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# Geologic Map of the Nisqually 7.5-minute Quadrangle, Thurston and Pierce Counties, Washington

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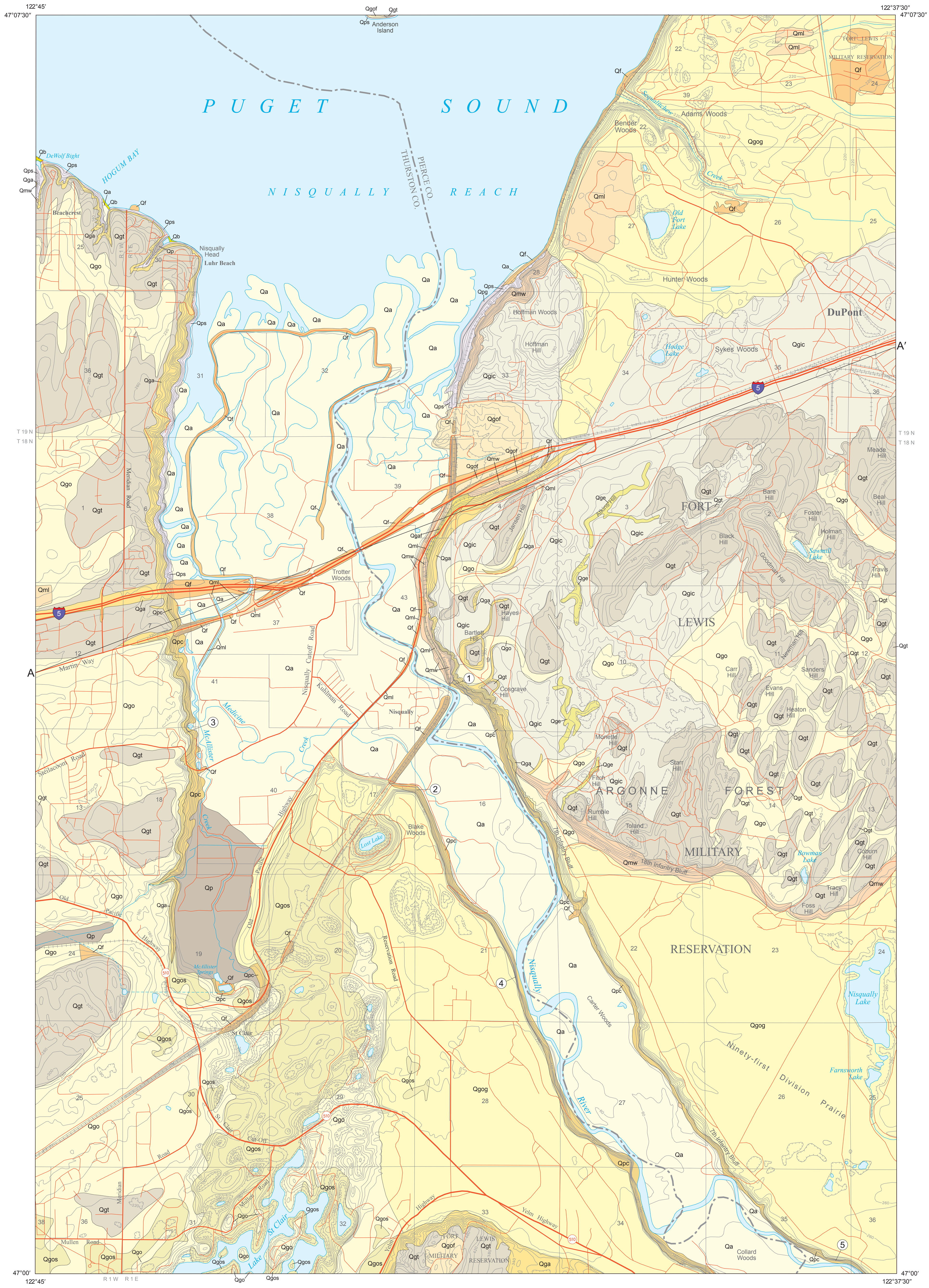

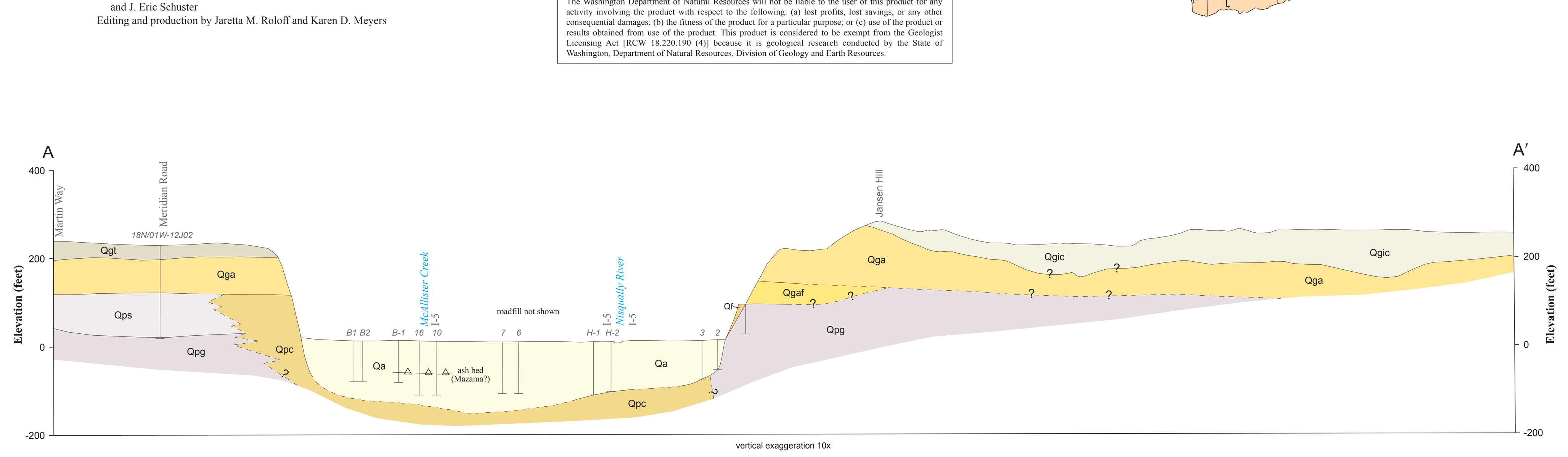

## INTRODUCTION

The Nisqually quadrangle is located at the south end of Puget Sound, straddling the Nisqually River, which is the boundary between Thurston and Pierce Counties. It includes part of Fort Lewis, which has limited access to areas used for artillery training, and part of the Nisqually Indian Reservation, which also has restricted access. The rest of the quadrangle is rural residential or agricultural land.

## GEOLOGIC HISTORY

Late Wisconsinan–age Vashon Drift covers most of the quadrangle. Pre-Vashon units are generally exposed only along coastal or river bluffs, where mass wasting is common. Landslides and colluvium disrupt and obscure the continuity of exposures so that pre-Vashon geologic history is not easily deciphered. In the Puget Lowland south of Tacoma, all finite radiocarbon ages reported before 1966 are suspect due to laboratory contamination (Fairhall and others, 1966, p. 501). Stratigraphic assignments based on these radiocarbon ages are now questionable and need to be re-evaluated. We have systematically sampled all datable material from nonglacial sediments subjacent to the Vashon Drift and found them to be older than previously reported. With a few exceptions, these sediments have been beyond the range of radiocarbon dating.

The antiquity of the pre-Vashon units causes radiocarbon dating to be of little help for making correlations, and abrupt facies changes within glacial and nonglacial units also render correlations tenuous. Despite these difficulties, we have developed a conceptual model for the more recent pre-Vashon geologic history that is consistent with our observations but by no means compelling.

The oxygen-isotope stage 4 glaciation, called the Possession Glaciation in northern Puget Sound, was mild relative to stages 2 and 6 (Mix, 1987, and Fig. 1), represented by the Vashon and Double Bluff Drifts respectively in the Puget Lowland. The Possession ice sheet probably did not extend far south of Seattle (Lea, 1984; Troost, 1999). Because the ice sheet blocked drainage out of Puget Sound to the Strait of Juan de Fuca, a proglacial lake was impounded covering most of the southern Puget Lowland. Streams flowing into this lake, such as the Nisqually, Puyallup, and Skokomish Rivers, formed an alluvial plain and deltas grading to lake level. These nonglacial sediments, deposited during stage 4, are all radiocarbon-infinite and overlie and interfinger with Possession outwash deposits. Once Possession ice no longer impounded the lake (but sea level was still significantly below modern sea level), existing drainages, such as the Nisqually and Puyallup Rivers, deeply and rapidly incised into their former alluvial plains and became entrenched. At least initially, stage 3, called the Olympia Interglaciation locally (Armstrong and others, 1965), was characterized by downcutting and erosion. As sea level began to rise, most deposition was confined to these entrenched channels. Because stage 3 sea level was probably about 100 feet lower than modern sea level (Ludwig and others, 1996, and references therein), stage 3 deposits were areally restricted. As Vashon ice advanced and sea level fell again at the beginning of stage 2, these rivers preferentially downcut in the same channels, thereby eroding most of the late Olympia deposits, so that finite-aged Olympia deposits are rare above sea level.

As Vashon ice moved southward and grounded across the Strait of Juan de Fuca during stage 2, it dammed the northern outlet of the Puget Sound basin. Proglacial streams carried fluvial sediments southward into the Puget Lowland filling proglacial lakes and eventually the Puget Sound basin, first with silts, then sands and gravels. These sediments form the ‘great lowland fill’ of Booth (1994). Ice overrode these sediments, covering most of them with till, or scoured them away to deposit till directly onto pre-Vashon sediments. Subglacial channels were subsequently eroded into the fill. Proglacial lakes became impounded in these channels at different elevations above today’s sea level as ice impinged on divides. The former lakebeds are presently the southernmost inlets of Puget Sound. (For a more thorough discussion of the subglacial channel network, see Booth, 1994, and Booth and Goldstein, 1994.) As these proglacial lakes spilled into lower-elevation basins and channels near the end of the Pleistocene, they deposited coarse, steeply dipping deltaic gravels along the margins of the channels and basins. Some of these deposits can be found near

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## MAPPING METHODS

For the present map, we inspected available construction site excavations, gravel pits, and roadcuts. We surveyed the shorelines by boat and took samples and measured sections at cliff exposures. Contacts between map units are commonly not exposed and are only approximately located. They are generally located by outcrop mapping, air photo and lidar interpretation, interpretations of water well logs from Washington Department of Ecology geotechnical site reports, and, in part, modified from Drost and others (1998). USDA soil maps (Pringle, 1990; Zulauf, 1979) helped guide the location of peats and the contacts between sandy and gravelly units. Location accuracy of contacts is judged to be about 200 ft in general. In addition, the contacts between some units are gradational. We have tried to consider geotechnical significance in mapping geological units and have attempted to show units only where they are thicker than 5 to 10 ft or mask the underlying lithology.


## ACKNOWLEDGMENTS

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## DESCRIPTION OF UNITS

### Quaternary Unconsolidated Deposits

#### HOLOCENE NONGLACIAL DEPOSITS

Qf — **Fill**—Clay, silt, sand, gravel, organic matter, shells, rip-rap, and debris; includes engineered and non-engineered fills; shown only where fill placement is extensive, sufficiently thick to be of geotechnical significance, and readily verifiable.

Qml — **Modified land**—Soil, sediment, or other geologic material that has been locally reworked to modify the topography by excavation and (or) redistribution.

Qa — **Alluvium**—Silt, sand, gravel, and peat deposited in stream beds and estuaries; may include some lacustrine and beach deposits.

Qb — **Beach deposits**—Mud and sand deposited in the intertidal zone or residual gravel on a wave-cut platform.

Qmw — **Colluvium and alluvial fans**—Loose soil and glacial sand and gravel deposited by soil creep and shallow ravelling on hillslopes and alluvial fan deposition, some of which occurred during the waning stages of the Vashon Stade of the Fraser Glaciation. Shown where colluvium or fan deposits are of sufficient thickness to mask underlying geologic strata.

Qp — **Peat**—Organic and organic-matter-rich mineral sediments deposited in closed depressions; includes peat, muck, silt, and clay in and adjacent to wetlands.

#### PLEISTOCENE GLACIAL DEPOSITS

**Deposits of Continental Glaciers—Cordilleran Ice Sheet**

VASHON STADE OF THE FRASER GLACIATION

Glacial sediments described in this section consist mostly of rock types of northern provenance, most from the Canadian Coast Range. A wide variety of metamorphic and intrusive igneous rocks not indigenous to the Puget Lowland and generally southerly directed current indicators help distinguish these materials from the volcanic-lithic-rich sediments of the eastern Puget Lowland and the Crescent Basalt/Olympic core–rich sediments of the western Puget Lowland.

Qgof — **Latest Vashon fine-grained sediments**—Lacustrine clayey and (or) fine sandy silt with sparse, disseminated dropstones; laminated and commonly vertically jointed; medium gray where fresh to pale yellow where dry and oxidized. In both fresh and oxidized exposures, this unit is distinguished by relatively darker (chocolate brown in oxidized exposures) horizontal bands about 1 in. thick that may represent annual winter depositional layers in a varve sequence; no more than about 20 apparent varves were counted in any exposure, suggesting a short life for the glacial lake(s) in which unit Qgof was deposited; present in deposits ranging up to 10 ft thick over much of southern Puget Lowland and most commonly found at elevations below about 140 ft; mapped where it is thought to be at least about 5 ft thick or where it masks the underlying geomorphology; includes deposits of glacial Lake Russell and other lakes of the Vashon glacial recession.

Qgos — **Latest Vashon recessional sand and minor silt**—Moderately well-sorted, moderately to well-rounded, fine- to medium-grained sand with minor silt; noncohesive and highly permeable; thickness inferred from wells reaches up to 100 ft; deposited in and around the margins of glacial lakes; surrounds numerous steep-walled lakes and depressions (kettles), evidence that this unit was largely deposited during deglaciation when there was stagnant ice occupying much of the southern Puget Lowland.

Qgog — **Vashon recessional outwash gravel (Steilacoom Gravel)**—Pebble to boulder gravel exposed in the southeast corner of the Lacey quadrangle and the eastern half of the Nisqually quadrangle. At Dupont, just outside of the map area, the gravel is about 200 ft thick with large foresets that dip west-northwest toward Puget Sound, forming the Sequalichew Delta of Bretz (1913), who interpreted it as discharge from glacial Lake Puyallup.

Qgo — **Vashon recessional outwash**—Recessional and proglacial stratified, moderately to well-rounded, poorly to moderately sorted outwash sand and gravel of northern or mixed northern and Cascade source, locally containing silt and clay; also contains lacustrine deposits and ice-contact stratified drift. Some areas mapped as unit Qgo may instead be advance outwash (unit Qga), as it is difficult to tell the difference between the two without the presence of an intervening till.

Qgt — **Vashon till**—Unstratified and, in most exposures, highly compacted mixture of clay, silt, sand, and gravel deposited directly by glacier ice; gray where fresh and light yellowish brown where oxidized; unsorted and, in most exposures, of very low permeability; most commonly matrix-supported but may be clast-supported; matrix generally has a more gritty feel than outwash sands when rubbed between fingers, due to being more angular than water-worked sediments; cobbles and boulders commonly faceted and (or) striated; ranges in thickness from wispy, discontinuous layers less than 1 in. to more than 30 ft thick; thicknesses of 2 to 10 ft are most common; mapped till commonly includes outwash clay, silt, sand, gravel, or ablation till that is too thin to substantially mask the underlying, rolling till plain; erratic boulders are commonly associated with till plains but may also occur as lag deposits where the underlying deposits have been modified by meltwater; typically, weakly developed modern soil has formed on the cap of loose gravel, but the underlying till is unweathered; local textural features in the till include flow banding and apophyses commonly extending 10 to 15 ft downward into underlying sand and gravel that are oriented transverse to ice flow direction.

Qgic — **Ice-contact deposits**—Mix of deposits from undifferentiated dynamic ice and dead ice. Dynamic ice deposits include lodgment till, drumlins, and advance outwash; dead-ice deposits include ablation till, subglacial water flow deposits (such as eskers), and recessional outwash; typically lacks thick, continuous, or widespread deposits of lodgement till at the ground surface, though small till exposures and detrital till fragments are common; topography formed by a mix of subglacial, ice-marginal, and recessional processes.

Qge — **Eskers**—Sinuous, steep-walled mounds of loose gravel and sand deposited in ice-confined channels by glacial meltwater.

Qga, Qgaf — **Vashon advance outwash**—Sand and gravel and lacustrine clay, silt, and sand of northern or mixed northern and Cascadian source, deposited during glacial advance; locally contains nonglacial sediments, typified by silt rip-ups, cobbles, and peat rip-ups as lag along channel sides and bottoms; gray where fresh, light yellowish gray where stained; isolated exposures of lacustrine silt and clay (unit Qgaf) resemble older glaciolacustrine units. Age of maximum Vashon ice advance in the map area was previously estimated to be approximately 14,000 radiocarbon yr B.P., based on apparent post-glacial deposits in the central Puget Lowland that were radiocarbon dated at about 13,600 radiocarbon yr B.P. (Porter and Swanson, 1998). However, five more-recently obtained radiocarbon dates from deposits that underlie Vashon till in the southern Puget Lowland, including a deposit of unit Qgaf in this quadrangle, indicate a maximum ice advance after about 13,400 radiocarbon years B.P. (Borden and Troost, 2001, and this study), leaving very little time for the glacial advance and recession into the southern Puget Lowland; most exposures mapped as Vashon till lack geochronologic data and are interpreted as Vashon till based on occurrence at or near the top of the stratigraphic section.

#### PLEISTOCENE DEPOSITS OLDER THAN VASHON DRIFT

Qps — **Pre-Vashon sand-size or finer deposits**—Massive to cross-bedded sand interbedded with laminated silt and minor peat, diatomite, and gravel; immediately subjacent to Vashon Drift and generally overlying unit Qpg. This unit is thought to be of nonglacial origin, and is dominated by varied Cascade-source volcanic lithic rock types. These sediments have previously been referred to the Kitsap

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