3D geologic map of the Darrington 7.5-minute quadrangle, Skagit and Snohomish Counties, Washington

Disclaimer

Citation and link

This 3D geologic map is derived from previously published geologic mapping and analysis. Some of the borehole data are considered preliminary and have not been examined for accuracy of either location or lithologic identification. While lithologic identification for all wells was made by the author of the published geologic map, not all of the wells shown in this 3D product were necessarily used to construct the geologic cross section. The map, cross section, and the borehole data within the 3D model are not intended for analytical use. Instead, the published map and (or) pamphlet should be consulted for original data and interpretation.

Click anywhere within this box to dismiss this disclaimer and continue.

- [x] Layer001
- [x] Layer002

No Separation | 5% | 50% | 100%

5

Probe | 1x Z-Scale | 10x Z-Scale | Default Scale | 10

Web tutorial

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Peter Goldmark - Commissioner of Public Lands

3D PDF INSTRUCTIONS

NAVIGATION
(1 of 2)

- Click inside the window to manipulate the 3D view—the compass will rotate to point towards north
- Hold the left mouse button and move the mouse to tilt the view
- Use the mouse wheel to zoom
- Hold both the right and left mouse buttons to pan the view
- Toggle individual layers in the lower left corner
- Change the vertical scaling or layer separation in the lower toolbar
- Selecting an object will display its data below

OBJECT DATA

undefined

undefined

undefined

undefined

3D model creation: Ashley A. Cabibbo

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WASHINGTON STATE DEPARTMENT OF Natural Resources
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Division of Geology and Earth Resources
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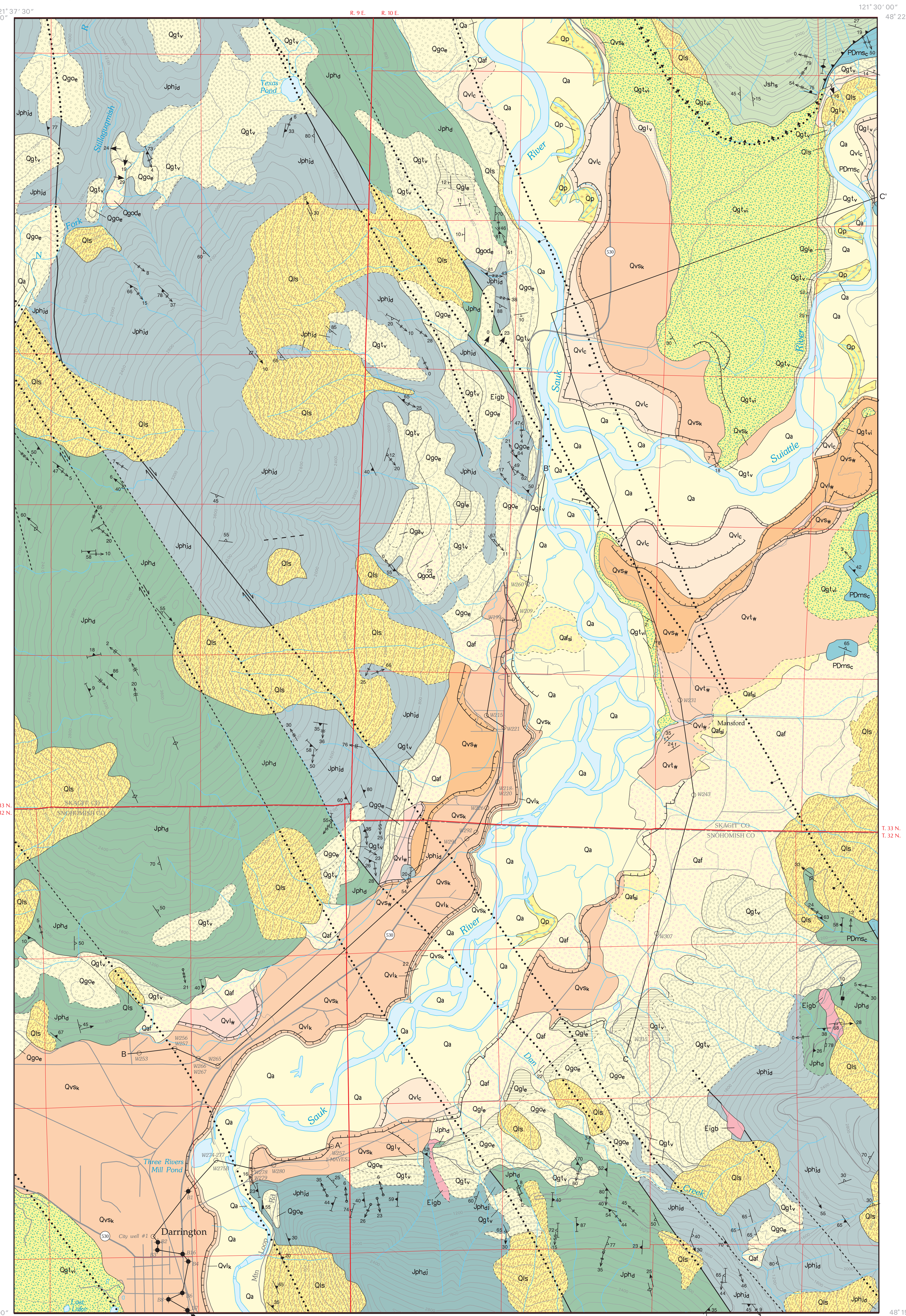
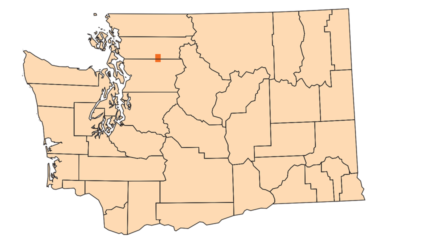
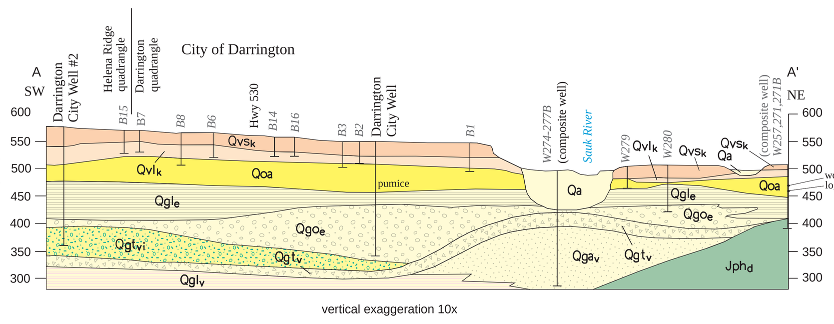


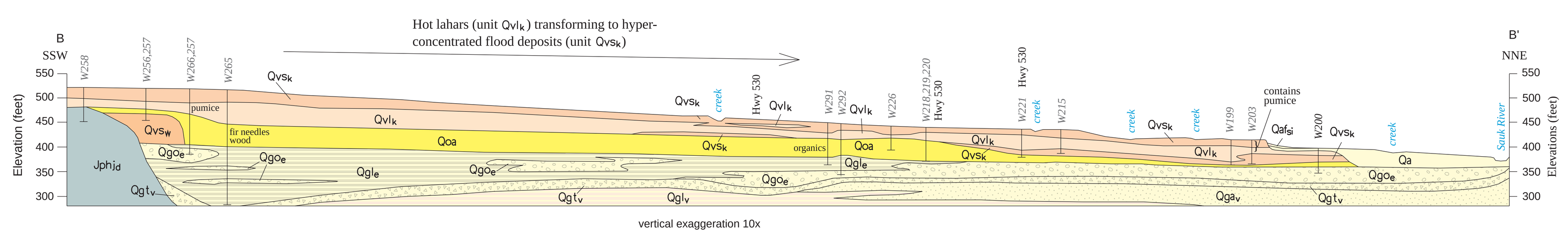
Lambert Conformal projection
1927 North American Datum
Washington coordinate system, south zone
Base map information from the Washington Department of Natural Resources, Geographic Information System 1997
Digital Cartography by Anne C. Heinitz and Donald T. McKay, Jr.

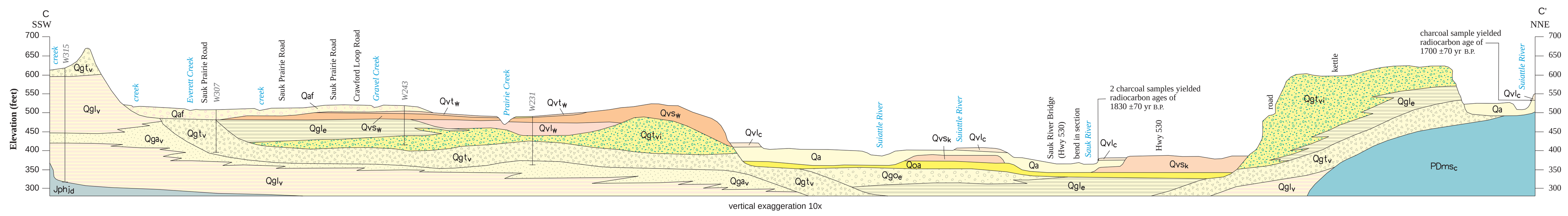
scale 1:24 000

contour interval 100 feet









Note that the cross sections are not straight lines but segments that connect geotechnical or water well boring logs and thus contain multiple bends. Most segments traverse areas of good to excellent geologic mapping control. The numbers above the wells or borings provide our assigned identification number; water wells begin with "W" and geotechnical borings begin with "B".

Geologic Symbols

Contact—Dashed where inferred

Fault, unknown offset—Long dashed where approximately located; short dashed where inferred; dotted where concealed

Normal fault—Bar and ball on downthrown side; dotted where concealed

Right-lateral strike-slip fault—Half arrows indicate relative apparent strike-slip motion; dashed where approximately located

Thrust fault—Sawteeth on upper plate; dotted where concealed

Latest Pleistocene to Holocene fluvial terrace—Hachures on scarp side

Strike and dip of bedding (may be combined with other symbols)

inclined (glacial and alluvial deposits only)

inclined—indicates foreset bedding (glacial and volcanic deposits only)

inclined

Trend and plunge of fold axes (may be combined with other symbols)

Overturned minor fold axis (combined with F2 fold axis symbols below)

Minor F1 (first-generation) fold axis; arrow indicates the direction of plunge

Minor F2 (second-generation) fold axis and (or) crenulation lineation; arrow indicates direction of plunge

Minor F3 (third-generation) fold axis and (or) crenulation lineation; arrow indicates direction of plunge

Minor F2 M-shaped fold axis and (or) crenulation lineation; arrow indicates direction of plunge

Minor F2 Z-shaped fold axis and (or) crenulation lineation; arrow indicates direction of plunge

Minor F2 S-shaped fold axis and (or) crenulation lineation; arrow indicates direction of plunge

Strike and dip of tectonic foliation and fold axial planes (may be combined with other symbols)

Penetrative tectonic foliation (undifferentiated); generally crystalloblastic S1 (first-generation) cleavage in the Shuksan Suite

inclined

inclined—may locally represent S2 or S3 foliation

vertical—may locally represent S2 or S3 foliation

Strongly developed semi-penetrative to locally penetrative S2 (second-generation) axial plane foliation or F2 axial plane

inclined

vertical

F2 axial plane (no S2 foliation)

inclined

vertical

Strongly developed semi-penetrative to locally penetrative S3 (third-generation) axial plane foliation or F3 axial plane

inclined

Strike and dip of fractures and joints (may be combined with other symbols)

Joint, undifferentiated

inclined

vertical

Subsidiary minor fault or slickensided fracture plane

inclined

Trend and plunge of tectonic lineations

Lineation, undifferentiated (mostly stretching lineations and crenulation lineations; rarely pencil lineations, slickenlines, or boudins); arrow indicates direction of plunge

inclined

Stretching lineation; arrow indicates direction of plunge

inclined

Trend and plunge of current flow direction indicators (flutes, pebble imbrications, etc.)

inclined

Well and Borehole Symbols

Water well

GeoEngineers, Inc., geotechnical borehole

Description of Map Units

Field mapping of the Darrington 7.5-minute quadrangle was completed during the summers of 2001 and 2002. Field observations were supplemented by whole-rock and clast geochemical analyses, pumice and ash (glass) microprobe analyses, radiocarbon dating, petrographic (thin section) analyses of bedrock, clasts, and mounted Quaternary sands, and subsurface analyses using water wells and geotechnical borings. A copy the sample site map can be obtained by writing Joe Dragovich at the Washington Division of Geology and Earth Resources, PO Box 47007, Olympia, WA 98504-7007, joe.dragovich@wadnr.gov. Alphanumeric codes following color descriptions refer to the Munsell rock color chart (Munsell Color, 1998) and are for dry samples.

QUATERNARY SEDIMENTARY AND VOLCANIC DEPOSITS

Holocene Nonglacial Deposits

Qa, Qp — **Alluvium, undivided (Holocene)**—Gravel, gravelly sand, sand, and cobbly gravel with rare boulders; gray; subrounded to rounded clasts; loose, well-stratified, and well-sorted; plane-bedded sands common; locally contains up to 40% reworked gray or reddish gray Glacier Peak dacite with boulder fraction locally greater than 50% dacite; locally rich in granitic and (or) phyllite clasts. Overbank deposits are mostly loose or soft to stiff, grayish brown to olive-gray stratified sand, fine sandy silt, silt, silty clay, and minor peat (unit Qp). Several radiocarbon ages from sticks in peat and organic sediments yield ages of less than 600 yr B.P. for surficial Sauk River alluvium.

Qoa — **Older alluvium (Holocene) (cross sections only)**—Sand, gravel, cobbly gravel, silt, clay, and peat locally with abundant wood and organic matter (downed trees, shrubs, paleosols, and swampy deposits) (cross sections A–A′, B–B′, C–C′). Unit Qoa occurs below units Qvl_k and Qvs_k (mid-Holocene). The uppermost portion of unit Qoa commonly contains organic materials and is interpreted as a forest buried by Glacier Peak volcanic deposits (unit Qvl_k) during the mid-Holocene.

Qaf, Qaf_{si} — **Alluvial fan deposits (Holocene)**—Diamicton; massive to weakly stratified with angular to rounded, locally derived clasts; mostly poorly sorted debris-flow or debris-torrent deposits, locally modified by fluvial processes. Alluvial fans mostly disconformably overlie glacial or Glacier Peak volcanic deposits and locally interfinger with alluvium. Silt deposits locally divided into unit Qaf_{si} along the distal portions of some large alluvial fan complexes.

Qls — **Landslide complexes (Holocene)**—Boulders, cobbles, and gravel in a soft sand, silt, and (or) clay matrix; mostly poorly sorted and unstratified with locally derived angular to rounded clasts. Includes deep-seated landslides such as slump-earthflows and a few of the most prominent debris slide and talus or rockfall deposits. Scarps and deposits are mapped together as unit Qls.

Late Pleistocene and Holocene Glacier Peak Volcanic and Sedimentary Deposits

We correlate the volcanic assemblages in the study area with the Chocolate Creek, Kennedy Creek, and White Chuck assemblages of Beget (1981, 1982) that inundated valleys during late Holocene, mid-Holocene, and late Pleistocene eruptive episodes of Glacier Peak. These deposits are exposed as terraces with age increasing with elevation. For example, White Chuck assemblage terraces are typically up to 80 ft (24 m) above the modern flood plain and are higher than later volcanic assemblages. Glacier Peak dacite is homogeneous and contains plagioclase, hornblende, and hypersthene ± augite and (or) olivine phenocrysts and rare biotite; each assemblage appears to have a generally similar but distinctive dacite-clast trace-element geochemistry (Dragovich and others, 1999, 2000a,b,c,d; J. D. Dragovich, Wash. Divn. of Geology and Earth Resources, unpub. data).

Chocolate Creek Assemblage

We mapped a lahar deposit in the Darrington quadrangle that lithologically and temporally correlates with similar lahar deposits and volcanic alluvium near Glacier Peak and in the lower Skagit River valley. We informally assign the name Chocolate Creek assemblage to this deposit, which is similar to 1,800 yr B.P. deposits described by Beget (1981, 1982) along Chocolate Creek adjacent to Glacier Peak. This deposit probably resulted from the downstream transformation of one or more pyroclastic flows along the Suiattle and Sauk Rivers. In the study area, the lahar forms a 1.5 m terrace-capping bed that overlies alluvium. This terrace is 12 to 15 ft above river level along the Suiattle and Sauk River flood plains and channels. In the White Chuck and Suiattle River valleys east of the study area, the Chocolate Creek assemblage is composed of at least three distinct lahars (Beget, 1981; J. D. Dragovich, Wash. Divn. of Geology and Earth Resources, unpub. data). In the study area, radiocarbon dating yielded ages of 1,700 ±70, 1,620 ±70, and 1,830 ±70 yr B.P. from charcoal obtained from silt and silty sand in alluvium directly below the lahars at two sites (cross section C–C′) (Dragovich and others, 1999, 2000a,b,c, 2002b; J. D. Dragovich, Wash. Divn. of Geology and Earth Resources, unpub. data).

Qvl_c — **Non-cohesive lahar (Holocene)**—Silty sandy gravel to gravelly sand; few cobbles and rare boulders; compact and dacite-rich; clasts typically 1 to 2 cm but locally 20 cm in maximum dimension. Matrix is composed of very pale brown (10YR 7-3) fine to coarse ash containing crystals of plagioclase, hornblende, hypersthene, and quartz, plus or minus augite and vitric and dacite lithic fragments. Gray to dark gray (GLEY 1 4/N-6/N) and light gray (GLEY 1 7/N to 10YR 7/1) dacite clasts are mostly angular to subangular and semi-vesicular to vesicular and compose 70% to 93% of the clasts; also contains scattered, altered, weak red (10R 5/3) dacite clasts; locally contains scattered very pale brown (10YR 8/4) pumice clasts; locally overlain by a very thin bed of reworked light brown (10YR 7/3) ash; minor exotic clasts include lacustrine clay rip-up clasts and granitic and orthogneiss clasts. Deposits commonly vertically symmetrical with a crudely normally graded top and a reversely graded base; faint basal horizontal lamination and water and (or) gas escape pipes observed locally.

Kennedy Creek Assemblage

The Kennedy Creek assemblage (KCA) originated from Glacier Peak and flowed down the Sauk and Stillaguamish River valleys about 5,100 to 5,400 yr B.P. (Beget, 1981, 1982; Dragovich and others, 1999, 2000a,b,c; J. D. Dragovich, Wash. Divn. of Geology and Earth Resources, unpub. data). The KCA forms a prominent 15 to 25 ft (5–8 m) high terrace. Stratigraphic relations as well as geochemical and petrographic data suggest that the assemblage resulted from inundation by lahar(s) that transformed into hyperconcentrated flood(s) downstream through interaction with river water. This transformation is similar to the mechanism envisioned by Pierson and Scott (1985) for similar Mount St. Helens deposits. Hyperconcentrated flood deposits in the quadrangle thicken to the north in the Sauk River drainage as a result of this transformation. Subsequent fluvial incision and channel migration locally reworked the top of the KCA. The KCA forms a flat divide between the Sauk and Stillaguamish Rivers. Beget (1981) suggested that the divide formed during deposition of the latest Pleistocene White Chuck assemblage, diverting the Sauk River north to the Skagit River east of the study area. (White Chuck volcanic inundation occurred during the close of the last glaciation, when organic productivity was low and organic deposition was rare to nonexistent.) However, unit Qoa, which underlies the volcanic sediments of the divide (cross sections A–A′, B–B′, C–C′), contains organic material at various stratigraphic levels, implying quiescent post-glacial deposition representing much of the early Holocene. Therefore, we associate formation of this divide with deposition of the mid-Holocene KCA rather than the White Chuck assemblage.

Qvs_k — **Volcanic sediments, undivided (Holocene)**—Hyperconcentrated flood deposits, lahars, and volcanic alluvium; medium- to coarse-grained sand and thick beds of gravelly sand and cobbly sandy gravel; loose; dacite-rich. Locally contains lahar beds of silty sandy gravel with few cobbles and boulders; these beds are similar to unit Qvl_k; but are too thin (0.5–2 m or 1.5–6 ft) to separate at map scale; some lahars occur within granular hyperconcentrated flow deposits (this study; J. D. Dragovich, Wash. Divn. of Geology and Earth Resources, unpub. data). Locally capped by reworked light brownish gray to light yellowish brown ash (10YR 6/2, 6/4, 7/1, 2.5YR 6/3) or ash with scattered lenses rich in pumice lapilli. Clasts include 70% to 98% light gray to gray (GLEY 1 5/N-7/N) dacite locally with scattered dark gray (GLEY 1 2.5/N-4/N) and altered pale red to dark reddish gray dacite (10YR 5/2, 10R 3/1, 7/2, 6/2-6/3); locally contains up to 50% pale yellow, very pale brown, light gray, white, or pinkish white pumice (GLEY 1 5/N-8/N, 2.5YR 8/1-8/2, 10YR 5/1, 7/2, 8/1-8/3) as lenses or scattered clasts. Locally contains cobble- to boulder-sized rip-up clasts of silt and (or) clay that were probably eroded from deposits mapped near Glacier Peak by Beget (1981) as sediments of volcanically dammed lakes. Nonlahar beds are typically nongraded to crudely graded and nonstratified; locally contains weak horizontal stratification, plane bedding, and cross bedding including rare antidunes. Stratigraphy and clast compositions indicate both fluvial and hyperconcentrated flood depositional mechanisms for the nonlaharic sediments. Reworked terrace-capping tephra probably represents one or more waning flood deposits. Locally divided into:

Qvl_k — **Non-cohesive lahar (Holocene)**—Silty sandy gravel to gravelly sand locally with cobbles and rare boulders up to 1 m (3 ft); compact; dacite-rich with clasts typically 1 to 2 cm (0.4–0.8 in.) but locally 10 to 30 cm (4–12 in.) in size. Very pale brown (10YR 7/3) lahar matrix consists mostly of reworked pyroclasts of fine to coarse ash with crystals of hornblende, hypersthene, plagioclase, quartz, and rare augite, with vitric fragments and fragments of dacite. Dacite clasts are angular to subangular, abundant (80–98% of clast component), and vesicular to locally non-vesicular; some frothy flow banding; mostly gray (GLEY 1 5/N-6N) with some scattered altered reddish gray dacite (2.5Y 6/2) and pale yellow, pale brown, and pink pumice (10YR 8/2, 10R 8/3). Unit also contains rare boulder-sized rip-up clasts of lacustrine clay and minor exotic clasts of granite, phyllite, and vein quartz. Nonstratified deposits with weak normal grading occur near the top of the deposit. Commonly contains dewatering and (or) gas-escape pipes; rarely contains crudely defined, meter-scale horizontal stratification defined by coarse-tail (gravel and cobble) grading; rarely contains flame structures, internal truncation surfaces, and very thin ash beds. Paleomagnetic analysis of dacite clasts (J. Ladd, Western Wash. Univ., written commun., 2002) suggests deposition as a hot lahar. Although base was not observed, deposit appears to be mostly laterally continuous and may be as thick as 15 m (49 ft) (cross sections A–A′, B–B′, C–C′); overlain by volcanic sediments of unit Qvs_k (this study; J. D. Dragovich, Wash. Divn. of Geology and Earth Resources, unpub. data).

White Chuck Assemblage

The White Chuck assemblage resulted from Glacier Peak eruptions during Fraser deglaciation (~11,200–12,700 yr B.P.) (Beget, 1981, 1982; Porter, 1978; Foit and others, 1993). Deposits of the White Chuck assemblage commonly overlie dacite-poor recessional outwash of unit Qgo_e.

Qvs_w — **Volcanic sediments, undivided (late Pleistocene)**—Hyperconcentrated flood deposits, lahars, and volcanic alluvium; medium- to coarse-grained sand, sandy gravel, and cobbly sandy gravel; loose; dacite-rich. Lahars consist of poorly sorted, nonstratified gravelly silty sand and silty sandy gravel with some cobbles and scattered boulders up to 44 cm (17 in.). Volcanic alluvium and hyperconcentrated flood deposits typically contain 50% to 95% white and light to dark gray (GLEY 4/N-8/N) or altered reddish gray or weak red (10R 6/1, 10R 4/3) dacite, commonly with white (10YR 8/1) to pinkish white or pale yellow to very pale brown pumice (2.5Y 8/2; 10YR 7/4, 8/2-8/3) (up to 16 cm or 6.3 in.) that locally constitutes up to 50% of the clasts; also contain pumice-rich lenses, cobble to boulder rip-up clasts of lacustrine or glaciolacustrine clay, and clasts of White Chuck vitric welded tuff. Deposits vary from massive, crudely graded, or weakly horizontally stratified to rarely well-stratified with plane or cross bedding (this study; Beget, 1981; J. D. Dragovich, Wash. Divn. of Geology and Earth Resources, unpub. data). Locally divided into:

Qvt_w — **Pumice (late Pleistocene)**—Terrace-capping pumiceous ash, ash-lapilli, and lapilli deposit forming a 'pumice plain'; moderately to well-sorted; 0.3 to 2.7 m thick with pumice clasts up to 17 cm; pumice is white (GLEY 1 8/N, 2.5Y 8/1), pink (7.5YR 8/2, 7/3), or very pale brown or yellow (7.5YR 8/3, 10 YR 8/3-8/6) and ash is pale brown (10YR 8/4) to pale yellow (2.5Y 8/4); exotic clasts generally absent. Locally, pumice lapilli layers are interbedded with ash and ash-lapilli layers. Varies from nonstratified to locally plane- or cross-bedded; overlies dacitic sands and gravels of unit Qvs_w. Homogeneous glass composition, phenocryst types, and stratigraphic position and distribution suggest that the pumice plain deposit is a waning flood deposit; drainage blockage by receding glacial ice in the Sauk River valley may have promoted 'ponding' of this deposit.

Qvl_w — **Non-cohesive lahar (late Pleistocene)**—Cobbly to locally bouldery gravelly sand commonly with a trace of ash; compact; light reddish brown; dacite-rich; dacite clasts up to 55 cm (22 in.); pumice clasts up to 4 cm (1.5 in.) and commonly flow-banded. Matrix composed of crystal-vitric fine to coarse sand with hornblende, quartz, plagioclase, pumiceous ash, and pumice. Dacite composes 60% to 95% of the gravel and cobble component and is white and light to dark gray (GLEY 1 4/N-8/N, 2.5Y 8/1-8/2) and less commonly weak red (10R 4/3); dacite clasts are mostly angular and vesicular with flow banding in some clasts. Locally abundant brown to very pale brown and pink to white (10YR 8/2-8/4; 7.5YR 5/3, 8/4, 5YR 8/1) pumice concentrated near the top of the lahar. Rare gravel- to boulder-sized rip-up clasts of clay or clay with scattered gravel (probable dropstones) and rounded to subrounded clasts of granite, phyllite, and vein quartz. Mostly nonstratified with weak normal grading near the top; symmetrical coarse-tail grading. Commonly overlies recessional outwash. Thin reworked(?) beds of ash-sized tephra at contact with outwash at a few localities. Deposit ~1.5 m (5 ft) to perhaps locally 20 m (70 ft) thick (cross section C–C′).

Pleistocene Glacial Deposits

Deposits of the Fraser Glaciation

Deposits of the Vashon Stade and Everson Interstade of the Fraser Glaciation of Armstrong and others (1965) occur throughout the study area. Vashon Stade continental ice advanced up the Skagit, Sauk, and Stillaguamish River valleys about 15,500 to 15,000 yr B.P., blocking the major river valleys and forming temporary lakes in front of the advancing ice. Vashon ice covered the entire study area until about 14,000 yr B.P. The maximum extent of the Fraser continental ice lobe is mapped near the study area, directly east of Darrington (Tabor and others, in press). Deglaciation commenced about 13,500 yr B.P. and the map area was probably fully deglaciated by about 11,500 yr B.P. (Porter and Swanson, 1998; Dethier and others, 1995; Pessl and others, 1989). Ice occupation in the study area appears likely during deposition of at least part of the White Chuck assemblage (units Qvs_w and Qvl_w).

Everson Interstade

Qgo_e — **Recessional outwash (Pleistocene)**—Sand, sandy gravel, gravelly sand, and sandy cobbly gravel with some boulders; loose, braided river to locally deltaic deposits; clasts are subrounded and commonly polymictic with locally abundant granite and locally derived subangular phyllite and vein quartz; rare interlayered thin to laminated beds of sandy silt and silt. Locally contains rip-up clasts of glacial lake deposits. Non- to well-stratified; meter-thick, subhorizontal beds commonly crudely defined by variations in cobble, gravel, and sand content; pebble imbrication, scour, and local low-amplitude cross-bedding common. Typically poor in Glacier Peak dacite and (or) pumice (0–5%). However, some of the outwash sands and gravels south of the Stillaguamish River and directly west of the Darrington quadrangle contain as much as 40% dacite and pumice probably derived mostly from the late-glacial White Chuck assemblage. Locally divided into:

$Qgod_e$ — **Deltaic outwash (Pleistocene)**—Sand, sandy gravel, and cobbly sandy gravel; loose; moderately to well-sorted; beds are commonly 5 m (16 ft) thick with planar foreset beds in sets ten(s) of meters high dipping 25 to 30 degrees toward the valley; locally overlain by cobbly gravel topset beds along a scoured contact; typically contains locally derived clasts of phyllite, vein-quartz, greenstone, and sandstone mixed with clasts of Canadian provenance.

Qgl_e — **Recessional glaciolacustrine deposits (Pleistocene)**—Silty clay, clay, silty sand, and sand with local dropstones; gray to light gray; well-sorted; loose, soft, or stiff, nonstratified to laminated with rhythmite beds typically 1 cm (0.4 in) thick resembling varves; contains decimeter-wide sand dikes in the Stillaguamish valley; probably formed in glacial lakes impounded by retreating glacial ice; locally interfingers with recessional outwash and is inferred to be 10 ft thick (cross sections A–A′ and B–B′).

Vashon Stade

Qgt_{vi} — **Ice contact deposits (Pleistocene)**—Sand, gravelly sand, gravel, and bouldery cobbly gravel locally with interlayered beds of silty sand or sandy gravel; poorly to well-sorted; loose; boulders to 1.3 m (4.3 ft); typically clast-supported; rare flow and (or) ablation tills with a sand to silt matrix; beds are typically a decimeter to several meters thick. Contains near-ice structures, including oversteepened foreset bedding, ice-shear folds, and kettles, and subhorizontal beds of fluvial outwash typical of unit Qgo_e. Clasts are of mixed Canadian (granitic and orthogneiss locally >50%) and local (for example, greenschist) provenance; locally contains clasts of Glacier Peak dacite (up to 20%, typically 3–5%); dacite clasts are light to dark gray or pale red and up to 0.95 m (3 ft) wide; also locally contains lenses rich in pumice. Ice-contact deposits are richer in dacite and pumice than most recessional outwash; it is likely that some White Chuck assemblage detritus followed ice-marginal paths toward the Stillaguamish River basin during deglaciation (this study; Dragovich and others, 2002a; J. D. Dragovich, Wash. Divn. of Geology and Earth Resources, unpub. data). Abundance of gravel- to boulder-sized rip-up clasts of glaciolacustrine clay suggest excavation of lake deposits by glacial-ice and (or) subglacial-melt breakout mechanisms; ice-contact deposits are inferred to locally interfinger with glaciolacustrine deposits (unit Qgl_v) (cross section C–C′).

Qgt_v — **Till (Pleistocene)**—Nonstratified, compact, matrix-supported mixture of clay, silt, sand, and gravel in various proportions with disseminated cobbles and boulders; typically mottled dark yellowish brown to brownish gray, grayish blue, or very dark gray; matrix consists of silty fine to coarse sand (± clay). Includes clasts of Canadian and local provenance; up to 90% of clasts are locally derived and include angular to subangular phyllite or greenstone and rare Glacier Peak dacite. Till unconformably overlies bedrock in elevated alpine settings and locally occurs in the low valley-bottom glacial terraces, thus mantling topography.

Qga_v — **Advance outwash (Pleistocene)**—Medium to coarse sand, pebbly sand, and sandy gravel with scattered lenses and layers of pebble-cobble gravel; locally contains fine silty sand, sandy silt, and clay interbeds; well-sorted; compact. Subhorizontal bedding or cross-stratification predominant; localized cut-and-fill structures and trough and ripple cross-beds. Mostly Canadian provenance, some locally derived clasts, and little or no Glacier Peak dacite. Interfingers with and conformably overlies unit Qgl_v as a result of glacial lake impoundment during ice advance up the Stillaguamish and Sauk River valleys; composite sections of advance outwash and glaciolacustrine deposits are up to 150 ft (46 m) thick. Primarily fluvial in origin; based on stratigraphic relations including subsurface stratigraphy, some advance outwash is inferred to be deltaic (cross sections A–A′, B–B′, C–C′).

Qgl_v — **Advance glaciolacustrine deposits (Pleistocene)**—Clay, clayey silt, silt, silty clay, and silty fine sand with local dropstones; gray to light gray; stiff; well-sorted; thinly bedded or laminated. Silts and clays are dark gray, blue gray, and gray, weathering to pale yellowish brown; 1 to 4 cm (0.4–1.6 in.) thick rhythmite bedding ('varves?') common, normally graded from silt to clay. Soft-sediment and (or) ice-shear deformational features are common and include tilted and contorted bedding, overturned folds, and flame structures; overturned fold geometries are consistent with ice shear during ice advance up the major river valleys. Locally overlain by and interbedded with unit Qga_v (cross sections A–A′, B–B′, C–C′).

TERTIARY INTRUSIVE ROCKS

Eigb — **Gabbro (Eocene)**—Gabbro or diabase dikes, sills, and small irregular intrusions; nonfoliated; equigranular, medium-grained; greenish gray; some of the bodies appear to intrude faults; contains hornblende (commonly uralitic), plagioclase (mostly labradorite), and minor clinopyroxene phenocrysts; common alteration minerals include disseminated calcite, quartz, sulfides, and sericite. Although not directly dated, gabbros are probably Eocene and possibly Oligocene in age and may represent feeder bodies for volcanic rocks near the map area (Jones, 1959; Vance, 1957; this study; Dragovich and others, 2002a).

MESOZOIC TO PALEOZOIC LOW-GRADE METAMORPHIC ROCKS (BLUESCHIST FACIES)

Thrust-faulting and nappe formation in the Northwest Cascades System occurred in the Cretaceous (~110–90 Ma) (see Brown, 1987). The Chilliwack Group of the Excelsior nappe of Tabor and others (1994) structurally underlies the Shuksan nappe in the northeast part of the Darrington quadrangle.

Easton Metamorphic Suite of the Shuksan Nappe

The Easton Metamorphic Suite of Tabor and others (1994) includes the Darrington Phyllite, semischist of Mount Josephine, and the Shuksan Greenschist. These units are interlayered on mountain to outcrop scales and are interpreted to be oceanic crust (Shuksan Greenschist and part of the Darrington Phyllite) and submarine fan deposits (part of the Darrington Phyllite and the semischist of Mount Josephine). Semischist and phyllite are locally interlayered on a scale of millimeters to meters; these are interpreted as distal turbidite and basin-plain deposits. Shuksan Greenschist is mostly mid-oceanic-ridge metabasalt. Rocks of the Easton suite typically have a penetrative S1 (first-generation) foliation, with bedding transposed subparallel to S1 and abundant quartz segregation along S1. The Easton Metamorphic Suite is probably Jurassic (Armstrong and Misch, 1987; Brown and others, 1982; Brown, 1986, 1987; Gallagher and others, 1988; Tabor and others, 1994; Dragovich and others, 1998, 1999, 2000a).

Darrington Phyllite and (or) semischist of Mount Josephine (Jurassic)—Metasediments of the Shuksan nappe are divided into three map units on the basis of the percentage of interbedded phyllite and semischist:

Jph_d — 90–100% Darrington Phyllite (0–10% semischist of Mount Josephine)

Jph_{dj} — 50–90% Darrington Phyllite (10–50% semischist of Mount Josephine)

Jph_{jd} — 0–50% Darrington Phyllite (50–100% semischist of Mount Josephine)

Darrington Phyllite consists of sericite-graphite-albite-quartz phyllite to graphitic quartz phyllite (metashale or metasiltstone) with rare interbeds of micaceous quartzite (metachert) and albite schist; some phyllite is bluish black to black due to disseminated graphite (relict organic matter); silver-colored phyllites are muscovite rich; metamorphic minerals include chlorite, epidote, muscovite, lawsonite, and rare garnet; large albite porphyroblasts observed locally. Phyllites characteristically display two to locally three generations of folding. The second generation of folding (F2) is the most conspicuous and commonly has a subhorizontal fold axis oriented west-northwest or east-southeast.

Semischist of Mount Josephine consists of lithic-subquartzose semischist (metasandstone) and feldspathic metawacke; rare metaconglomerate; light green gray, green gray, medium gray, and light bluish gray. Semischist typically contains abundant stretched relict sand grains of polycrystalline and monocrystalline quartz, albitized plagioclase, and sparse lithic fragments; metamorphic minerals are similar to those of the Darrington Phyllite (Jones, 1959; Morrison, 1977; Tabor and others, 1988, 1994, in press; Dragovich and others, 1998, 1999, 2000a).

Jsh_s — **Shuksan Greenschist (Jurassic)**—Mostly well-recrystallized metabasalt; strongly S1 foliated; locally includes iron- and manganese-rich quartzite (metachert) and graphitic phyllite interlayers; greenschist locally contains epidote segregations or primary layers and is mostly shades of greenish gray and weathers to light olive gray; blueschist is bluish gray to bluish green. Greenschist commonly layered on a centimeter scale; S1 foliation and layering are commonly folded on an outcrop scale. Relict igneous minerals locally include saussuritized and albitized plagioclase laths, actinolized hornblende, and rare clinopyroxene. Metamorphic minerals include albite, actinolite, epidote, and chlorite with lesser lawsonite, Mg-pumpellyite, muscovite, spessartine, and calcite. In rocks of the appropriate iron composition and oxidation state, Na-amphibole (for example, crossite) replaces actinolite as the primary metamorphic amphibole to form blueschist instead of greenschist; greenschist and blueschist are locally interleaved at outcrop scale (Haugerud and others, 1981; Brown, 1986; Tabor and others, 1988, in press; Morrison, 1977; this study).

Chilliwack Group of the Excelsior Nappe

The Chilliwack Group is largely volcanic arc in origin. U-Pb ages and fossils indicate that the Chilliwack Group is largely Permian to Devonian in age (see Tabor and others, 1994).

$PDms_c$ — **Metasedimentary rocks (Permian to Devonian)**—Volcaniclastic metawacke, volcanic subquartzose metasandstone, and meta-argillite with minor marble and phyllite and rare chert and pebble metaconglomerate. Graded beds, rhythmites, and load casts locally prominent. Locally contains basaltic to rhyolitic greenstone. Greenstone includes breccia, tuff, and flows and is locally amygdaloidal and pillowed. Metamorphic minerals include albite, chlorite, epidote, and minor lawsonite, aragonite, and calcite. Rocks grade from slightly deformed to phyllitic with pronounced foliation generally subparallel to bedding (Tabor and others, 1988, in press; Vance, 1957; this study)

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Geologic Map of the Darrington 7.5-minute Quadrangle, Skagit and Snohomish Counties, Washington

by
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