NATURAL RESOURCES

GEOLOGIC MAP OF THE EASTON AREA, KITTITAS COUNTY, WASHINGTON

by Eric S. Cheney

WASHINGTON
DIVISION OF GEOLOGY
AND EARTH RESOURCES

Open File Report 99-4
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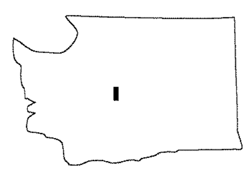

Location of map area

WASHINGTON STATE DEPARTMENT OF
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Geologic Map of the Easton Area, Kittitas County, Washington

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INTRODUCTION

Easton is located in Kittitas County in central Washington on the eastern side of the Cascade Range (Fig. 1). The Easton area is important because it is west of the reasonably well- known Tertiary stratigraphy and structure of the Wenatchee 1:100,000 quadrangle of Tabor and others (1982) and south of the well-known portion of the Straight Creek fault (Tabor, 1994; Tabor and others, 1984, 1993, in press). The Straight Creek fault is the major northerly trending fault of the northern Cascade Range. It dextrally displaces pre-Tertiary units 80 to 192 km (Tabor and others, 1993, in press).

The central Cascade Range is dominated by Mesozoic crystalline rocks and Eocene volcanic and sedimentary rocks (Fig. 2). Current concepts of the geology are dominated by the regional mapping of Tabor and others (1982, 1984, 1993, in press). These authors believed that the Eocene stratigraphy differs somewhat in three regional structural blocks that are juxtaposed in the Easton area and extend beyond it. Their Teanaway River and Manastash River blocks are east of the Straight Creek fault and their Green River–Cabin Creek block is west of the fault. The Yakima River valley, which is traversed by Interstate 90, separates the Teanaway River block on the northeast from Manastash River block on the southwest (Tabor and others, 1984 [fig. 2], in press [fig. 2]).

According to this view, the two blocks east of the Straight Creek fault contain the oldest Eocene rocks. In the Teanaway River block, strongly deformed Eocene sandstone and siltstone of the Swauk Formation and interbedded intermediate to felsic volcanic rocks of the Silver Pass Member of the Swauk Formation are overlain by relatively undeformed basaltic flows of the Eocene Teanaway Formation, which are in turn overlain by coal-bearing fluvial sandstones of the Roslyn Formation. The lithologies of the Swauk, Silver Pass, and Teanaway succession seem to be repeated in the Manastash block by the sandstones of the Manastash Formation, the volcanic rocks of the Taneum Formation, and the basalt of Frost Mountain, respectively. Rocks in the Manastash block are strongly folded and faulted. In contrast, only the strongly deformed sedimentary and volcanic rocks of the somewhat younger Eocene to early Oligocene(?) Naches Formation were mapped in the Green River–Cabin Creek block west of the Straight Creek fault.

Previous mapping at 1:62,500 (Stout, 1964), 1:125,000 (Smith and Calkins, 1906; Foster, 1960; Hammond, 1980) and 1:100,000 (Tabor and others, in press) did not resolve the stratigraphy (especially of the Naches Formation) and, therefore, the structure of the Easton area. Hence, the location of the southern end of the Straight Creek fault was poorly known. Tabor (1994) and Tabor and others (1984, in press) placed the Straight Creek fault at the contact between the Naches Formation of the Green River–Cabin Creek block and the other Eocene formations of the Teanaway River and Manastash River blocks. Thus they concluded that the trace of the fault curves southeastward along the length of Kachess Lake, and that east of Easton this fault has three southeasterly splays.

The obvious problem with this interpretation is the location of the pre-Tertiary crystalline rocks. The Shuksan Greenschist and the orthogneiss of Hicks Butte, which are dextrally offset by the fault from similar units in the northern Cascade Range, occur southwest, not northeast, of the southerly curving fault at Easton. Plate 1 extends the Tertiary stratigraphy of the Teanaway River and Manastash blocks into the Easton area (at the expense of the Naches Formation) and thereby shows that the southern end of the Straight Creek fault does not curve to the southeast; the fault is west of Easton and strikes to the south. Thus, the Shuksan Greenschist and the orthogneiss of Hicks Butte at Easton are, in fact, east of the Straight Creek fault.

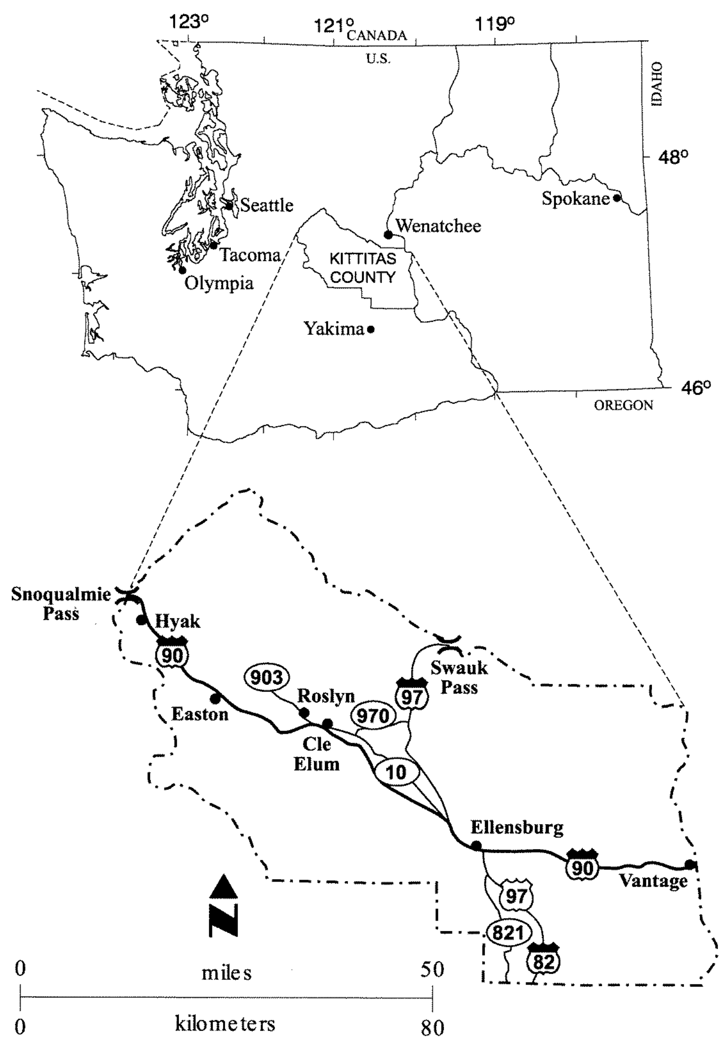


Figure 1. Index map.

Mapping for the present study was conducted from 1993 to 1998 on 1:24,000 U.S. Geological Survey (USGS) topographic maps, provisional editions of which were first published in 1989. Due to the dense forest and thick Quaternary deposits so typical of the Cascade Range, outcrops in the Easton area are sparse, and virtually all contacts between bedrock units are covered. Mapping was primarily along logging roads and ridges.

Earlier workers found the stratigraphy difficult to decipher because outcrops and access roads were minimal, similar lithologies occur in two or more formations, fossils are rare, and radiometric dates are meager. The more detailed topographic maps and improved network of roads now permit individual lithologic units to be mapped along strike; that is, some known units can be followed into and through the area, thereby generating a coherent lithostratigraphy. Despite the stratigraphic problems, earlier workers did adequately describe the lithologies; these are summarized by Tabor and others (in press). Therefore, this report gives only brief lithologic descriptions.

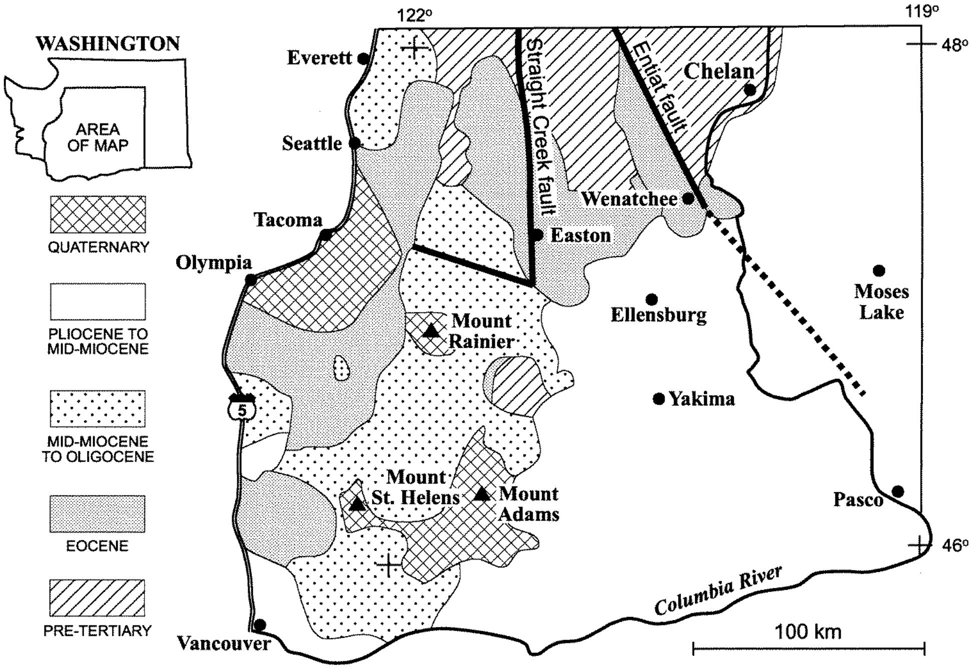


Figure 2. Ages of rocks in south-central Washington. Previous authors showed the Straight Creek fault passing east of Easton and curving southeastward. This study (Plate 1) shows the fault striking southward and passing west of Easton.

STRATIGRAPHY

The major factors that confused the stratigraphy and structure of the Easton area are that (1) the Naches Formation seemed to contain lithologies that occur in all of the other formations and (2) the internal stratigraphy of the Naches Formation was unknown. Whereas each of the other formations contains a predominant lithology, such as arkosic rocks (Swauk and Roslyn Formations), felsic volcanic rocks (Taneum Formation), and basaltic rocks (Teanaway Formation), the Naches was thought to contain all of these in subequal amounts.

Pre-Naches Rocks

The most distinctive formation is the Teanaway and its equivalents. It contains sections of black (commonly subophitic or amygdaloidal) basalt 0.25 to 2.5 km thick. Thus, the Teanaway is the major marker unit. That is, the formational identities of lithologically similar units are herein based primarily upon their position with respect to basaltic Teanaway rocks.

For example, arkosic rocks of the Swauk, Taneum, Teanaway, Roslyn, and Naches Formations and their equivalents are virtually indistinguishable. However, the Swauk and Taneum occur stratigraphically below the Teanaway, whereas the Roslyn and Naches are above the Teanaway. Many arkosic rocks and basaltic rocks that Smith and Calkins (1906), Foster (1960), and Tabor and others (in press) included in the Naches Formation are here assigned to the Teanaway Formation.

Similarly, some felsic volcanic rocks of the Taneum (and equivalents), Teanaway (and equivalents) and Naches Formations can be indistinguishable in hand specimen and outcrop. However, the Taneum is below the Teanaway; the Naches is above it, and felsic rocks interbedded with basalt are considered to be Teanaway.

The key to understanding the stratigraphy and structure of this area is near the eastern margin of Plate 1 west of the Tucker Creek fault. Stout (1964), Tabor (1994), and Tabor and others (in press) mapped the rocks west of the Tucker Creek fault as Naches Formation. East of the Tucker Creek fault, Tabor and others (in press) mapped a southwesterly dipping succession that, from the base upwards, consists of Manastash Formation (feldspathic to quartzose sandstone), Taneum Formation (mostly felsic volcanic rocks), and the basalt of Frost Mountain. Plate 1 shows that the same three units occur in the same order and with similar southwesterly dips west of the Tucker Creek fault, where they previously were mapped as Naches.

Another problem area was south of Big Creek in the southern portion of Plate 1. Here a thick section of predominantly arkosic rocks is overlain by a thick section of predominantly black, subophitic, and amygdaloidal basalt. These units dip northeastward. The arkosic rocks do contain pale green dacitic to andesitic interbeds (unit Esv in the explanation to Plate 1) like those described in the Swauk Formation by Tabor and others (1982, in press). Smith and Calkins (1906), Stout (1964), Hammond (1980), and Tabor and others (in press) included these thick arkosic and basaltic units in the Naches Formation. However, the great thicknesses of these units and their stratigraphic order imply that they are Manastash and Frost Mountain, respectively. An apparent problem is that no felsic rocks (equivalent to those of the Taneum Formation) occur between the arkosic and basaltic rocks in the Big Creek area. However, southeast of the area mapped in Plate 1, felsite does occur between the arkosic and basaltic rocks (Tabor and others, in press). Significantly, Tabor and others (1984, in press) noted that in the Teanaway River block, the Swauk Formation and Silver Pass Volcanics are more tightly folded than the Teanaway Formation; thus, an unconformity occurs below the Teanaway. Erosion beneath this unconformity is inferred to have caused the variable thickness of the Taneum Formation in the Easton area and to have completely removed the Taneum south of Big Creek.

Heretofore, the Roslyn Formation has not been recognized in the Easton area. Arkosic rocks in the Cole Creek syncline are here assigned to the Roslyn Formation because they overlie the basalt of Frost Mountain (Teanaway Formation) and because they are thicker than other arkosic units in the basalt of Frost Mountain. The mapped pattern of these arkosic rocks also suggests that they erosionally truncate a felsic volcanic unit associated with the basaltic rocks; thus, these arkosic rocks probably are not part of the basalt-bearing Teanaway Formation. Conceivably, these arkosic rocks could be the basal portion of the Naches Formation, but elsewhere in the Easton area, the basal portion of the Naches is felsic volcanic rock (unit Enf_1).

Naches Formation

Previous investigators could not recognize stratigraphic subdivisions of the Naches Formation at the scale at which they mapped. However, mapping at 1:24,000 shows that five predominantly conformable lithostratigraphic units occur in the Naches west of the Straight Creek fault (Plate 1). The thicknesses of these units range from 70 to 700 m and vary along strike.

The five units at Log Creek, from the base upward, are (1) felsic volcanic rocks, unit Enf_1; (2) an interval of green volcaniclastic rocks, some of which contain clasts of felsic rocks, and minor green basalt, unit Enm; (3) a second interval of felsic volcanic rocks, unit Enf_2, (4) green volcaniclastic rocks that are locally well bedded and generally without either felsic clasts or intercalated basalt, unit Ena; (5) arkosic sandstone with green and black siltstone, unit Ens (but similar lithologies occur lower in the section along Cabin Creek and Log Creek).

Most of the felsic volcanic rocks of the Naches Formation probably were ash flows. Although most outcrops are aphanitic and texturally nondescript, some are flow-banded, some contain lithic clasts, and a few have spherulites or flattened pumiceous fragments. Isoclinal flow banding of various orientations is best displayed on the western shore of Kachess Lake. Some outcrops of felsic rocks have angular, centimeter-scale clasts of similar felsic rock. The lack of vertically and laterally continuous outcrops makes a description of individual ash flows impossible. The eruptive source of these rocks is unknown, but the presence of lithic clasts implies that it was nearby. Sources might be unconformably overlain by either the Oligocene to Middle Miocene or by the Middle Miocene to Pliocene rocks shown in Figure 2.

The Naches Formation at Log Creek does contain intervals of arkosic sandstone and black and green siltstone that are compositionally similar to units in the other formations. These intervals in the Naches, unlike most of the volcanic and volcaniclastic units, provide reliable strikes, dips, and form lines for stratigraphy and structure.

Areas of Naches Formation east of the Straight Creek fault are compositionally similar to the two basal units west of the Straight Creek fault. Because they may not be precisely the same two units as those west of the fault, they are labeled units Enf_1? and Enm? on Plate 1.

All previous investigators from Smith and Calkins (1906) to Tabor and others (in press) used the Naches Formation as a 'wastebasket' for lithostratigraphic units that they could not easily match with formations east of the Straight Creek fault. Smith and Calkins (1906) mapped and defined the Naches from the Naches valley (south of Plate 1) northward to Log Creek. As noted above, south of Big Creek, Smith and Calkins (1906) and subsequent mappers assigned arkosic units here recognized as Swauk/Manastash and basaltic rocks here assigned to Teanaway/Frost Mountain to the Naches Formation. Thus, prior to the present mapping, significant amounts of arkosic and basaltic rocks were part of the standard definition of the Naches (Smith and Calkins, 1906; Foster, 1960; Tabor and others, 1984, in press).

The significance of the present 1:24,000 mapping is that it identifies the other Eocene formations west of the Tucker Creek fault and even west of the Straight Creek fault. It also restricts the Naches to lithostratigraphic units above these other formations. The most complete succession of these younger units is in the Cole Butte anticline cored by Teanaway Basalt along Log Creek. This and other successions on Plate 1 south of the Yakima River have felsic volcanic rocks and mafic to intermediate volcaniclastic rocks, but almost no basalt and only minor arkose.

The basaltic rocks on Amabilis Mountain north of the Yakima River and west of Kachess Lake that are mapped here as Teanaway Formation deserve comment. These basaltic rocks do not look like Teanaway; instead, they have a greenish gray matrix, glomeroporphyritic plagioclases, and green (chloritic) amygdules. These characteristics are here abbreviated as 'gga'. Within the gga basalt on the west side of Amabilis Mountain is a mappable arkosic unit and unmappable intermediate volcaniclastic rocks (some with a few grains of quartz). Foster (1960) described similar rocks on Keechelus Ridge to the north as augite-bearing basalt with plagioclase about An_{60}.

The gga basalt is chloritically altered. The lighter color of the matrix of gga basalt makes the rock appear to be rather felsic, and some of the chloritic amygdules have irregular, flame-like shapes that mimic flattening of pyroclasts in felsic rocks. However, no planar fabrics occur in the matrix, the glomeroporphyritic plagioclases, or the amygdular chloritic fillings.

The cause of this alteration is not certain. However, Amabilis Mountain has several tiny granitic plutons and dikes (Plate 1), and Foster (1967) described many more small plutons in gga basalt on Keechelus Ridge. These intrusions (the larger ones are shown as unit ΦMi on Fig. 3) are satellitic to the Snoqualmie batholith to the west and north. Thus, granitic plutons may be more extensive in the subsurface below Amabilis Mountain and Keechelus Ridge. Perhaps, hydrothermal fluids driven by these plutons altered the basalt.

The identity of gga basalt is controversial. Smith and Calkins (1906) included it in the Teanaway Formation. However, because gga basalt does look different than typical black Teanaway basalt, and because the Naches Formation, by the previous definition of Smith and Calkins had abundant basalt, Foster (1960) assigned gga basalt to the Naches; Tabor and others (1984, in press) followed suit. Typical black Teanaway basalt does occur on the summit of Amabilis Mountain, but at the time of Foster's mapping, Amabilis Mountain was inaccessible (Foster, 1960, p. 115). Because the gga basalts on Amabilis Mountain occur with and below, not above, typical black Teanaway basalt, they are here reassigned to the Teanaway (unit Etg on Plate 1), not the Naches. Because these gga basalts are almost on strike with gga basalt on Keechelus Ridge described by Foster (1960), the Keechelus Ridge rocks also are removed from the Naches and restored to the Teanaway (Fig. 3), as originally mapped by Smith and Calkins (1906). Additionally, Tabor and others (1984) estimated that the gga basalt of Keechelus Ridge is 1500 to 3000 m thick and that the maximum thickness of the Teanaway east of the Straight Creek fault is 2500 m.

Plate 1 indicates that the Naches Formation is unconformable upon all other formations. Between Cole Creek and Big

Creek, the Naches (unit Enf_1?) is unconformable upon the Roslyn (unit Er) and Teanaway (units Etb and Ets) Formations. Near Easton, the Naches is unconformable upon pre-Tertiary rocks, and the Swauk, Taneum, and Teanaway Formations. On Amabilis Mountain, unit Enf_1 is unconformable upon the Teanaway (units Etb, Etg, and Ets).

Quaternary

Tabor and others (in press) portrayed both Quaternary and bedrock units on their 1:100,000 map. This obscured the map patterns of the bedrock units. To enhance these patterns, Quaternary units are not shown in Plate 1, but they do occur in most valleys. Areas of extensive Quaternary deposits in Plate 1 can be discerned by the absence of the strike and dip symbols used for bedrock units and by the use of dotted lines for contacts and faults.

STRUCTURE

The stratigraphic revisions described above, especially in the southwesterly dipping succession west of the Tucker Creek fault, indicate that the structure of the Easton area is substantially different than reported by previous mappers. The major differences are the recognition of a major anticline along the Yakima Valley and the locations of the Straight Creek and Taneum Lake faults.

Folds

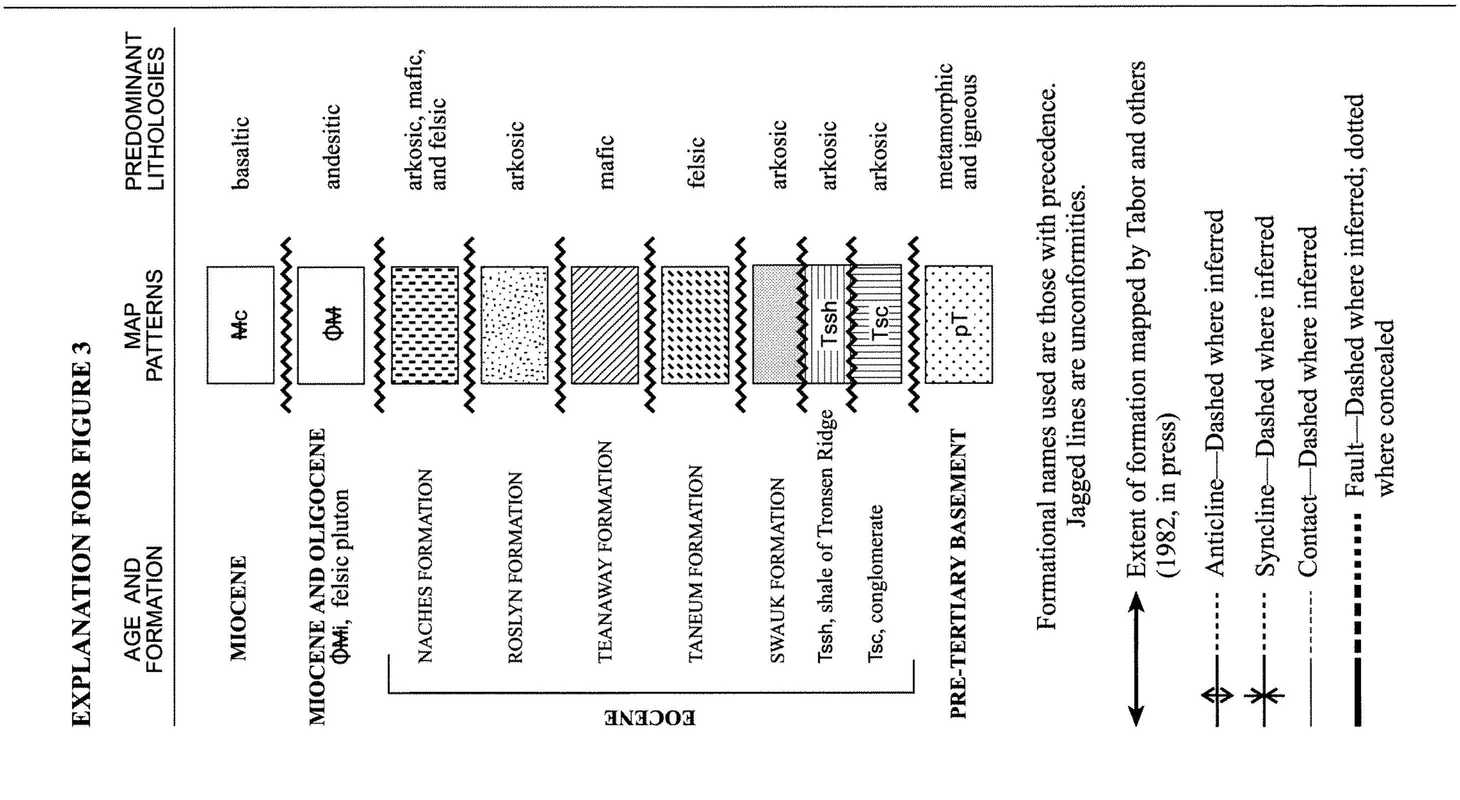
The major anticline along the Yakima Valley is partially outlined by the southwesterly dipping succession of Manastash, Taneum, and Frost Mountain on both sides of the Tucker Creek fault (in the so-called Manastash River block). A northeasterly dipping succession with a similar lithostratigraphy exists on the northeast side of the valley (the so-called Teanaway River block) in the limb of the syncline cored by the Roslyn Formation (Fig. 3). Thus, a major anticline (cored by pre-Tertiary rocks) occurs along the Yakima Valley.

Recognition of the major anticline has important implications for regional stratigraphy. Figure 3 indicates that historically the same stratigraphic intervals on opposite limbs of this major anticline have been given different formational names. Thus, as Tabor and others (1984, in press) and Cheney (1994) suspected, Manastash is stratigraphically equivalent to Swauk; Taneum is equivalent to Peoh Point and Silver Pass, and the basalt of Frost Mountain is equivalent to the Teanaway. Because the names Swauk, Taneum, and Teanaway have precedence (Tabor and others, 1984), only they are used hereafter.

More than one period of folding occurred. The axial traces of the major anticline along the Yakima Valley and of the syncline to the northeast cored by Roslyn Formation are virtually on strike with the Ainsley Canyon anticline and Kittitas Valley syncline, respectively, mapped by Tabor and others (1982) in the middle Miocene Columbia River Basalt Group to the east (Fig. 3). The limbs of the major anticline are considerably steeper in the Eocene rocks in the Easton area than in the Columbia River Basalt Group to the southeast. Along the southwestern shore of Kachess Lake, the Swauk is locally overturned. The gentle regional dips of the Oligocene to Middle Miocene rocks (Tabor and others, in press) and of the Middle Miocene Columbia River Basalt Group rocks (Tabor and others, 1982) imply that most of the folding was pre-Oligocene.

The 1:24,000 mapping provided lithostratigraphic evidence for three smaller northwesterly trending folds. Tabor and others (in press) recognized these folds on the basis of reversals of dips in mostly undivided Naches Formation (their unit Tn). A syncline in the drainages of Big Creek and Cole Creek involves the Taneum, Teanaway, Roslyn, and Naches Formations. Another syncline in upper drainage of Log Creek affects the Swauk and Teanaway Formations. A faulted anticline in lower Log Creek exposes Teanaway basalt below Naches units.

A fourth fold may occur on Amabilis Mountain. The gga basalt of the Teanaway Formation might be along the crest of an anticline with the Swauk Formation of Thetis Creek in its core. If so, the anticline has a sinuous northerly trend. Due to multiple periods of folding (and attendant unconformities), the strikes



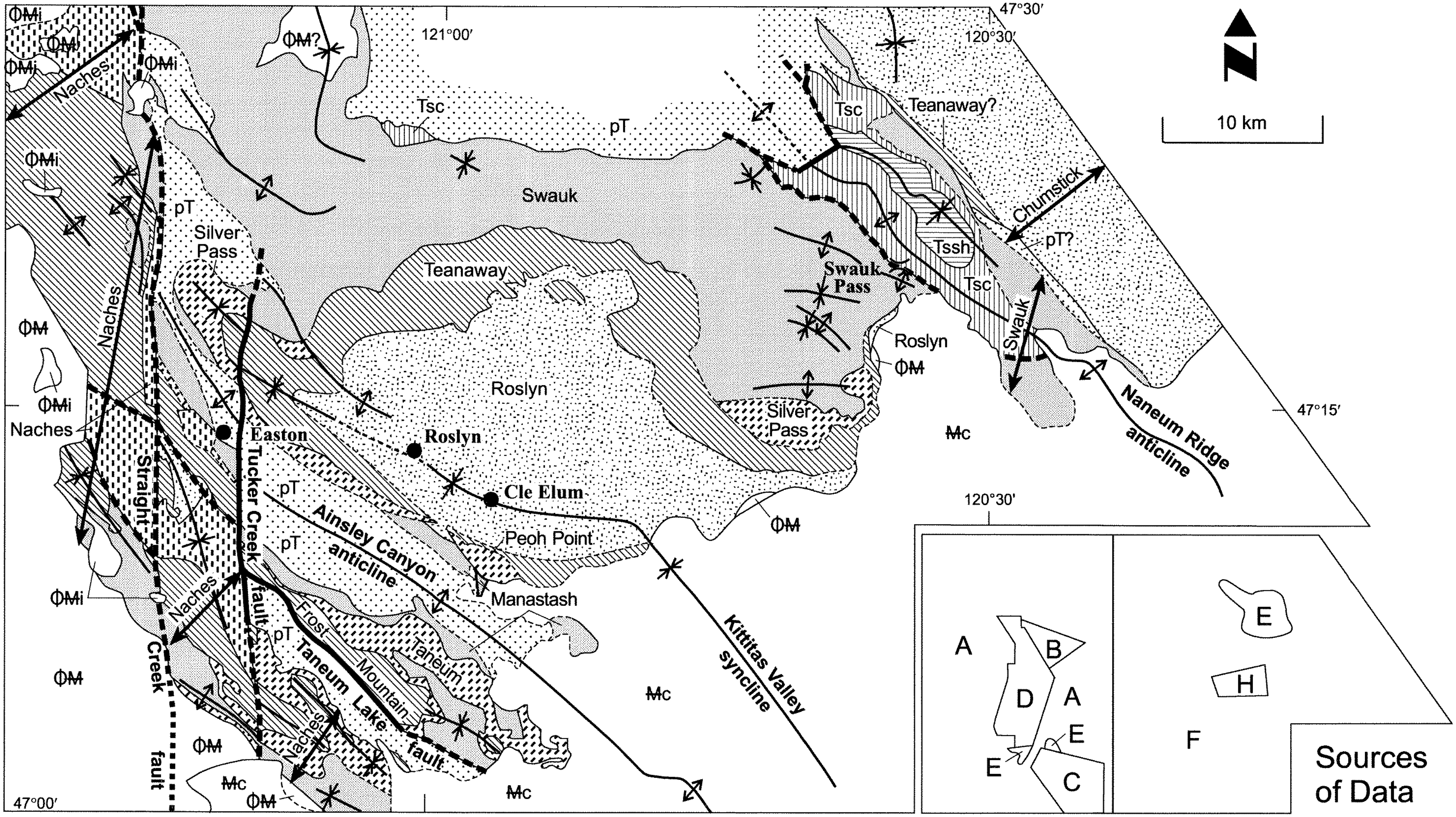


Figure 3. Regional geologic setting of the Easton area. The sources of data shown in the inset map are: (A) Tabor and others, in press; (B) Foster, 1960; (C) Hammond, 1980; (D) this paper; (E) unpublished 1:24,000 mapping by author; (F) Tabor and others, 1982; (G) Gresens, 1983; and (H) Margolis, 1994. Map explanation is on the facing page. Different belts of the same formation were given different formational names by Tabor and others (1982, in press). Here, formations that are considered equivalent are shown in the same pattern; thus, Swauk = Manastash; Taneum = Silver Pass = Peoh Point; Teanaway = the baalt of Frost Mountain; and Roslyn = Chumstick. The bold, double-headed arrows with formational names show the extent of formations as mapped by Tabor and others (1982, in press); for example, immediately west ot the Straight Creek fault, what Tabor and others (in press) mapped as Naches Formation is here regarded as Swauk, Teanaway, and Naches Formations.

and dips in pre-Naches units in this and the Cole Butte anticline do not necessarily define the axial trace of the fold.

Faults

The Straight Creek fault is the major northerly trending fault in the area. Tabor and others (in press) believed that a major northeasternmost splay of the Straight Creek fault strikes southeastward down the Yakima Valley and is the boundary between the Teanaway River and Manastash River blocks. Such a fault could account for the absence of the Swauk Formation and the discontinuous nature of the Taneum Formation along the northeastern limb of the Ainsley Canyon anticline. The alternative offered here for these discontinuities is that the unconformity at the base of the Taneum locally eliminates the Swauk and the unconformity at the base of the Teanaway locally eliminates both the Swauk and the Taneum. Thus, no significant fault is required along the valley. The Teanaway River and Manastash River structural blocks of Tabor and others (1984, in press) are simply the opposing limbs of the Ainsley Canyon anticline composed of the same but discontinuous formations.

The offset continuation of the southwesterly dipping limb northwest of the Tucker Creek fault indicates that the Tucker Creek fault is not a major splay of the Straight Creek fault as Tabor and others (1984, in press) supposed. Instead, the Straight Creek fault is somewhere to the west of Tucker Creek.

The Straight Creek fault is here placed at the largest structural discontinuity in the Easton area, which passes about 2.7 km west of Easton. This discontinuity places the southwestern limb of the Ainsley Canyon anticline, which here is composed of pre-Naches formations and portions of the Naches Formation, against other portions of the Naches Formation. The Swauk, Taneum, Teanaway, and Naches Formations occur on both side of this discontinuity. In contrast to the map of Tabor and others (in press), such a trace also places all Shuksan Greenschist and all of the gneiss of Hicks Butte east of the fault, which is consistent with major dextral movement on the Straight Creek fault. Thus, the Straight Creek fault strikes southerly not southeasterly.

This location of the Straight Creek fault is based solely on the map pattern. The fault has no major (and few minor) topographic expressions. Due to the paucity of outcrops, it is not known whether joints or minor faults are more numerous closer to the Straight Creek fault. A landslide involving Teanaway basalt does occur along the trace of the fault on the south side of Cabin Creek. South of Big Creek, the fault presumably is unconformably overlain by the Oligocene to middle Miocene rocks (Fig. 3).

The amounts of vertical and dextral displacements on the Straight Creek fault are difficult to determine. The apparent lack of 'piercing points' implies that the amount of dextral displacement is greater than half of the length of the fault mapped in the Easton area, or greater than 13 km.

Vertical displacement on the Straight Creek fault may be minimal. Along Kachess Lake, the Naches Formation on the west is faulted against older Eocene rocks, and possibly the pre-Tertiary crystalline basement. Thus, the east side is probably up, as it is in the northern Cascade Range. On the divide between Cole and Big Creeks, stratigraphically different Naches felsic rocks are faulted against each other, implying only modest uplift of the eastern block.

Two northerly trending faults appear to be satellitic to the Straight Creek fault. The limited dextral displacement ($<$2.1 km) on the Tucker Creek fault indicates that it is not a major splay of the Straight Creek fault. A fault near the confluence of Big Creek and Greek Creek juxtaposes westerly dipping Teanaway lithologies against Naches lithologies to the west. This fault at Big Creek probably is the southern extension of the Tucker Creek fault. West of the Straight Creek fault and south of the Yakima River valley, the Cabin Creek fault places Naches Formation against Teanaway basalt in the core of a northerly trending Cole Butte anticline.

Near Goat Peak, a northwesterly trending fault places Naches Formation against Taneum and Teanaway. The Taneum Lake fault of Goetsch (1978) is a major northwesterly trending fault that cuts Eocene and pre-Tertiary rocks southeast of Easton (Tabor and others, in press). A comparison of the 1:100,000 map of Tabor and others (in press) with Plate 1 shows that the Tucker Creek fault offsets the Taneum Lake fault from the fault at Goat Peak by the same distance it offsets Eocene and pre-Tertiary rocks. Thus, the fault at Goat Peak is inferred to be the northwestern offset portion of the Taneum Lake fault. The Straight Creek fault truncates this northwesterly trending segment of the fault on the eastern end of Cabin Mountain.

The northwesterly striking Tacoma Pass fault is west of the Straight Creek fault (Plate 1). Due to the absence of Taneum felsites in the Log Creek syncline of Hammond (1980) and the presumed dextral history of the Straight Creek fault, the Tacoma Pass fault probably is not a sinistral offset of the Taneum Lake fault.

Another northwesterly trending fault is inferred in the Yakima River valley west of the Straight Creek fault. Such a fault would explain why the northeasterly dipping panel of Naches strata on Cabin Mountain appears to dip below the older Teanaway on the southern side of the valley and on the southwest side of Amabilis Mountain. Because the sense of movement on this fault (southwest side down) is the opposite of the fault at Goat Peak, these are not offset portions of the same fault.

The Straight Creek and the Taneum Lake faults segment the Easton area into three blocks somewhat different than those inferred by Tabor and others (1984, in press). An important difference between Plate 1 and the maps of Foster (1960) and Tabor and others (1984, in press), who used different formational names in each block, is that the Swauk, Taneum, Teanaway, and Naches Formations occur in all three blocks. If the arkosic rocks above the Teanaway in the Cole Creek drainage are Roslyn, the Roslyn Formation occurs in two of the blocks.

Subtle stratigraphic and structural differences among the blocks suggest that significant strike-slip displacement may have occurred on the bounding faults. For example, as Tabor (1994) noted, the different crystalline basements northeast and southwest of the Taneum Lake fault may indicate significant dextral displacement.

Additionally, in the northeastern block (Fig. 3), the Silver Pass equivalent of the Taneum locally rests directly upon the crystalline basement (without any intervening Swauk Formation). In the central block between the Taneum Lake and Straight Creek faults, the Taneum Formation is missing between the Swauk and Teanaway, but it does reappear farther to the southeast in this block (Fig. 3). Likewise, the Taneum is missing from the southern part of the block west of the Straight Creek fault.

Lithologies in the Teanaway Formation vary from block to block. Felsic volcanic rocks are common in the Teanaway west of the Straight Creek fault and north of the Taneum Lake fault, both in the area of Figure 3 and elsewhere (Tabor and others, 1982), but not southwest of the Taneum Lake fault.

The unconformity at the base of the Naches Formation also varies from block to block. In the block northeast of Taneum

Lake fault, the Naches Formation rests unconformably upon the pre-Tertiary rocks, Swauk, Taneum, and Teanaway. In the central block between the Taneum Lake and Straight Creek faults, the basal felsite of the Naches truncates various units of the Teanaway (and the Roslyn, if the uppermost arkosic unit at Cole Creek is Roslyn). West of the Straight Creek fault, the basal felsite of the Naches only overlies the Teanaway.

ECONOMIC GEOLOGY

The western margin of the Blowout Mountain pluton and the adjacent Ohanapecosh Formation are propylitically altered. Conceivably, this alteration could be an indicator of porphyry copper-like mineralization. However, no evidence of previous mining exists, and the lack of supergene sulfide enrichment in the recently glaciated Cascade Range makes the possibility of economic copper mineralization remote.

Weathered portions of Naches felsites are quarried in numerous places in the Blowout Mountain and Easton quadrangles for surfacing of logging roads.

DESCRIPTION OF MAP UNITS

Tertiary Intrusive Rocks

ΦMi **Tonalitic intrusions (Oligocene–Miocene)**—These are unit Tit of Tabor and others (in press). They occur along and west of the Straight Creek fault. The largest is the Blowout Mountain pluton; according to Stout (1964) it ranges from diorite to quartz gabbro, with plagioclase being An_{48} to An_{57}. The northern end of the Blowout Mountain intrusion and the adjacent Ohanapecosh Formation are propylitically altered and rusty weathering.

Tertiary Sedimentary and Volcanic Rocks

Φo **Ohanapecosh Formation (Oligocene)** — Pale green, unbedded, and unsorted andesitic volcaniclastic rocks. Centimeter-scale fragments vary from angular white felsite to pale green flame-shapes (flattened shards?). Feldspars and rare mafic minerals are generally less than a few millimeters in diameter. Adjacent to the western margin of the Blowout Mountain intrusion, the rocks are propylitically altered; intense weathering of altered rocks makes them white and rusty. This is unit To of Tabor and others (in press).

Naches Formation (Eocene)—Rhyolite, andesitic volcaniclastic rocks, basalt, and arkosic sandstone and siltstone. Thicknesses of mapped units range from 70 to 700 m and vary along strike.

Enf **Felsic volcanic rocks**—From older to younger, these are units Enf_1 and Enf_2. Unit Enf is mostly aphanitic, white and rusty yellow (jarositic) weathering, and intricately jointed on a centimeter scale. Unweathered Enf is gray to black, has conchoidal fracture, and is aphyric (or has only minor, millimeter-scale phenocrysts of feldspar or quartz); megascopic mafic minerals are absent. Some rocks are flow banded; some are spherulitic; others contain angular, centimeter-scale fragments of felsic volcanic rocks similar to the matrix of Enf. Pyrite is common on hairline fractures, especially in unweathered aphanitic rocks.

Except for their relative stratigraphic positions (caused by intervening units of Ens, Enm, and Ena), the units Enf_1 and Enf_2 are indistinguishable from each other. These felsites were classified as rhyolite (unit Tnr) by Tabor and others (in press). Much of the unit Tnr of Tabor and others (in press) is here shown as felsite in the Teanaway and Taneum Formations (see units Etf and Eaf).

Ens **Arkosic sandstone, siltstone, and shale**—Sandstone is tan to white weathering; grains typically are less than 1 mm; siltstone is commonly olive and micaceous; shale and some siltstones are black. Tabor and others (in press) labeled such rocks unit Tns, but most of their unit Tns is here assigned to the Swauk, Teanaway, and Roslyn Formations. Other arkosic interbeds exist in the Naches Formation; because they rarely are more than twenty meters thick, they are too thin to map at 1:24,000.

Ena **Well-bedded andesitic volcaniclastic rocks**—Fresh rocks are green to brown. Fragments are as long as 40 cm but commonly less than 3 cm; accretionary lapilli are rare. Clasts are typically feldspar porphyries; clasts of amygdaloidal basalt are rare. Beds are typically less than 0.2 m thick. Rare felsic volcaniclastic layers are up to 2 m thick. Unit Ena is part of unit Tn of Tabor and others (in press).

Enm **Predominantly intermediate unsorted and unstratified volcaniclastic rocks**—Dark lithic clasts are most common, but some rocks contain white clasts similar to unit Enf. Clasts are typically 3 to 20 cm long, but some are as long as 40 cm. Clasts of basalt are pale green. Unit Enm is part of unit Tn of Tabor and others (in press). Unit Tnm? near Big Creek was mapped as Ohanapecosh Formation (unit To) by Tabor and others (in press).

Er **Roslyn Formation arkosic sandstones (Eocene)**—These arkosic rocks are compositionally similar to those in the Swauk and Teanaway Formations. They are part of unit Tn of Tabor and others (in press).

Teanaway Formation (Eocene)—Mostly basalt with lesser felsic volcanic rocks and minor arkosic sandstone.

Etf **Felsic volcanic rocks**—These white and rusty weathering aphanitic felsites are similar to those in the Naches Formation (Enf units), except that they rarely contain lithic fragments. Tabor and others (in press) mapped them as Naches felsites (unit Tnr). The only distinguishing feature of Teanaway felsites is that they are bounded above or below by basalt (units Etb or Etg).

Ets **Arkosic sedimentary rocks**—These rocks are similar to the arkosic sedimentary rocks of the Naches, Roslyn, and Swauk Formations. They contain minor volcaniclastic interbeds, like unit Esv in the Swauk Formation. Their only distinguishing feature is that they are bounded by basalt.

Etb **Basalt**—Black and commonly subophitic and amygdaloidal. Arkosic interbeds and gabbroic bodies in the basalt generally are too small to map separately. Weathering of basaltic and gabbroic rocks typically generates brown (geothitic) soil, not the rusty yellow (jarositic) soil typical of units Enf and Etf. South of the Taneum Lake fault and east of the

Straight Creek fault, Tabor and others (in press) mapped this basalt as undivided Naches Formation (unit Tn) and Naches basalt (unit Tnb). Tabor and others (in press) included the gabbroic rocks in unit Tdg.

Etg **Basalt**—Pale greenish gray, augite-bearing basalt with glomeroporphyritic plagioclase and chloritic amygdules. The pale color of the matrix is due to chloritic alteration. These were mapped as Teanaway basalt by Smith and Calkins (1906) but as Naches Formation (glomeroporphyritic basalt on Keechelus Ridge, unit Tnbg) and as undivided Naches (unit Tn) on Amabilis Mountain by Tabor and others (1984, in press).

Eaf **Taneum Formation (Eocene)**—Mostly felsic volcanic rocks. These rocks are similar to the felsic rocks in the Teanaway (unit Etf) and Naches Formations (Enf units), but some have distinguishing characteristics, such as up to a few percent hornblende, spherical to variably flattened centimeter-scale white and black or green fragments or replacements of pumice, a few grains of quartz, a few percent of pale green, tabular grains of feldspar less than 3 mm long, a crude foliation outlined by the feldspar, and a pale-green matrix. Tabor and others (in press) mapped the felsites as Silver Pass volcanic rocks (unit Tssp), Naches rhyolite (unit Tnr), and undifferentiated Naches Formation (unit Tn). Arkosic units in the felsites are too thin to map separately.

Swauk Formation (Eocene)—Predominantly arkosic sandstones and siltstones with minor volcaniclastic rocks.

Ess White weathering, micaceous arkosic rocks like those in other formations. Possible distinguishing characteristics of Swauk arkosic rocks are a few scattered pebbles generally less than 2 cm long, very rare palm fronds, no interbedded basalt, and interbedded dacitic to andesitic volcaniclastic rocks (unit Esv) generally too small to map; none of these features are ubiquitous. Some sandstones previously mapped as Manastash Formation contain 55 to 60 percent quartz (Tabor and others, in press). Sandstone is tan to white weathering; below the A-horizon it commonly generates sandy white soils. Siltstones are commonly micaceous and are either olive green or black. Plant fossils occur in many siltstones in this and the Teanaway Formation. Tabor and others (in press) mapped portions of the Swauk as undifferentiated Naches Formation (unit Tn) and as Naches sandstone (unit Tns).

Esv **Volcanic rocks**—Rare dacitic to andesitic rocks in unit Ess. Most are too thin to map at 1:24,000. These rocks were mapped as the Silver Pass volcanic member (unit Tssp) of the Swauk Formation by Tabor and others (1982, in press).

Mesozoic Metamorphic Rocks

Khb **Orthogneiss of Hicks Butte (Cretaceous)**—Tonalitic, medium-grained orthogneiss, unit Khb of Tabor and others (in press).

Jes **Shuksan Greenschist (Jurassic)** — Phyllitic greenschist. This is the Shuksan Greenschist of the Easton Metamorphic Suite, unit Kes of Tabor and others (in press).

SUMMARY

A new series of 1:24,000 topographic maps and an evolving network of logging roads permitted mapping at 1:24,000. This detailed mapping shows that much of what was formerly mapped as Naches Formation at smaller scales consists of older Eocene formations (Swauk, Taneum, Teanaway, and Roslyn). Recognition of these older Eocene units in the Easton area shows (Fig. 3) that the area is characterized by a major northwesterly striking anticline. This fold is cut by the Straight Creek fault. The stratigraphy and structure of the Eocene rocks show that the trace of the Straight Creek fault does not curve southeastward east of Easton as commonly supposed but, instead, is west of Easton and strikes southward. The latest movements on both the Taneum Lake fault and the Straight Creek fault are post-Naches.

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