that it postdates the beginning of accretionary wedge formation (Snively and others, 1993). On Big Skidder Hill, the attitudes in the Lyre Formation are variable. The attitudes of the overlying sandstone of Snow Creek generally strike north or north-northeasterly, which suggests an angular unconformity between the units. However, Spencer (1984) argues for a conformable contact at the base of the sandstone of Snow Creek (unit **Tss**), and outcrops of the Snow Creek unit along Snow Creek can be interpreted as being near the nose of an eastward-plunging syncline. The eastward plunge of the fold along upper Snow Creek, the eastward dips of most units, and the northwest-striking depositional contacts between the Lyre and the Crescent Formations in the southwestern part of the quadrangle are caused by eastward tilting of the entire area during uplift of the Olympic Mountains since about 18 Ma (Brandon and others, 1998).

We interpret the east-west-striking fault on the south flank of Big Skidder Hill to be a reverse fault where the Lyre Formation is faulted over sandstone of Snow Creek. We did not observe fault-scarp breccias in the sandstone of Snow Creek that would indicate uplifted rocks during deposition, and this lack suggests that the fault formed later, due to north-south shortening of rocks exposed on the Olympic Peninsula. Another east-west-striking fault with south-side-up motion may exist about a mile north of Big Skidder Hill. Lacking strong evidence of the dip of the fault on the north side of Big Skidder Hill, we map it as an irregular vertical fault with the north side up. A concealed fault to the north helps to explain the presence of the Eocene(?) micaceous sedimentary rocks on the north side of Big Skidder Hill, topographically above the Aldwell Formation-age basaltic rocks (unit **Tebs**) in the Salmon Creek drainage; alternatively, the geometry is consistent with a syncline, but there is little structural data to support the syncline interpretation.

In the southwest corner of the quadrangle, the right-lateral Bon Jon Pass Fault trends northwest along Deadfall Creek and the Little Quilcene River. This fault is exposed in a quarry near the summit of the pass (just west of the quadrangle) where a 33-ft-wide (10-m-wide) shear zone with strong horizontal slickensides juxtaposes Crescent Formation submarine deposits on the southwest with Crescent Formation basaltic flows on the northeast. Locally, these slickensides indicate right-lateral offset. Northeast-trending faults cutting through Cedar Flat

juxtapose Lyre Formation with the Crescent Formation and may be normal or left-lateral faults kinematically related to the Bon Jon Pass Fault.

A north-northwest-trending linear trough in the center of the quadrangle extends along Ripley Creek and the north fork of Andrews Creek and through the valley west of Big Skidder Hill. West of Little Skidder Hill, unconsolidated deposits conceal the contact between the sandstone of Snow Creek and the Lyre Formation. Outcrops along the walls of the Snow Creek drainage reveal several near-vertical fractures, some that indicate right-lateral offset, but the deposits along the linear trough probably conceal a fault with a major west-side-up component of movement.

An apparently high-angle, north-south-trending fault truncates the east-west fault pair bounding the Lyre Formation on Big Skidder Hill (cross section $A'—A''$). These bounding faults

reappear on the east side of the Snow Creek valley about 0.5 mi north of Big Skidder Hill, suggesting some sinistral movement on the mostly concealed, north-trending fault, but major movement is up to the west. Both north-trending faults reflect the uplift of the Olympic Mountains to the west.

Overall, observed and inferred folds and the fault pattern generally suggest north-south shortening in post-Snow Creek time, a conclusion consistent with underthrusting of the Crescent Formation beneath Vancouver Island and continued northward migration of the Coast Range in response to oblique subduction (Clowes and others, 1987; Wells and others, 1998).

On the west end of Big Skidder Hill, the lidar DEM reveals a northeast-trending linear scarp that has about 3 ft (1 m) of displacement, northwest side down, demonstrating post-17-ka faulting. The scarp clearly cuts the major north-trending glacial grooves.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

NONGLACIAL DEPOSITS

- af Artificial fill (Holocene)**—Mud, sand, and gravel of varying proportions, possibly including debris such as concrete, logs, timbers, or brick. Thickness generally greater than 2 m. Mapped where fill substantially obscures or has altered original geologic deposit. Includes some small areas of extensively modified older deposits
- Qb Beach deposits (Holocene)**—Soft sand, silt, and mud deposited or reworked by wave or tidal action at head of Port Discovery. Contains logs and timbers at or above high tide. Elevation of deposits is within 2 m of mean higher high water
- Qf Alluvial fan deposits (Holocene and Pleistocene)**—Moderately sorted to unsorted sand, gravel, cobbles, and silt with moderate to low surface slopes. Includes debris flow and fluvial deposits. Numbers in subunits relate fans to stratigraphic position of alluvial terrace and alluvial deposits (Qa1, Qa3, Qa4, and Qa5). Fan matched with alluvium by smooth transition; contact somewhat arbitrary. Older fan deposits commonly separated from younger by low scarp. Alluvial fan deposits are mostly divided into the following subunits:
- Qf5 Unit 5 (Holocene)**
- Qf4 Unit 4 (Holocene and Pleistocene)**
- Qf3 Unit 3 (Pleistocene)**
- Qf1 Unit 1 (Pleistocene)**
- Qa Alluvium (Holocene and Pleistocene)**—Moderately sorted, unconsolidated deposits of cobble gravel, pebbly sand, and sandy silt along the floodplain of Snow and Salmon Creeks south of Port Discovery and along Snow Creek. Gradational with and includes sediment equivalent to unit Qb. Relative age position in terrace subunits (Qa1–Qa4) not known. Correlation of subunits in northern tributary of Salmon Creek with units in main Salmon Creek is uncertain. Alluvium is mostly divided into the following subunits:
- Qa5 Unit 5 (Holocene)**
- Qa4 Unit 4 (Holocene and Pleistocene)**
- Qa3 Unit 3 (Pleistocene)**
- Qa2 Unit 2 (Pleistocene)**—Probably marginal drainage deposits to Fraser Glaciation ice along the east side of mostly bedrock terrane on the west side of the quadrangle and include recessional outwash

- Qa1 **Unit 1 (Pleistocene)**—Probably marginal drainage deposits to Fraser Glaciation ice along the east side of mostly bedrock terrane on the west side of the quadrangle and include recessional outwash
- Qw **Wetland deposits (Holocene and upper Pleistocene)**—Peat, marsh, and bog deposits, with some intermixed sand, silt, and clay. Unit is very soft, water saturated, and occupies shallow depressions in till (Qvt) or other low-lying areas. South of Crocker and Leland Lakes, this material was previously mapped (Haecussler and others, 1999) as Vashon stade recessional sand (Qvrs) and may include some recessional sand
- Qls **Landslide deposits (Holocene and upper Pleistocene)**—Diamictos of angular clasts of bedrock and surficial deposits derived from upslope and commonly includes trees. Includes areas of irregular, hummocky topography. Poorly consolidated. Landslide about 2.2 mi (3.5 km) south of Port Discovery consists of house-sized blocks of Lyre Formation conglomerate
- Qci **Indurated colluvium (Pleistocene?)**—Indurated, unsorted, iron-stained angular colluvium on flanks of Olympic Mountains in southwestern part of map area. Inferred to predate Vashon stade, because sediment is indurated and lying on bedrock

GLACIAL DEPOSITS

Deposits of Vashon Stade of Fraser Glaciation of Armstrong and others (1965) (Pleistocene)

- Qvrg **Gravel-dominated recessional outwash deposits (upper Pleistocene)**—Stratified, unconsolidated, gravel-dominated sand and gravel deposits. May include interbeds of sand-dominated recessional outwash
- Qvrf **Fine-grained recessional glaciomarine or glaciolacustrine deposits (upper Pleistocene)**—Stratified firm fine silt with rounded dropstones of pebbles and cobbles along Highway 20, southeast of Port Discovery. Coarse silt and sand are interbedded. Beds are greater than 1–3 in (3–10 cm) thick. Some contacts between beds are convoluted, and sand dikes and blobs are present. Local cross bedding. Overlies probable till
- Qvri **Ice contact deposits (upper Pleistocene)**—Sand, gravel, and silt, commonly with disrupted or no stratification, characterized by surface morphology of steep-walled channels, collapse features, eskers, and common alluvial flats
- Qvt **Till (upper Pleistocene)**—Compact and firm, light- to dark-gray, nonstratified diamict containing subangular to well-rounded clasts, glacially transported and deposited. Clasts are commonly granitic and were derived from the Cascade Range or Canada. Commonly overlies advance outwash deposits (units Qval and Qvas) in the eastern part of the quadrangle and bedrock in the western part of the quadrangle. Generally forms an undulating surface with a few meters to a few tens of meters relief. However, west of Crocker Lake, more than 246 ft (75 m) of till is exposed
- Qrg **Rilled ground (upper Pleistocene)**—Deposits with many small parallel gullies. Where above about 400 ft (122 m), may represent zones of sandy outwash sediments (Qvas) interbedded or intermixed with Qvt or in landslides (Qls) derived from such sandy till. Rilled ground is not shown separately where formed in mapped landslides. Area below 400 ft (122 m) east of Leland Lake could be thin Qvt over Qvas
- Qvrf **Fine-grained recessional glaciomarine or glaciolacustrine deposits (upper Pleistocene)**—Stratified firm fine silt with rounded dropstones of pebbles and cobbles along Highway 20, southeast of Port Discovery. Coarse silt and sand are interbedded. Beds are greater than 1–3 in (3–10 cm) thick. Some contacts between beds are convoluted, and sand dikes and blobs are present. Local cross bedding. Overlies probable till
- Qvas **Sand-dominated advance outwash deposits (upper Pleistocene)**—Well-bedded, sand-dominated, compact sand and gravel deposits. May have interbeds of silt or clay. Deposited by streams and rivers issuing from front of advancing ice sheet. In the vicinity of Crocker Lake and south, Qw was previously mapped as sand-dominated recessional outwash
- Qvv **Valley-fill glacial and glaciofluvial deposits (upper Pleistocene)**—Bedded, sandy-matrix, clast-rich, compact diamict with angular clasts and a few large boulders, interbedded with firm fine to coarse sand and silt and clast-poor clayey matrix diamict, which we consider as till. Clasts are commonly basaltic with probable local provenance. Occupies the headwaters of the Little Quilcene River drainage in the southwestern part of the map area
- Qval **Advance outwash lake deposits (upper Pleistocene)**—Laminated to massive silt, clayey silt, and silty clay deposited in a lowland lake south of Port Discovery. Sediment is firm

SURFICIAL DEPOSITS AND BEDROCK

prevt **Pre-Vashon-stade till deposits (upper Pleistocene and (or) older)**—Probable older deposits of unknown composition. May include some Vashon stade advance outwash and bedrock. Mapped on assumption that thickness of Qvt is 30–50 ft (10–15 m) or less

BEDROCK

Tss **Sandstone of Snow Creek (upper Eocene)**—Sandstone and silty sandstone turbidite. Beds 5 cm to 1 m thick. Contains channelized interbeds of pebble and granule conglomerate and siltstone as much as 3 ft (1 m) thick. Clasts are dominantly quartz and chert

Tl **Lyre Formation (upper Eocene)**—Pebble and cobble conglomerate in a matrix of medium- to coarse-granule sand. Very similar to unit Tluc

Tluc **Upper conglomerate member**—Pebble and cobble conglomerate in a matrix of medium- to coarse-granule sand. Contains some sandstone interbeds. Dominantly chert, basalt, and conglomerate clasts in decreasing order of abundance (Spencer, 1984). Clasts to 3 ft (1 m)

Tlav **Andesite tuff and breccia**—Andesite and hornblende-andesite tuff and breccia, white to light gray. Locally contains rare leaves and carbonized wood. Commonly massive, but some tuffs are thin bedded

Tllc **Lower conglomerate member**—West of Cedar Flat, unit is predominantly thick-bedded to massive conglomerate; to the south, thin- to thick-bedded sandstone with minor conglomerate is most common. Conglomerates are composed of well-rounded pebbles and cobbles of chert with lesser amounts of metasedimentary and igneous rocks, quartz, and graywacke. Lower part of unit south of Snow Creek locally includes some angular to rounded basalt clasts. Sandstones are fine to coarse grained and commonly contain scattered pebbles. Siltstone is sandy and thinly to faintly bedded

Tems **Micaceous sediments (Eocene?)**—Massive, buff-brown micaceous siltstone and fine sandstone on the north side of Big Skidder Hill. Bedding commonly indistinct or not present

TebS **Basaltic sediments (middle Eocene)**—Basaltic conglomerate and breccia and fine- to medium-grained, dark-gray to black, massive sandstone, with thin local interbeds of dark siltstone. Lowermost few meters are gray-green argillaceous limestone pods and basaltic sedimentary breccia. Total thickness is approximately 755 ft (230 m) along Salmon Creek

Ta **Aldwell Formation (middle and upper Eocene)**—Massive to bedded mudstone and turbidite sandstone, basaltic conglomerate, lithic sandstone, and siltstone

Crescent Formation (lower, middle, and upper Eocene)

Tcb **Basalt breccia**—Rubbly, reddish-weathering basaltic breccia. No silty or sandy matrix, indicating subaerial eruption of lava. Minor basalt flows

Tcf **Basalt flows**—Massive basaltic lava flows. Locally with calcite or zeolite-filled vesicles and pyroxene phenocrysts. Some flows have red oxidized tops indicating subaerial eruption. Minor basaltic breccia

Tcfb **Basalt flows and breccia**—Rubbly, reddish-weathering basaltic breccia and massive basaltic lava flows in roughly equal proportions. Breccia contains no silty or sandy matrix. Some flows have red oxidized zones

Tcs **Basaltic submarine deposits**—Pillow lava and pillow and lapilli breccia, amygdular lava flows, dark-gray calcareous mudstone, basaltic siltstone and sandstone. Intruded by basaltic sills. At head of Little Quilcene River, sandstone makes up approximately half of section

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