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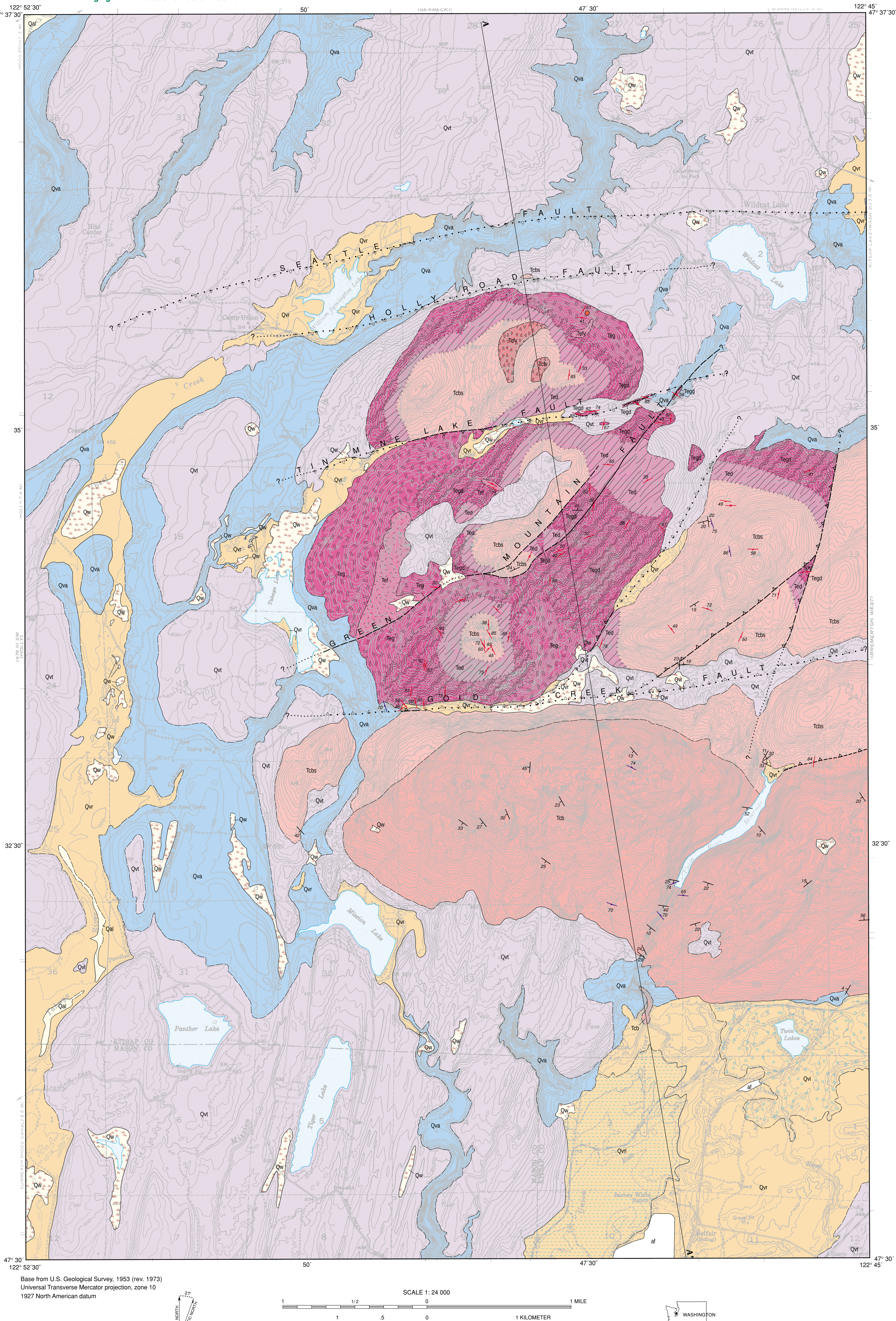
Preliminary geologic map of the Wildcat Lake 7.5' quadrangle Kitsap andMason counties, Washington

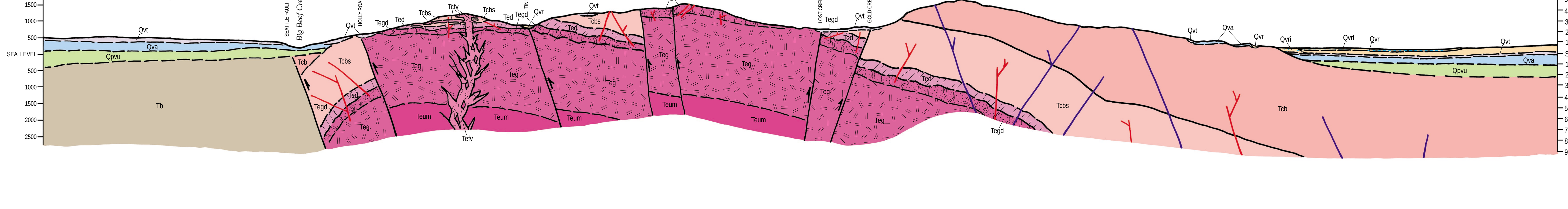


Base from U.S. Geological Survey, 1953 (rev. 1973)
Universal Transverse Mercator projection, zone 10
1927 North American datum

APPROXIMATE MEAN DECLINATION, 1995 (TRUE NORTH, MAGNETIC NORTH, 21°)

SCALE 1: 24 000

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC DATUM OF 1929



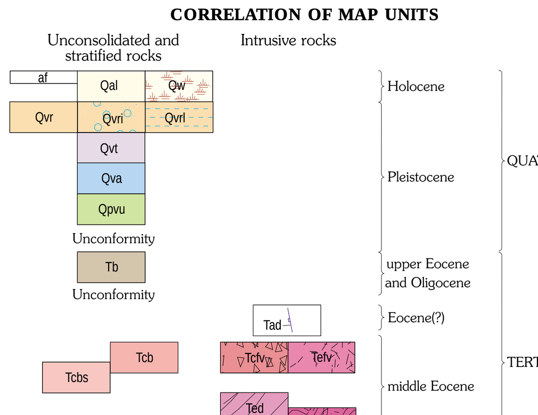
GEOLOGIC MAP OF THE WILDCAT LAKE 7.5' QUADRANGLE KITSAP AND MASON COUNTIES, WASHINGTON

By

Peter J. Haeussler and Kenneth P. Clark

2000

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

UNCONSOLIDATED DEPOSITS

Post-glacial deposits

af **Artificial fill (Holocene)**—Concrete in dam at northeast end of William Symington Lake, fill along railroad near Twin Lakes, and sanitary landfill near Barney White Ranch with modified recessional outwash gravels and lake deposits

Qal **Alluvium (Holocene)**—Moderately sorted deposits of cobble gravel, pebbly sand, and floodplain sandy silt along Stavis Creek and the Tahuya River

Qw **Wetland deposits (Holocene and late Pleistocene)**—Peat deposits with some intermixed sand, silt, and clay. Unit commonly occupies shallow depressions in till (unit Qvt) or low-lying areas of recessional outwash (Qvr or Qva)

Glacial and Interglacial Deposits

Deposits of the Vashon Stade of Fraser Glaciation of Armstrong and others (1965) (late Pleistocene)—Divided into:

Recessional outwash deposits—Divided into:

Qvr **Stratified sand and gravel (late Pleistocene)**—Stratified and unconsolidated buff-colored sand and gravel deposits

Qvri **Ice-contact deposits (late Pleistocene)**—Stratified and unconsolidated buff-colored sand and gravel deposits with pitted outwash topography in southeastern part of map area. Sediments locally show deformation as a result of sag, slump or collapse.

Qvrl **Recessional lake deposits (late Pleistocene)**—Laminated to massive silt, clayey silt, and silty clay deposited in a lowland lake in the southeastern corner of the quadrangle. Inferred as recessional because 1) sediments lie above diamict in boreholes beneath landfill near Barney White Ranch, and 2) elevation of a foreset/topset bed transition at McKenna Falls (Thorson, 1989) indicates deposition of sediment into recessional glacial Lake Russell (see Waitt and Thorson, 1983)

Qvt **Till (late Pleistocene)**—Compact light to dark gray non-stratified diamict containing subangular to well-rounded clasts, glacially transported and deposited. Clasts are commonly granitic and were derived from Canada. Commonly overlies advance outwash deposits (unit Qva) and bedrock on Green and Gold Mountains. Forms undulating surface, with sediment a few meters to about 20-m thick (Deeter, 1979)

Qva **Advance outwash deposits (late Pleistocene)**—Stratified to non-stratified gravel deposits. Locally consolidated and hard. Upper meter may weathered buff to brown. Clasts are usually moderately to well rounded and less than 40-cm across. Some deposits are diamicts that were deposited as debris flows issuing from front of advancing ice sheet. Debris flow deposits differentiated from till by: 1) lack of clasts larger than 40-cm, 2) large cobbles commonly touching rather than matrix supported, 3) high proportion (roughly 40% or more) of large clasts, and 4) usually not as hard as till

Qpvu **Pre-Vashon deposits, undifferentiated (Pleistocene)**—Glacial and interglacial sediments, inferred to underlie Vashon-age deposits and shown only on cross section

BEDROCK

Stratified rocks

Tb **Blakely Formation (Upper Eocene and Oligocene)**—Siltstone, sandstone, lapilli tuff, and pebble to cobble conglomerate. Most of section is of Oligocene age, but also includes late Eocene forminifera of the Refugian Stage (see Yount and Gower, 1991). Appears only on cross section, where it is inferred north of the Seattle fault

Crescent Formation (Middle Eocene)—Divided into:

Tcb **Massive basaltic lava flows**—Lavas contain pyroxene phenocrysts and calcite- or zeolite-filled amygdules. Texture in thin section is intergranular, with rock consisting of 45% labradoritic plagioclase, 35% augitic clinopyroxene, 15% opaques, and minor olivine and orthopyroxene. Individual flows are typically 10-m thick. Inferred to be subaerial because of a lack of interbedded sedimentary rocks. Exposed thickness is at least 180 m, but may be more than 1-km (Clark, 1989)

Tcbs **Submarine basalt and related volcaniclastic rocks**—Dominantly greenish-weathering submarine basalt flows interbedded with tuffs, tuff breccias, basaltic breccias, graded lithic and tuffaceous sandstones, basaltic siltstones, and conglomerates. No pillows recognized, vesicles are generally filled with calcite. In thin section plagioclase typically composes about 50% of the rock, clinopyroxene 35%, and opaques about 10%. Sedimentary interbeds usually less than one meter thick and up to 10-m thick. These volcaniclastic rocks include altered lithic tuffs, volcanic breccias, aquagene crystal-lithic tuffs, graded basaltic sandstones and siltstones, and welded tuffs. Approximately 180-m thick. Intruded by dikes of basalt and diabase of unit Ted

Tcfv **Felsic volcanic(?) rock**—Fine-grained pinkish-orange to brown weathering amygdaloidal quartz latite. Forms tabular bodies that could be either conformable interbeds or younger sills in submarine basalt. Probable high-level or extrusive equivalent of felsic intrusive rock, unit Tef. Intergranular porphyritic or intergranular glomeroporphyritic; alteration minerals comprise about 50% of rock

Intrusive rocks

Tad **Porphyritic and aphanitic andesite and dacite dikes (Eocene?)**—Medium to light grey. Dikes cut all other bedrock units. In thin section, consists of of about 50% plagioclase, 5-20% quartz, and 10-15% amphibole, and about 15% other mafic minerals. Textures are, in decreasing abundance, pilotaxitic porphyritic, glomeroporphyritic with a felty groundmass, and hyalopilitic

Tefv **Felsic intrusive rocks (Eocene?)**—Quartz monzonite, quartz diorite, tonalite. Texture in thin section is intergranular granophyric. Intrudes basalts that appear to cut leucogabbro of unit Teg

Ted **Sheeted dikes of basalt and diabase (Eocene)**—Sheeted dikes are dark greyish black on fresh surfaces and weather bluish to greenish grey. Dikes are a few centimeters to 10-m wide, but are most commonly 1-m wide. Dike margins are chilled on either one or both sides. Textures range from very fine grained to diabasic and microgabbroic. Augite is dominant pyroxene in thin section. Dikes are amygdaloidal where they intrude the overlying submarine basalts and sediments. Zone consisting entirely of dikes is about 150-m thick

Teg **Leucogabbro and pegmatite intruded by dikes of basalt and diabase (Eocene)**—Leucogabbro and pegmatite, described in unit Tegd, either fine or coarse grained occur as screens between dikes of basalt and diabase. Dikes, of unit Ted, are up to 10-m wide but are commonly 1-m wide. Medium grey on fresh surfaces, weathers light gray to orange gray

Tegd **Leucogabbro and pegmatite (Eocene)**—Massive leucogabbro, either fine or coarse grained. Medium grey on fresh surfaces, weathers light gray to orange gray. Texture in thin section is intergranular and glomeroporphyritic with phenocrysts of plagioclase and less commonly augitic pyroxene. Plagioclase ranges in composition from labradorite to bytownite. Overall rock composition is approximately 45% plagioclase, 40% clinopyroxene, up to 5% brown hornblende, and 5% opaques. The brown hornblende is interstitial to other mineral phases. 'Pegmatoid' denotes very coarse grained intrusive rocks associated with the leucogabbro. End members of the pegmatoid are gabbroic and granophyric. Gabbroic pegmatoid has intergranular texture with ophitic to subophitic plagioclase grains to 3-4 cm. Rock composition is approximately 45% plagioclase, 40% clinopyroxene, and 5-10% magnetite. Granophyric pematoid is intergranular granophyric with grains to several centimeters across and an overall composition of 40% oligoclase, 10-20% pyroxene, 25% quartz, 10% micrographic regions, up to 10% magnetite, and minor epidote and microcline

Teum **Ultramafic rocks (Eocene)**—Ultramafic rocks beneath Green and Gold Mountains inferred from modeling aeromagnetic and gravity data. Shown only on cross section. Rocks must be dense and magnetic

EXPLANATION

Contact — Dashed where approximately located

Contact — Gradational between igneous units

Fault — Dashed where approximately located; dotted where concealed

Fault — U, upthrown side; D, downthrown side

Reverse fault —Dashed where approximately located; dotted where concealed

Fault — Showing relative horizontal movement

Pb-U and apatite fission track sampling locality

Strike and dip of beds
15 Inclined
Horizontal

Strike and dip of dikes
85 basalt and diabase of unit Ted
86 andesite of unit Tad

GEOLOGIC SUMMARY

INTRODUCTION

The Wildcat Lake quadrangle lies in the forearc of the Cascadia subduction zone, about 20-km east of the Cascadia accretionary complex exposed in the Olympic Mountains (Tabor and Cady, 1978), and about 100-km west of the axis of the Cascades volcanic arc. The quadrangle lies near the middle of the Puget Lowland, which typically has elevations less than 600 feet (183 m), but on Gold Mountain, in the center of the quadrangle, the elevation rises to 1761 feet (537 m). This anomalously high topography also provides a glimpse of the deeper crust beneath the Lowland. Exposed on Green and Gold Mountains are rocks related to the Coast Range basalt terrane. This terrane consists of Eocene submarine and subaerial tholeiitic basalt of the Crescent Formation,which probably accreted to the continental margin in Eocene time (Snavely and others, 1968). The Coast Range basalt terrane may have originated as an oceanic plateau or by oblique marginal rifting (Babcock and others, 1992), but its subsequent emplacement history is complex (Wells and others, 1984). In southern Oregon, onlapping strata constrain the suturing to have occured by 50 Ma; but on southern Vancouver Island where the terrane-bounding Leech River fault is exposed, Brandon and Vance (1992) concluded 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 complex, exposed in the Olympic Mountains west of the quadrangle, developed by frontal accretion and underplating (e.g. Clowes and others, 1987). The Seattle basin, part of which lies to the north of Green Mountain, also began to develop in late Eocene time due to forced flexural subsidence along the Seattle fault zone (Johnson and others, 1994). Domal uplift of the accretionary complex beneath the Olympic Mountains occurred after ~18 million years ago (Brandon and others, 1998). Ice-sheet glaciation during Quaternary time reshaped the topography of the quadrangle, and approximately two-thirds of the map area is covered with Quaternary deposits related to the last glaciation. Geophysical studies and regional mapping indicate the Seattle fault lies north of Green Mountain. This fault produced a large earthquake about 1000 years ago and may pose a significant earthquake hazard (Bucknam and others, 1992; Atwater and Moore, 1992; Karlin and Abella, 1992; Schuster and others, 1992; Jacoby and others, 1992). We found no evidence of Holocene faulting in the Wildcat Lake quadrangle.

Geologic mapping within and marginal to the quadrangle began with Willis (1898), who described glacial deposits in Puget Sound. Weaver (1937) correlated volcanic rocks in the quadrangle to the Eocene Metchosin Volcanics on Vancouver Island. Sceva (1957), Garling and Moleenar (1965), and Deeter (1978) all focussed on mapping and understanding the Quaternary stratigraphy of the Kitsap Peninsula, but they also examined bedrock in the quadrangle. Reeve (1979) was the first to examine the igneous rocks on Green and Gold Mountains in some detail, and Clark (1989) significantly improved Reeve's (1979) mapping. Clark's (1989) mapping was conducted soon after extensive logging on the mountains. A surficial geologic map of the Seattle 1:100,000-scale quadrangle, which includes the Wildcat Lake 1:24,000-scale quadrangle, was published by Yount and others (1993). Yount and Gower (1991) also published a bedrock geologic map of the Seattle quadrangle. Geologic mapping for this report was conducted by Haeussler in the spring and summer of 1998 and in the winter of 1999. We could not substantially improve upon the bedrock mapping of Clark (1989) and thus it is incorporated into this map. Well data in the southeastern corner of the map area also helped to constrain the surficial mapping (Geomatrix Consultants, 1997). In addition, 1995 vintage 1:12,000-scale aerial photographs were also used in mapping Quaternary deposits. Geologic time scale is that of Berggeren and others (1995).

STRATIGRAPHY

Tertiary Bedrock

Lithologic similarity, similar chemistry, similarity in age, and proximity lead us to assign the volcanic and volcaniclastic rocks at Green and Gold Mountains to the Crescent Formation exposed on the Olympic Peninsula to the northwest, west, and southwest (Arnold, 1906; Tabor and Cady, 1978). Clark (1989) compared subaerial volcanic rocks of the Crescent Formation on Green and Gold Mountains (unit Tcb) to the lower and upper Crescent Formation on the Olympic Peninsula. The average subaerial flow thickness (9 m) at Green and Gold Mountains is thinner than flows in the Crescent Formation elsewhere (flow thicknesses of 30-50 m), and the size of vesicles (7 cm) is much larger than the largest vesicles in the Crescent Formation elsewhere (<4 cm). Nonetheless, Clark (1989) concluded the differences could be explained by proximity of the Green and Gold Mountains rocks to the volcanic source, whereas the others were distal. In addition, both rock units are subalkaline and tholeiitic, both have minor and trace elements that plot in the same fields on discriminant diagrams.

There are seven radiometric ages from the igneous rocks on Green and Gold Mountains. Duncan (1982) analyzed samples from three basalt flows along the northwestern shore of Sinclair Inlet, southeast of Bremerton, and east of the Wildcat Lake quadrangle. Whole rock K-Ar ages were between 43.3 and 49.2 Ma. Two of the samples were reanalyzed with the $^{40}Ar/^{39}Ar$ method, and yielded whole-rock total-fusion ages of 51.7±2.4 and 55.3±3.1 Ma. Duncan (1982) also step heated a whole-rock split and interpreted a 55.4±3.2 Ma age. Clark (1989) obtained, through Duncan, two $^{40}Ar/^{39}Ar$ total-fusion dates on one sample of leucogabbro. The ages were 50.4±0.6 Ma and 49.2±0.8 Ma. We obtained a $^{206}Pb/^{238}U$ age of 50.5±0.6 Ma from leucogabbro at the base of Green Mountain (Haeussler and others, 2000).

At localities northwest of the quadrangle, basaltic submarine deposits of the Crescent Formation have Ulatisian-age foraminifera (Yount and Gower, 1991). No ages were obtained from the subaerial basalts, but the overlying Aldwell Formation has benthic foraminifera and mollusks with ages from upper Ulatisian to lower Narizian (Spencer, 1984). Therefore, these subaerial Crescent Formation basalts have ages around 46-50 Ma on the time scale of Berggren and others (1995). By correlation, it is likely the Crescent Formation basalt flows in the Wildcat Lake quadrangle are of the same age. The fact that the $^{40}Ar/^{39}Ar$ dates on the basalt flows analyzed by Duncan (1982) were slightly older could be explained by: 1) recoil effects, because the $^{40}Ar/^{39}Ar$ analyses were whole rock, 2) the Crescent Formation basalts may be slightly time transgressive, or 3) the Crescent Formation basalts are lower Ulatisian rather than upper Ulatisian. The geochemical signature of the basalts and leucogabbro on Green and Gold Mountains indicates they are related. Therefore, because the $^{40}Ar/^{39}Ar$ ages are older than the $^{206}Pb/^{238}U$ age, we infer the $^{40}Ar/^{39}Ar$ ages probably suffer from excess argon or recoil.

The rock column exposed on Green and Gold Mountains, referred to as the 'Bremerton rocks' by Clark (1989), is somewhat like that of an ophiolite with basal gabbro beneath a locally sheeted dike complex, beneath submarine basalts and volcaniclastic rocks, beneath subaerial basalt flows. Clark (1989) found more than 60 m of basal leucogabbro and pegmatoid (unit Teg). Numerous diabase and basaltic dikes intrude the upper part of this unit and mapped it separately (unit Tegd). The overlying sheeted dike complex is approximately 150-m thick and consists entirely of dikes of diabase and basalt. The submarine volcanic unit (Tcbs) consists of basalt flows interbedded with basaltic sandstone, siltstone, tuffs, and basaltic breccia. Overlying the submarine volcanic unit are subaerial basalt flows (unit Tcb) more than 180-m thick. Trace-element data from intrusive and extrusive rocks are similar, suggesting they are related (Clark, 1989). The pseudostratigraphy differs from an idealized ophiolite stratigraphy in several important ways (Clark, 1989): 1) It lacks a basal ultramafic complex, 2) the Green and Gold Mountain dike complex has a thickness of about 150 m, in contrast to more than a kilometer of sheeted dikes in typical oceanic crust, 3) the dikes are locally, but not ubiquitously, sheeted, and 4) the Green and Gold Mountain sequence is capped by subaerial basalt, whereas most ophiolites are overlain by deep marine sediments. Clark (1989) found that the geochemistry of the gabbro and basalts is transitional between normal mid-ocean ridge basalt (MORB) and enriched oceanic island basalt. Preliminary modeling of aeromagnetic and gravity data over Green and Gold Mountains (Haeussler and others, 2000) indicate there are highly magnetic, dense rocks within a few kilometers of the surface, beneath Green an Gold Mountains. Therefore, there probably is a basal ultramafic complex. Despite the differences between the Green and Gold Mountains rocks and ophiolites, the presence of the dike section on Green and Gold Mountains and the overall pseudostratigraphy of an ophiolite indicate that these rocks formed in an extensional environment.

Andesite dikes are the youngest bedrock unit (blue dike symbol on map). These dikes cut all other rock units, and Clark (1989) reported geochemical data from one sample. It has extremely low Ti, low P, high Zr relative to Nb, and very low Cr, which are consistent with a high degree of partial melting. Clark (1989) concluded, based on this chemistry and crosscutting relations that the dikes are not related to the other rock types on Green and Gold Mountains.

Surficial Deposits

Overlying the Tertiary bedrock are unconsolidated deposits related to the last glaciation—the Vashon stade of the Fraser glaciation of Armstrong and others (1965). The Vashon ice sheet first covered the study area around 17,400 yr B.P., reached its maximum extent in southern Puget Sound around 16,950 yr B.P. (Porter and Swanson, 1998), and covered the region with up to 1500 m of ice (Booth, 1987). As the ice sheet advanced south of Port Townsend, it blocked northward drainage from the Puget Sound region and formed proglacial lakes that drained southward into the Chehalis River and then to the Pacific Ocean. There are no outcrops of the sediments deposited in these laces within the quadrangle, even among the lowest exposures along Big Beef and Stavis Creeks. However, clay was encountered in boreholes at the Olympic View Sanitary Landfill, south of Barney White Ranch along the southeastern edge of the quadrangle, which we infer was deposited as proglacial lake sediments. This clay lies approximately at sea level and is overlain by sandy and gravelly advance outwash (unit Qva) deposited by streams and rivers issuing from the front of the advancing ice sheet. Excellent exposures of advance outwash can be seen along a road leading down to Big Beef Creek northwest of Wildcat Lake. A couple meters above the level of the creek, there is a foreset-topset transition. Further up the section, sand and gravel was deposited as debris flows, with poor to no sorting, but there is a weak alignment of clasts. The percentage of cobbles in the debris flows appears to generally increase up section. Till (unit Qvt) marks the presence of the ice sheet in the study area, and mantles most upland surfaces. Till was found on Green Mountain at elevations up to 1350 feet (410 m). Ice overrode both Green and Gold Mountains, rounding the mountaintops. Green and Gold Mountains deflected the ice sheet as it found the easiest way over the mountains. Linear features in the till plane north of the mountains trend southwest, whereas those south of the mountains trend south-southwest. Granitic clasts within the till attest to a source at least 150km away in the Coast Mountains of British Columbia.

The Puget lobe rapidly retreated from its maximum extent, leaving the Wildcat Lake quadrangle ice free by about 16,500 yr B.P. (Porter and Swanson, 1998), and a series of proglacial lakes formed. The largest of these is named Lake Russell (Bretz, 1913), and it drained to the south to the Chehalis River (Thorson 1979, 1980; Waitt and Thorson, 1983). Silt and clay (unit Qvrl) near the Union River was deposited into Lake Russell. At least 20 large deltas were built out into Lake Russell (Thorson, 1980), and one of these deltas is located in the southeastern part of the map area. A foreset-topset transition within these recessional outwash sands and gravels (unit Qvr) at a quarry near McKenna Falls indicates the shoreline elevation of Lake Russell in the map area was 95.7 m (Thorson, 1989). The contact between the recessional lake deposits and the deltaic sand and gravel deposits is gradational and can be seen by examining outcrops along Old Navy Yard Way southwest of Twin Lakes. Other recessional outwash sands and gravels were found along the Tahuya River, and near the headwaters of Big Beef Creek, near, and southwest of, William Symington Lake. Some of the recessional sand and gravel was probably deposited in subglacial channels. The recessional sediments southeast of Mission Lake cut into the till and the underlying outwash sand and gravel, across the fabric in the fluted till plane. The streams presently occupying this ravine are underfit with respect to the meanders in the ravine, and if the stream formed after deglaciation, the stream path would have been parallel to the fluted till surface, rather than across it. Thus it probably formed as a subglacial channel. Knob and kettle topography within well-sorted sand and gravel in the vicinity of Twin Lakes indicates these recessional sediments were deposited in contact with stagnating ice.

Accompanying and outlasting deglaciation was isostatic rebound. Rebound at McKenna Falls is estimated as 49 m by taking the current elevation of the topset-foreset transition (95.7 m) and subtracting the elevation of the Black Lake spillway (46.7 m; see also Thorson, 1989).

The modern depositional environment includes alluvium (unit Qal) and wetland deposits (unit Qw). There is alluvium along the numerous streams in the map area, but these deposits are almost always too narrow to be mapped at 1:24,000 scale. Many of the wetland deposits are perched on till, indicating the till has poor drainage characteristics. Other wetlands, such as those surrounded by recessional outwash sand and gravel southwest of Tahuya Lake, appear to be filled kettles, which developed in contact with ice. Human modification of the topography is mostly seen as artificial fill (unit af) at the Olympic View Sanitary Landfill, near Barney White Ranch.

STRUCTURAL HISTORY

It is clear that the Green and Gold Mountains area has been uplifted. However, there is also an important older structural history related to rifting and emplacement of the sheeted dikes. Clark (1989) found that most dikes had north-northeast strikes, but there was considerable variation in dike orientations (Figure 1). This suggests there was east-southeast–west-northwest extension at the time of emplacement of the dikes, but perhaps the scatter in dike orientations indicates emplacement during a transtenstional strain regime where σ_1 or σ_2 rotated about a vertical axis. There is a north-northeast trending magnetic high in the aeromagnetic data that parallels the trend of the most common dike orientation. This suggests that the dikes may contribute significantly to the aeromagnetic signature.

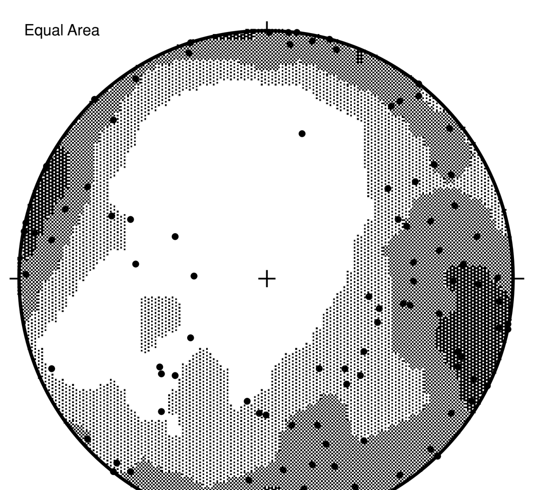


Figure 1. Kamb-contoured plot of poles to dikes of diabase and basalt. Black dots are poles to dikes. Data from Clark (1989).

Major faults within the quadrangle strike east-west. The most significant of these is the Seattle fault, which lies north of Green Mountain, and is indicated by aeromagnetic and gravity surveys of the region (Blakely and others, 1999a, 1999b). The Seattle fault extends along the southern edge of the Seattle basin from the east side of Lake Sammamish across Puget Sound to the Green and Gold Mountains area. On a regional scale, the Seattle fault records south-side up motion, indicated by the presence of bedrock uplifts—including Green and Gold Mountains, along the south side of the fault (Johnson and others, 1994). Johnson and others (1994) infer that the Seattle fault has been active since the Seattle basin started to form in late Eocene time. We obtained a preliminary apatite fission-track date of 32 ± 5 Ma (Haeussler and others, 2000) from leucogabbro also dated by Pb-U. This date is consistent with uplift of Green Mountain coincident with initial contraction across the Seattle fault and flexural subsidence of the Seattle basin. We found no evidence in the field or on aerial photographs for surface offset on the Seattle fault in the map area. The Tin Mine Lake fault, which lies between the two lobes of Green Mountain, and the Gold Creek fault, which lies between Green and Gold Mountains, are indicated by the prominent east-west strike of the valleys they occupy, as well as by offsets in the ophiolitic pseudostratigraphy. Another roughly east-west striking fault, which we refer to as the Holly Road fault, is located along NW Holly Road, just north of Green Mountain. This fault is indicated by the juxtaposition of submarine basaltic sediments along the road with leucogabbro on the north side of Green Mountain at its lowest elevations. The similar strike of the five east-west faults in the map area (the Seattle fault, the Tin Mine Lake fault, the Gold Creek fault, the fault near the Union River Reservoir, and the Holly Road fault) indicate they are related. We infer that the faults have reverse motion, because the Seattle fault has contractional structures, such as reverse motion fault-cored folds along its strike (Pratt and others, 1997). Thus, we infer the other east-west faults are probably also reverse faults. We infer that the three northern faults are south dipping and that the Gold Creek fault is north dipping, but the dip angle is unconstrained.

Clark (1989) mapped three additional faults with northeast or north-northeast strikes. The Green Mountain fault is a left-lateral oblique fault, which bisects Green Mountain. Clark (1989) observed left-lateral slickensides on fault surfaces in outcrop. Northwest-side-down sense of dip-slip motion on the fault is also indicated by offset of the ophiolitic pseudostratigraphy. On slickensided surfaces, the dip-slip slickensides were the youngest. The Lost Creek fault is southeast of the Green Mountain fault and has a strike and sense of separation similar to the Green Mountain fault, and is principally indicated by a geomorphic lineament and offset in the pseudostratigraphy. The Union River fault, located north of the Union River reservoir, follows a north-northeast trending topographic lineament. West-side-up movement along this fault is indicated by offset of the ophiolitic pseudostratigraphy.

The relationship between these northeast-striking faults and the east-west striking faults is uncertain. Clark (1989) concluded the northeast striking faults formed in the late stages of the same extensional event that produced the mafic dikes, based on his inference that the dip-slip motion was normal, and on their orientation. If these faults were normal, then the extension direction of the most common dike orientation is similar to the extension direction inferred by the faults. If the northeast-striking faults were related to dike intrusion, we suggest there would be faults that cut the lower, but not the entire, ophiolitic pseudostratigraphy. However, such faults have not been found. We suggest that the northeast-striking faults may be related to contractional and/or oblique motion on the Seattle fault and related faults.

Overall, the deformation and fault pattern generally suggests north-south compression after Crescent Formation time, a conclusion consistent with underthrusting of the Crescent beneath Vancouver Island and continued northward migration of the Coast Range in response to oblique subduction (Clowes and others, 1987; Wells and others, 1998).

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