RECONNAISSANCE GEOLOGY OF THE
MATHENY RIDGE - HIGLEY PEAK AREAS,
OLYMPIC PENINSULA, WASHINGTON

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CONTENTS

Introduction 5
Topography 5
Geomorphology 7
   Glacial Geology 7
   Slope Stability 9
Structure 10
   Lithologic Layering 10
   Primary Cleavage 11
   Shears 11
   Folds 11
   Minor Structures 14
Lithologies, Lithologic Relations 14
Volcanic Rocks 18
   Geochemical Data 18
Unit Descriptions 25
   Quaternary 25
   Tertiary 26
Acknowledgments 28
References Cited 29
FIGURES

Figure 1. Index map.

Figure 2. Equal-area lower hemisphere projection of 271 poles to lithologic layering attitudes in the study area.

Figure 3. Equal-area lower hemisphere projection of poles to 134 attitudes measured on the primary cleavage ($S_1$).

Figure 4. Equal-area lower hemisphere projection of poles to 20 secondary shear sets.

Figure 5. Equal-area lower hemisphere projection of the axes of 17 select folds that bend lithologic layering and the primary cleavage and poles to 4 pencil lineations.

Figure 6. Total-Alkali-Silica (TAS) diagram for classifying volcanic rocks according to IUGS standards (Le Bas and others, 1986).

Figure 7. Plot of rock vs. average MORB chemistry for a selected suite of minor and trace elements (Pearce, 1982). Null points are arbitrarily plotted to maintain visual trends from Pearce's (1982) original plots.

Figure 8. TiO$_2$-MnO-P$_2$O$_5$ plot (Mullen, 1983) for Matheny Ridge area basaltic rocks. Average values of nearby Crescent Formation and Grays River volcanics (Phillips and others, 1989) plotted for comparison.

PLATE

TABLES

Table 1. Locations of basaltic rocks sampled for whole-rock chemical analysis.

Table 2. Major and minor oxide values determined by X-ray fluorescence (XRF) at Washington State University, reported as %. Top part of table shows raw values; bottom part shows values recalculated to equal 100%.

Table 3. Trace element data determined by XRF, reported as parts per million (ppm).
INTRODUCTION

This report describes geologic studies of the area between the Quinault River valley and Sams Ridge that lies west of the Olympic National Park and east of the West Boundary Road (U.S. Forest Service Road 21). The study area is shown on Figure 1.

This work was undertaken to support the Department of Natural Resources state geologic map program (Schuster, 1992) as well as to provide information for forestry, petroleum, and wildlife studies. The main objective was to resolve structure and stratigraphy of the area mapped as "Tertiary undifferentiated" on the only geologic map of the area (Tabor and others, 1978a).

Olympic Peninsula is composed of an outer horseshoe-shaped, east-plunging anticlinorium defined by the map patterns of Crescent Formation basalts and the overlying sedimentary and volcanogenic rocks of Eocene and younger age (Tabor, 1982; Palmer and Lingley, 1989; Brandon and Calderwood, 1990). These rocks have been called the "Peripheral Rocks" (Tabor and Cady, 1978a) or "Crescent Terrane" (Babcock and others, 1994). The Peripheral Rocks, which were deposited on older accreted terranes, are now tectonically superimposed over coeval units that comprise hemipelagic sedimentary and minor volcanogenic rocks deposited on the Juan de Fuca plate (Tabor and Cady, 1978b; Orange, 1990; Lingley, 1995). These Eocene to middle Miocene accreted units are called the Core Rocks (Tabor and Cady 1978a).

The study area is entirely covered by of the Core Rocks or by Quaternary sediments. Tabor and Cady (1978a) and Rau (1976, 1973) subdivided the Core Rocks into major lithic assemblages, mainly on the basis of subtle differences among large packets of remarkably monotonous lithologies. Tabor and Cady were unable to assign rocks within the study area to the major lithologic assemblages, hence this study. The mapping depicted on Plate 1 represents an incremental increase in our knowledge of the geology of the western margin of the Olympic Mountains.

The Core Rocks are chiefly feldspathic litharenites with lesser amounts of lithofeldspathic arenitic sand, siltstone, shale, and various basaltic lithologies (Lingley, 1995; Tabor and Cady, 1978a; Koch, 1968). No identifiable fossils have been collected during this study. Although several samples were processed for foraminiferal content, W. W. Rau was unable to recognize any microfossils owing to intense induration of these rocks (Washington Department of Natural Resources, 1996 oral communication).

TOPOGRAPHY

The study area consists of four heavily-forested ridges and intervening valleys that trend and diminish in elevation westward. From the north, these are, Sams Ridge, Matheny Ridge, the ridge separating the North and Middle Forks of the Salmon River, and the ridge trending westward from Higley Peak, a 915 m forested knob directly north of Lake Quinault. The
topographic culmination of the study area is a 1,035 m. knob on the eastern end of Matheny Ridge.

The area is drained by the Sams, Salmon, Raft, and Quinault Rivers and by Matheny Creek, all of which flow westward down the slope of the Juan de Fuca accretionary prism. Hook Branch and Prairie Creek are important tributaries of the Quinault River and Matheny Creek, respectively. Several tributary streams, including Hook Branch and Canoe Creek, have a distinctive "hook" shape when viewed in plan. The broad, flat-floored Queets and Quinault valleys lie within the northern and southern margins of the study area, respectively.

GEOMORPHOLOGY

Most valleys within the study area have V-shaped profiles except in their upper reaches where they broaden into basins that have cirque-shaped plans and are commonly filled with thick colluvial deposits. However, the Sams River as well as the upper parts of Matheny, Prairie and Finley Creeks have U-shaped profiles. Below 250 m elevation, the Queets, Sams, and Quinault rivers deposited alluvium across 1-2 km wide plains.

The study area can be divided into two geomorphic areas on the basis of drainage patterns: the northeastern third is characterized by a moderately-developed trellis drainage whereas drainages to the southwest have a dendritic pattern. The trellis pattern extends north of the study area into the Tshletshy Creek area. The trellis pattern is best developed at north-trending tributary valleys that are perpendicular to the eastern parts of the Sams River and of Matheny and Tshletshy Creeks. In these areas, first- and second-order creeks draining northward (22 drainages) are sub-linear, steep, v-shaped, and mostly trend due north (Plate 1).

Glacial Geology

Previous studies of glacial geology in the study area concentrated on the Queets (Thackray, 1996) and Quinault (Moore, 1965) valley glaciers. In this study, we emphasize less extensive glacial units near the headwaters of the Sams River and Matheny, Prairie, and Canoe Creeks similar to the Tshletshy glacier of Tabor (1987). Localized till outcrops, faceted spurs, cirque-shaped valleys, U-shaped profiles, and other lines of evidence suggest wide spread alpine glaciation was present in the study area, but thick colluvium masks and deeply incised streams have eroded most glacial deposits.

The study area lies south of the Queets Valley, where Thackray (1996) mapped four drift units resulting from alpine glaciers that flowed out of the Queets Valley and spilled southward to form terraces and terminal moraines that impinge on the westernmost portions of the study area. The youngest of these units, the early-Wisconsin aged Hoh Oxbow drift, forms a series of outwash terraces and dead ice landforms that blanket the northwestern end of Matheny Ridge. Farther south,
where Matheny Creek issues out of the higher hills and onto the broad Queets valley, outwash terraces consist of Lyman Rapids drift, which he considers to be late Wisconsin advance. Strata underlying the Lyman Rapids drift in the Queets Valley near the study area constrain the maximum age of this unit to 57,900 years bp (Thackray, 1996). The Hoh Oxbow drift ranges from 49,000 to 14,480 years bp (Thackray, 1996). Thackray’s Whale Creek drift, of questionable Illinoian age, forms the westernmost sediments in the study area. A Whale Creek end moraine encroaches on the study area where the Salmon River crosses Forest Road 23 (Thackray, 1996).

Moore (1965) identified three alpine events in the Quinault Valley. The youngest unit, the Chow Chow drift covers the study area north of Highway 101 and south of the topographic rise onto the Higley Peak ridge. The rise is blanketed with older unit, the Humptulips drift. Humptulips drift mapped on the Thimble Mountain 7.5 minute topographic sheet (Moore, 1965) is contiguous with Whale Creek drift mapped on the Salmon River East topographic map (Thackray, 1996). Moore also mapped Humptulips drift in Wright Canyon and other drainages southeast of Lake Quinault.

All major and most subsidiary drainages in the eastern half of the study area terminate in cirque-shaped basins with steep headwalls. Most of the cirque-shaped basins are filled with angular colluvium. However, a few localized diamictons with subrounded and sub-spherical cobbles and boulders are present in the study area. We observed no striated boulders or outcrops. Probable till is present in several places at altitudes less than 500 m along Sams River and in the flat T-shaped basin which forms the headwaters of Prairie Creek (Unit Qat - Plate 1). We believe that these cirque-shaped basins and diamictons are glacial features that formed as a result of an older alpine glaciation. Ice appears to have accumulated in cirques with floors at about 750 m elevation in the Sams River drainage and about 600 m on Prairie Creek.

While no hanging valleys enter the Queets or Quinault from the study area, well-developed hanging valleys, such as Wright Canyon issue out above the southern side of the Quinault valley at elevations of about 400 m. Cooler microclimates on the shaded north side of generally east-west ridges probably cause glaciers and the resulting hanging valleys to form only on the north sides of the ridges. We speculate that hanging valleys are better preserved south of the Quinault because these were cut in resistant Crescent Formation basalts, and hanging valleys in the study area are less preserveable because the weaker sandstone/shale sequences of the Core Rocks were easily eroded during rapid uplift of the accretionary prism.

Many of the northern ends of the subsidiary (north- or south- trending) ridges terminate as faceted spurs. The tops of these facets are typically at elevations of 1,000 m near the headwaters of Sams River and Matheny Creek and about 700 m in the central parts of these drainages. In map view, the facets parallel the curves of Sams Rivers and Matheny Creek. These same patterns are present north of the study area on the north side of Sams Ridge, where Tabor (1987) postulated a Tslehtsby valley glacier. Facets are present on the south side of the Quinault River (Quinault Ridge). These facets appear to result from truncation by alpine valley glaciers flowing down Sams River and Matheny Creek.
The flat, T-shaped basin near the headwaters of Prairie Creek is of particular interest. The eastern margin of this basin appears to be a north-trending cirque whose headwall is located about 1 km west of Higley Peak. The glaciated valley leading away from the cirque headwall makes an abrupt turn to the west and then flows south into the Quinault drainage. The east-flowing western limb of the "T" terminates at a low topographic sill that separates the flat basin from the headwaters of the Middle Fork of the Salmon River. The Salmon River valley lacks till or geomorphic evidence of glaciation, so any ice that calved westward over the topographic sill from the Prairie Creek basin did not accumulate in that area.

Moore (1965) maps Humptulips drift in Wright and Ziegler Canyons suggesting that drift in Prairie and Canoe Creeks may be equivalent to the Humptulips (and Whale Creek Drift?). Terrace deposits, such as the 100 m thick terrace located 250 m east of the Sams River bridge on Road 2180-500, may be the result of base level shifts caused by an ice dam at the Sams River - Queets valley confluence by younger, less extensive Hoh Oxbow ice.

Slope Stability

In general, the area is characterized by shallow mass wasting and fewer landslides than similar steep, high-relief sloped areas we have examined (e.g., Logan and others, 1988; Dragovich and others, 1990). However, the U.S. Forest Service (Quinault Ranger District, 1995) mapped about 300 small to medium (1,000 to 15,000 m$^2$) mass-wasting sites in the Matheny Creek drainage including about 50 debris torrents. The debris torrents are limited by gullies and range from about 250 to 4,000 m in length. The Quinault Ranger District study indicates that about 60 percent of these mass wasting sites are related to forest management and the remainder are natural. Large-scale creep is present directly east of a large slide in Sams River about two miles east of its confluence with the Queets River and on slopes directly west of Finley Creek in the southeastern corner of the study area.

The Prairie Creek slide, which originates above Forest Road 2190 at elevation 450 m is the largest (volumetrically) landslide in the study area that is related to steep slopes. (See Plate 1, Unit Qls.) It covers about 21,000 m$^2$ and displaces at least 17 m of colluvium and bedrock (depth recorded from inclinometer - S. Muesser-Wilson, U.S. Forest Service, 1996, oral comm.). Both of these large slides appear to have been caused by natural slope instability as opposed to forest management practices.

The relatively small number and shallow depth of most slides appears to be related to high levels of induration in the eastern two-thirds of the study area. Frequent paleo-slides may have reduced the amount of colluvium available to trigger recent slides. Farther west, on terraces of the Queets River and in tributaries of the Clearwater River, similar lithologies that are poorly indurated are subject to intense instability.
STRUCTURE

The study area consists mostly of a regional-scale northeast-dipping homocline (Figures 2, 3; Plate 1) with minor northwest- or southeast-plunging mesoscopic folds (Figure 5). (Also see Tabor and Cady, 1978b.) This homocline is interrupted by a regional zone of penetrative shearing, which we believe is a northwest-striking, east-dipping thrust fault, an interpretation originally suggested in Tabor and Cady (1978b) Northwest or southeast plunging folds and small northeast-striking faults have been observed in outcrop.

Lithologic Layering

Lithologic layering in the study area is generally well defined by the alternation of light-colored medium to thick bedded sandstone with darker thin-bedded units. The thin bedded units are composed of very fine grained sandstone and siltstones with minor amounts of shale. These units have sharp, planar contacts that are mostly parallel; bedding thick shows little variation in outcrop scale except in the thick-bedded (1-5 m) sandstone units. Few sole marks and cross beds, and little scour have been observed.

Bedding is most clearly defined in the eastern half of the study area. In the central part of the study area, bedding is disrupted by penetrative shearing, and sandstone beds have been stretched to rearrange the lithologic layering parallel to the dominant cleavage and sheared into numerous phacoids. In the western quarter, vegetation, relatively poor induration, and more intense weathering (due to lack of scouring by glaciers) obscure most outcrops. In some areas, bedding has been rearranged by shearing and is indistinguishable from scaly cleavage and rotated phacoids.

Three basic bedding characteristics are displayed in all sedimentary and some of the volcanogenic rocks within the study area. These bedding characteristics are a more useful mapping tool than grain size or lithology. (See Lingley, 1995.)

Most common are laminated and thin-bedded (0.5 to 15 cm) very-fine grained sandstone, siltstone, and shale units with sharp, laterally-extensive contacts that show little change in bed thickness within individual outcrops. (See Lingley, 1995: Lithofacies I.) The thin-bedded units have been called rhythmites by previous workers (e.g., Tabor, 1975; Rau, 1976). Cleavages, folds, and phacoids are best developed in the thin-bedded units. Thin bedded rocks near the headwaters of the North Fork of the Salmon River are thoroughly disrupted by shearing and folding and grade into a melange of orange-weathering broken and sheared shale with sandstone phacoids. Thin-bedded units are present throughout the study area and form two mappable units extending from Prairie Creek northwestward through the headwaters of the Salmon River to Matheny Creek. (Thts on Plate 1).

Medium bedded (0.10 to 1.0 m) sandstones with minor amounts of intercalated thin-bedded units are common in the eastern half of the study area. (See Lingley, 1995, Lithofacies IV) These
also have sharp contacts that are generally parallel, but some scouring has been observed. These are mapped as Thtm on Plate 1.

Homogeneous or banded, thick-bedded (0.5 to 5m), multistory sandstones form summits and ridges throughout the eastern two-thirds of the study area. (See Lingley, 1995: Lithofacies II). These have parallel or scoured contacts. These multistory units range in thickness from about 10 to 46 m. The sandstones become less deformed and more common in the eastern one-third of the study area where primary sedimentary structures are well preserved.

The mean bedding in the western and central portions of the study area strikes north 15° west dipping 42° northeast (Fig. 2). In the eastern portion of the study area, lithologic layering swings slightly to the east and has a mean attitude of north 5° east, 38° northeast.

Lithologic layering in the study area is thought to result from deep marine deposition, although a few shallow water bed forms and other sedimentary structures have been observed. We speculate that most of these rocks were laid down as submarine debris flows (multistory sandstones) or as associated submarine overbank deposits (thin- and medium bedded rocks).

Primary Cleavage

A penetrative scaly cleavage (S1) is present throughout western and central portions of the much of the study area (Fig. 3), but is weakly developed or absent in the eastern half (Plate 1). (Also see Tabor and Cady, 1978b.) This scaly cleavage is generally parallel or subparallel to S0. In the west-central parts of the area, S1 entirely obliterates S0 in thin-bedded, finer-grained strata. Where individual sandstones are interbedded with thin-bedded units, the sandstones are sheared out forming phacoids. S1 appears to flow around and rotate many of these phacoids (Fig. 4).

The primary cleavage probably formed in response to thrust faulting as the Core Rocks built into a critical taper (See Boyer and Lingley, 1992; Palmer and Lingley, 1989; Tabor and Cady, 1978b).

Shears

Shear zones, typically 10 to 30 cm thick, cut S0 and S1 at various angles. In this study, we did not measure a sufficient number of these shears to determine dominant orientations or to establish a sequence of shear-related deformation. Our observations on shear orientations are summarized in Figure 4.

Folds

Mesoscopic folds are fairly common throughout the study area. Most have an open-concentric geometry and bend both S0 and S1. Axial planes are generally sub-parallel with S0 and fold axes plunge northwest or southeast at shallow to moderate angles (Fig. 5). Folds are
Figure 2. Equal-area lower hemisphere projection of 271 poles to lithologic layering attitudes in the study area.
Figure 3. Equal-area lower hemisphere projection of poles to 134 attitudes measured on the primary cleavage ($S_1$).
commonly associated with small faults, either as drag or roll-over.

The fold pattern and geometry are consistent with thrust-driven folding.

Minor Structures

Pencils, or elongate splinters of shale or slate created by the intersection of S₀ and S₁ are present only in the eastern most part of the study area on the southern slope of Sams Ridge. Measured pencil attitudes in this area are N20°W30°S.

An axial plane cleavage was observed on Sams Ridge; however it appears this cleavage is related to a very late phase of deformation. In other outcrops, we observed wispy suggestions of a second cleavage, but we were unable to determine the orientations of these surfaces with confidence.

LITHOLOGIES, LITHOLOGIC RELATIONS

We have differentiated rocks in the study area on the basis of lithostratigraphic units that reflect gross lithologies and consistent bedding characteristics as described in lithologic layering, above.

Where possible, we have adopted the nomenclature of Tabor and Cady (1978a); we map bedrock units (Plate 1) with "Th-- labels" meaning "Tertiary Hoh rock assemblage". Tabor and Cady used this nomenclature to incorporate mapping of coastal areas between Pt. Grenville and the Hoh River Valley by W. W. Rau (1973; 1975; 1979) who mapped these rocks as part of his Hoh rock assemblage. The Hoh rock assemblage appears to include lithostratigraphic equivalents of bedrock units mapped herein and described below.

The eastern two-thirds of the study area are covered by a remarkably monotonous section of thick bedded, multistory sandstones separated by sheared and broken shale and/or medium-bedded units mapped as Thts on Plate 1. Although these exposures of Unit Thts resemble Thts as described by Tabor and Cady (1978a), Thts in the study area lacks cross-bedding and graded bedding. Unit Thts in the study area also resembles the Western Olympic lithic assemblage (Unit T₁₀ of Tabor and Cady, 1978a) and massive sandstone outcrops in Kimta Creek, which is located about 12 km east-northeast of the study area.)

West of Unit Thts, what appear to have been similar massive sandstone and fine-grained laminated units are so thoroughly disrupted by cleavage and shearing that none of the original bedding character remains and these are best described as a melange. We have mapped these rocks as Thm. Unit Thm is similar to rocks in the Clearwater River Shear Zone of Stewart (1970) and the Goodman Creek melange of Rau (1975), but does not resemble melanges of probable diapiric origin described
Figure 4. Equal-area lower hemisphere projection of poles to 20 secondary shear sets.
Figure 5. Equal-area lower hemisphere projection of the axes of 17 select folds that bend lithologic layering and the primary cleavage and poles to 4 pencil lineations.
by Rau and Grocock (1974) or Orange (1990). The Thm/Thst contact is gradational over a distance of more than 1 km. Therefore, we used continuity of \( S_0 \) across roadcut exposures as an arbitrary method of mapping the Thm/Thst contact. Where bedding is continuous from the top to the bottom of a large percent of typical roadcuts (5 to 10 m high), we mapped rocks as Unit Thts, regardless of amount of bedding-parallel deformation owing to \( S_1 \) or development of phacoids. Where all bedding is obliterated in most roadcuts, we mapped the rocks as Unit Thm.

Where exposed, the western margin of Thm is best defined contact in the study area. The contact generally trends northwest parallel with \( S_0 \) and is defined by the juxtaposition of gray-weathering Thm sandstones against monotonous orangish-gray brownish-gray weathering broken-shale and bedded fine sandstone dominated unit. Along the southern reach of the headwaters of the North Fork of the Salmon River, this contact trends due north and separates such disparate lithofacies (probable submarine channel sandstones from interdistributary or basinal thin-bedded strata) that it is difficult to interpret this structure as anything other than an east-dipping fault.

West of the contact, the aforementioned flysch is mapped as Thsr. The flysch is typically laminated and bedded 0.5 to 10 cm and consists mainly of very fine grained to medium grained sandstone with smaller amounts of dark gray siltstone and very dark gray shale. Even in these thin-bedded units, the sandstone/siltstone+shale ratio is generally greater than 1.0. We map this unit as Thsr rather than Thr because of it weathers brown and it is approximately on strike with exposures of Thsr north of the Clearwater River shear zone. The western end of this exposure appears to be progressively more deformed by bedding plane slip and multiple shear sets, but its western contact, though not exposed, is fairly distinct. Further west, a second exposure of northwest-trending Thsr is present.

In the western one quarter of the study area, two sections of undifferentiated sandstone, siltstone, and conglomerate are present. These strata, mapped as Unit Thsu, are mostly gray-weathering and resemble unit Thts except that the massive sandstone units are thinner (1-3 m), there appears to be a higher percentage of thin bedded strata, and \( S_1 \) is penetratively developed. Unit Thsu also contains a number of well-rounded, spherical to sub-spherical chert and volcanogenic pebble conglomerates. These clast-supported conglomerates are locally depicted as Unit Thc, can be distinguished from the ubiquitous intra-clast breccias and conglomerates by composition, clast matrix support, and sphericity.
VOLCANIC ROCKS

Geochemical Data

Five samples of rock from unit Tb of Tabor and Cady (1978a) were collected for chemical analysis. All the analyses reported here are by x-ray fluorescence (XRF) and were performed at Washington State University. Analyses consist of 10 major and minor oxides and a suite of 17 alkaline earth and transition trace elements. Volatiles were not determined and the analyses are normalized to 100 weight percent. Iron (FeO*) was determined as total iron expressed as FeO. Sample locations are given in Table 1; major and minor oxide values are given in Table 2; trace element data are shown in Table 3. Estimates of analytical and instrumental precision for the XRF analyses are given in Phillips and others, (1989).

Following guidelines of the International Union of Geological Sciences (IUGS) for volcanic rock names (Le Bas and others, 1986) and using the total alkali-silica (TAS) diagram, samples 3 and 5 are basalts, samples 2 and 4 plot on the common join among basalt, basaltic andesite, trachybasalt, and basaltic trachyandesite, and sample 1 is a basaltic trachyandesite (Figure 6). All of the samples are sodic by IUGS guidelines and so the basaltic trachyandesite can be more specifically named a mugearite.

We plotted most of the elements used by Pearce (1982) to discriminate oceanic lavas (Figure 7). However, our dataset does not include values for tantalum, hafnium, samarium, and ytterbium, which are set to arbitrary values in Figure 7. All are generally enriched relative to mid-ocean ridge basalt (MORB), although sample 4 is relatively depleted in thorium, sample 2 is depleted in chromium, and sample 1 is depleted in scandium and chromium. Sample 1 is more strongly discriminated from the other samples by using the Cerium/Strontium ratio, which suggests that it requires some contamination from a subduction zone (Pearce, 1982).

Using Mullen's (1983) petrogenetic criteria (Figure 8), sample 1 plots in the ocean island alkalic, or seamount alkalic field, and plots very close to the average (from Phillips and others, 1989) volcanics of Grays River, which were erupted into a forearc setting (Walsh and others, 1987). The other four samples plot in the mid-ocean ridge basalt field and are very close to the average of Crescent Basalt samples analyzed in Phillips and others (1989).

While the number of samples analyzed is small, the results suggest that the basaltic rocks found in the Matheny Ridge area represent two different tectonic or petrochemical environments. Their juxtaposition suggests either that the shears separating sample 1 from the others may have significant fault displacement or that some of the basalts may have been emplaced as olistostromal blocks rather than being in-place flows.
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Table 1. Locations of basaltic rocks sampled for whole-rock chemical analysis.
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<td>96.65</td>
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Unnormalized Results (Weight %)

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<td>SiO₂</td>
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<td>52.07</td>
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<td>11.8</td>
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<td>12.54</td>
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<td>0.197</td>
<td>0.205</td>
<td>0.181</td>
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<tr>
<td>CaO</td>
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<td>7.72</td>
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<tr>
<td>MgO</td>
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<td>7.69</td>
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<tr>
<td>K₂O</td>
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<td>1.09</td>
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<tr>
<td>Na₂O</td>
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</table>

Normalized Results (Weight %--Total = 100%)

Table 2. Major and minor oxide values determined by X-ray fluorescence (XRF) at Washington State University, reported as %. Top part of table shows raw values; bottom part shows values recalculated to equal 100%.
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</table>

Trace Elements (ppm)

Table 3. Trace element data determined by XRF, reported as parts per million (ppm).
Figure 6. Total-Alkali-Silica (TAS) diagram for classifying volcanic rocks according to IUGS standards (Le Bas and others, 1986).
Figure 7. Plot of rock vs. average MORB chemistry for a selected suite of minor and trace elements (Pearce, 1982). Null points are arbitrarily plotted to maintain visual trends from Pearce's (1982) original plots.
Figure 8. TiO$_2$-MnO-P$_2$O$_5$ plot (Mullen, 1983) for Matheny Ridge area basaltic rocks. Average values of nearby Crescent Formation and Grays River volcanics (Phillips and others, 1989) plotted for comparison.
UNIT DESCRIPTIONS

Quaternary

Qc - Massive and Stratified Colluvium

A few centimeters to several meters of colluvium blanket most slopes and gullies within the study area. Bedrock and older Quaternary deposits are present only in a limited number of road cuts. Landslide scarps, and strike ridges. Consequently, Unit Qc is not shown on Plate 1 so that other units may be depicted.

Unit Qc consists of clay-rich sand and organic debris together with poorly sorted subangular pebbles and cobbles of sandstone and/or basalt. Commonly stratified parallel with the slope and bedded 10 to 25 cm. Mostly medium grayish brown to dark reddish brown. The unit is generally well drained. Unusually thick colluvium probably results from slopes steepened by glacial erosion, high precipitation (up to 508 cm annually (Quinault Ranger District, 1995), poor induration, and rapid uplift.

Qls - Landslide deposits

This unit consists about 50 debris flows localized in gullies, such as the Prairie Creek slide, minor mid-slope landslides, and the deep-seated Higley Peak Road slide. The shallow mass-wasting deposits are mostly concentrated in steep gullies on the flanks of forested ridges. About half are related to forest practices (logging, road building) and half are natural.

Qu - Quaternary Undifferentiated

Includes alluvium; both early and late Wisconsin alpine drift, most commonly as patches of till, often overlain by colluvium; boulder-rich alluvial fan deposits; stratified lacustrine silts and sands; and unmapped landslide deposits.

Qa - Alluvium

Active alluvium and alluvium covered with young soils are present in all of the major river valleys and most of the Matheny Creek drainage at elevations less than . It consists mainly of round, sub-spherical pebbles, cobbles, and boulders of well indurated sandstone. Also included in Unit Qa are one or two 0.5 m thick loess beds in the Matheny Creek drainage.

Qat - Alpine Glacial Till

Alpine till occupying the upper reaches of Prairie Creek. This unit consists of a dark-brown gray, clay-matrix-supported, cobble and boulder compact diamicton. It is easily distinguished from Unit Qc because Qat contains rounded cobbles and boulders whereas Qc contains sub-angular clasts and Qc is often clast supported, stratified, contains voids between clasts, and
is usually less compact than till.

Tertiary Units

Thsr - Thin-bedded sandstone with siltstone and shale

Unit Thsr is sequence of monotonous thin-bedded very fine-grained sandstones, siltstones, and subordinate shales that vary in thickness from millimeters to a few centimeters. (See Lingley, 1995: Lithofacies I). These are flysch sequences or rythmites of Tabor and Cady (1978a) composed of D$_3$ and/or G facies (terminology used herein from Mutti and Ricci Lucchi, 1978.) Most are parallel bedded with no variation in thickness observed in outcrop scale. Graded bedding is uncommon, but a few units are composed of a basal sandstone bed that grades upward into siltstone and/or shale in turn. Most units show no obvious coarsening or fining-upward trends. The sandstone and siltstone beds have rectangular weathering profiles and commonly form a colluvium of 2 x 1 x 1-cm blocks. Weathering colors are generally dark gray, medium reddish brown, or a distinctive orange-brown.

Thts: Thick Bedded Sandstone

Unit Thts is composed mainly of non-graded, 1.0- to 17-m-thick multi-story massive sandstones and/or matrix-supported conglomerates. These coarse grained units are laterally discontinuous and vertically separated by 0 to >100 m of thin-bedded shales and laminated siltstones similar to Unit Thsr (B with D$_3$ and G facies) or by medium bedded sandstones and finer grained siliciclastic rocks (B, D, and E facies). Unit Thts also includes sandstones of similar thicknesses that have massive bases and widely spaced, parallel laminations and/or parallel banding developed within a meter of the top of individual beds (B facies). These are commonly conglomeratic or shale clast breccias; the granules or less common pebbles have roughly the same composition and weathering color as the finer matrix.

These sandstones are separated by thin-bedded turbidites or by thin- to medium-bedded sandstones with fine clastic interbeds. These resemble Units Thsr and Thm, respectively. Sandstone to shale ratios of lithofacies II are variable, dependent on the vertical separation between multi-story sandstone units. This vertical separation can exceed 100 m. Both the massive sandstone units and sandstone units with laminated/banded tops are generally lenticular, although map patterns suggest that some larger units are tabular.

Most Thst exposures include 5 or more vertically stacked beds, each ranging from 0.5 to 5 m thick. Most sandstone beds show no grading. However, a few poorly developed, normally graded beds (C$_1$) are present, but no coarsening-upward beds have been observed. Beds with widely spaced (0.5 to 3 cm) parallel laminae and banding are common in this lithofacies. Generally, these laminae are developed at the top of each bed. Dish structures are present in some outcrops, and loading features are noted on some bedding planes. Rare tool marks and current lineations together with the structural interpretation suggest mostly
southwest-directed paleocurrents.

Many massive or laminated/banded sandstone beds contain rip-up clasts or intraclasts of mudstone, very dark-gray siltstone, and/or tuffaceous siltstone. These are generally tabular and range from 0.3 mm to more than 30 cm in length. Most rip-up clasts parallel bedding. Many of the tabular rip-up clasts taper to very thin, fragile edges.

Thc - pebble conglomerate

Unit Thc is composed of clast-supported chert and volcanic pebble conglomerates with minor finer clastic rocks. Pebbles include sandstone, siltstone, shale, chert, andesite (?) Basalt, greenstone, tuff, and quartz clasts. These are bedded (0.5 to >4 m). The conglomerates are mostly disorganized but a few beds show weak imbrication. Pebbles are typically subspherical to oblate and measure 2 to 8 cm along the long axis and 1 to 3 cm in section. A few cobbles are present.

Thsu - Sandstone, siltstone, conglomerate undifferentiated

Mostly 0.15 to 1-m-thick nongraded sandstone beds vertically separated by 0 to >25 m of thin-bedded siltstone and shales. The sand-shale ratio in Unit Thsr commonly exceeds 0.75. For the most part, the thin-bedded units are laminated. The conglomerates are

Thm - melange

A band of intense shearing and phacoid development that parallels regional structure and extends about 10 km northwest from Lake Quinault may be related to thrust faulting. Shears are oriented sub-parallel and about 60 degrees to the lithologic layering. A scaly cleavage and crudely aligned phacoids are also sub-parallel to bedding.

Tb - Basalt

Basalt contains phenocrysts of altered plagioclase and titanaugite, rarely oxyhornblende in interstitial matrix, commonly altered to chlorite, spherene, and calcite. It is dense to variolitic or highly amygdaloidal with vesicles filled with calcite, zeolites, pumpellyite, and quartz. Veins of quartz and epidote are common, prehnite rare. Pillow are abundant, breccia rare. Minor diabase and (or) gabbro occurs as sills or dikes. Interbedded tuffs and volcanic-rich sediments include rare gray or red limestone, very rare red and green chert, and tuffaceous green or maroon slate (Tabor and Cady, 1978).
ACKNOWLEDGMENTS

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Leslie Lingley, Kitty Reed, and Matt Brunengo edited this report. Carl Harris produced the maps and some diagrams.
References Cited


542 Points

Contour Method: Schmidt (1925)
Counting Area: 0.010
Contour Interval: 1% Points per 1% Area
Maximum Contour: 6

Your Patterns Repeat Every 9 Intervals
Matheny - Attitudes of Cleavage I
North

134 Points

LEGEND (for first 9 intervals)

1- 1  6- 6  Contour Method: Schmidt (1925)
2- 2  7- 7  Counting Area: 0.010
3- 3  8- 8  Contour Interval: 1% Points per 1% Area
4- 4  9- 9  Maximum Contour: 14
5- 5  

NOTE: Contour Patterns Repeat Every 9 Intervals