Geologic Map of the Battle Ground 7.5-Minute Quadrangle, Clark County, Washington

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INTRODUCTION

The Battle Ground quadrangle lies on the northeast margin of the Portland basin west of the Cascade Range (fig. 1, map sheet). Much of the quadrangle consists of the Fourth Plains at elevations of 200 to 400 ft (60–120 m; Mundorff, 1964). Foothills (referred to as the Troutdale bench by Mundorff, 1964; fig. 1, map sheet) rise above the plains along the eastern and northeastern parts of the quadrangle. The Battle Ground quadrangle was previously included in a geologic map by Mundorff (1964) and in aquifer maps by Swanson and others (1993).

Soil and vegetation hide many geologic features in the area, and suburban development hinders access behind the many roads. For the present study, observations from 21 days of field mapping were compared against logs, summaries, and interpretations of field-located water wells (Mundorff, 1964; Swanson and others, 1993) and supplemented by interpreting drillers' logs of about 1,000 approximately located water wells. The resulting geologic-map interpretation relies on key outcrops, on geomorphic position of units, and on the well logs to indicate the projected surface positions of poorly exposed units. Several dozen well logs supplemented the field observations used to draw (vertically exaggerated) cross section A-A', for example. Most map contacts are approximate or inferred. Rock colors are designated using letters and numbers in the Munsell system. Geologic map units are defined by lithostratigraphic criteria (for instance the Skamania Volcanics) and in some cases also by allostratigraphic criteria where geomorphic surfaces help to define units (North American Commision on Stratigraphic Nomenclature, 1983). For example, depositional landforms help define the older alluvium unit and the alluvial-fan member of the Troutdale Formation.

Mundorff (1964) laid an excellent geologic foundation for this quadrangle in his description and geologic map of Clark County. The present more detailed map further subdivides some of the units he mapped and offers some reinterpretations. Figure 2 (map sheet) displays an interpretation of the stratigraphic relations in the quadrangle.

STRATIGRAPHY

PALEOGENE ARC VOLCANIC ROCKS

The oldest rocks in the quadrangle are zeolitized Paleogene intermediate to mafic lava flows. They form part of a widespread, heterogeneous sequence of rocks of the early Cascade volcanic arc, and their stratigraphic nomenclature remains unsettled (Swanson and others, 1989; Evarts and Swanson, 1994). Trimble (1963) termed such rocks the Sakamania volcanic series in an adjacent map area to the south and southeast. To avoid the improper use of the term "series" for lithostratigraphy (North American Commision on Stratigraphic Nomenclature, 1983), the rocks are here called the Skamania Volcanics, while recognizing that this name may be abandoned when future mapping better defines the volcanic rocks of this part of the Cascade Range. The Skamania Volcanics are widespread in the Yacolt quadrangle adjacent to the Battle Ground quadrangle on the east, where rocks at two localities suggest an age of late Eocene and possibly Oligocene. The first site is volcaniclastic rocks interbedded with flows 0.5 km east of the Battle Ground quadrangle along the north bank of the East Fork Lewis River, where a fossil flora (not described) was identified as late Eocene by R.W. Brown (Trimble, 1963). The second is a flow or sill, exposed in Finn Hill quarry 5 km east-northeast of the southeast corner of the Battle Ground quadrangle, that yielded a preliminary age of about 24.5 Ma on feldspar using the $^{40}Ar/^{39}Ar$ technique (R. Fleck, oral commun., 2001). This may be an alteration age. The Skamania Volcanics exhibit zeolite-grade metamorphism and were eroded before younger rocks were deposited on them. Bedding of the Skamania Volcanics in the Yacolt quadrangle mostly is horizontal or dips very gently west. The Skamania Volcanics may correlate in part with rocks that have been called the Goble Volcanics a few tens of kilometers to the northwest of the Battle Ground quadrangle. Such Paleogene arc-related volcanic rocks are widespread in the Cascade Range and other parts of the western United States (Swanson and others, 1989; Christiansen and Yeats, 1992; Evarts and Swanson, 1994; Cheney, 1997).

TROUTDALE FORMATION

Weakly consolidated nonmarine sedimentary rocks that unconformably overlie the Skamania Volcanics are referred to the Troutdale Formation, earlier included in the Satsop Formation of Bretz (1917). Hodge (1938) considered the Troutdale

Formation to be a great piedmont fan on the west side of the Cascade Range. He thought the formation was probably of early Pleistocene age. Later authors established ages of Pliocene and Miocene for rocks that were called Troutdale Formation, and established that part of the unit was deposited by an ancestral Columbia River while other parts are more locally derived from the Cascade Range (Trimble, 1963; Tolan and Beeson, 1984). Below I conclude that rocks assigned to the Troutdale Formation in this quadrangle may range up into the Pleistocene.

Mundorff (1964) divided the Troutdale Formation in and near this quadrangle into a conglomeratic upper member and a fine-grained lower member. On this map Mundorff's lower member is called the fine-grained member (QTtf), and both members are subdivided. The fine-grained member consists of clay, silt, sand, and minor conglomerate, contains plant fragments and lignite, and may represent a flood-plain environment. The member resembles and may correlate with the Sandy River Mudstone across the Columbia River in Oregon (Trimble, 1963). The clay is commonly sandy or gritty, and may in part have originated from weathering or alteration of tuffaceous, lithic, or glass components. A crossbedded sand facies can be mapped separately and identified on well logs (QTtfs).

Mundorff's conglomeratic upper member of the Troutdale Formation is mapped here as a succession of three informal map units: a quartzite-clast member, an overlying volcanic-clast member, and in my interpretation the youngest, an alluvial-fan member. The quartzite-clast member and volcanic-clast member are exposed on Mundorff's Troutdale bench and are extensively dissected. The quartzite-clast member (QTtq) lies concordantly on the fine-grained member. Northwesterly paleocurrents in the quartzite-clast member and a moderate abundance of distantly derived pebbles of white quartzite are consistent with fluvial deposition by an ancestral main stream having a course and sources similar to the modern Columbia River. The overlying volcanic-clast member (QTtv) is coarser grained, contains a greater proportion of clasts derived from the Skamania Volcanics, exhibits more westerly paleocurrent directions, and includes local diamicts. This member underlies dissected hills in the north part of the quadrangle. It may correspond to the Troutdale Formation Cascadian facies of Tolan and Beeson (1984), derived locally from an ancestral Cascade Range. Alternatively, its diamicts and its proximity to dissected mapped glacial drift (Qd) suggest the possibility that this map unit may include outwash or other drift of Pleistocene age. Trimble (1963) mapped gravel deposits in the Portland area of apparently similar stratigraphic position as the Springwater Formation (Pliocene-Pleistocene).

The alluvial-fan member (QTta) is mapped as an informal allomember using combined lithologic, paleocurrent-direction, and geomorphic criteria. A key concept on this map is that alluvial fans underlie broad dissected fan-shaped surfaces, such as in the northwestern part of the quadrangle near Goheen Airport, which embay and descend south or west from the base of the Troutdale bench foothills. This idea was inspired by Mundorff (1964), but I apply it not as he did to sparse very young fine-grained deposits, but instead to gravel that Mundorff considered to be part of the eroded Troutdale Formation. Gravel that underlies the fans is thus mapped and interpreted here as an alluvial-fan member of the Troutdale Formation that buttresses unconformably against eroded lower members. This member thus appears similar in stratigraphic position to gravel deposits in the Portland area that Trimble (1963) mapped as the Pleistocene Gresham Formation. The alluvial-fan member as seen in a cut-bank exposure on Mason Creek underlying the head of a fan surface is about 30 m thick and lies with erosional unconformity on the fine-grained member; it resembles the quartzite-clast member in cobble and pebble clast size, moderate degree of consolidation, and deep weathering but is more sandy and lenticular and is more dominated by clasts derived from the Skamania Volcanics with little quartzite or Columbia River Basalt. As interpreted on this map, this member is mapped to include gravel under fan-shaped surfaces north of and southeast of the East Fork Lewis River and large expanses of contiguous gravel. Paleocurrent directions in the member are to the southwest, consistent with an alluvial-fan origin from the Cascade Range foothills, in contrast to more north to northwest paleocurrents found for the quartzite-clast member and the sand facies of the lower member

The fans are downgradient not only from lower members of the Troutdale Formation but also locally from glacial drift. This relation suggests the possibility that the fans may have formed, in part, as Pleistocene outwash plains. The alluvial-fan member rests regionally with gentle relief on the Troutdale Formation fine-grained member across the southwest two-thirds of the quadrangle. This relationship, in light of my interpreted unconformity at the base of the alluvial-fan member, suggests widespread planation on the fine-grained member prior to or accompanying alluvial-fan deposition.

GLACIAL DRIFT

Mundorff (1964) recognized that glacial till and other drift is widely distributed across the Troutdale bench north of the East Fork Lewis River, indicative of major glaciation originating from the valley of the Lewis River to the north. Mundorff (1984) proposed the name Amboy Drift and suggested, on the basis of weathering-rind thickness on volcanic pebbles, that the drift may be correlative with the Hayden Creek Drift and early Wisconsin in age. Crandell (1987) felt that at least two drifts are present in the area: a younger one, tentatively correlated with the Hayden Creek Drift, that includes moraine ridges immediately north of the northeast part of the Battle Ground quadrangle, and an older, more weathered one typified by an exposure near Mason Creek in the northwesestern part of this quadrangle. Mapping for the current quadrangle did not attempt this subdivision and instead groups the drift as a single undivided map unit (Qd). The mapped drift is mostly till and exhibits surface boulders. Mapping for the adjacent Ariel quadrangle by R. Evarts (written commun., 2001) suggests that Crandell's (1987) younger drift occupies part of this undivided drift unit in the northeast part of the Battle Ground quadrangle. An older age for southern parts of the drift as mapped in the Battle Ground quadrangle is suggested by the drift's dissection by both Mason Creek and the East Fork Lewis River, and by the drift's position beneath the basalt of Battle Ground on hills as far as 3 km south of the East Fork Lewis River.

BORING LAVA

The Boring Lava of Treasher (1942) forms many basaltic eruptive centers in the Portland basin (Trimble, 1963; Mundorff, 1964). It is represented in this quadrangle by a field of olivine basalt flows and cinder cones mapped as the basalt of Battle Ground (Qb). At least three vent sites for the basalt of Battle Ground can be identified: two cones of basalt scoria (Qbs) mapped in this quadrangle, and the Battle Ground Lake maar crater 2 km southeast of them, beyond the quadrangle. New dating from a flow derived from the northern cone and from a dike or flow exposed in the maar establish the age of the basalt of Battle Ground as about 0.1 Ma (R. Fleck, unpub. data), making it among the youngest rocks of the Boring Lava (Conrey and others, 1996).

TERRACE DEPOSITS

A terrace or terrace pair 30 to 40 m high along the valley of the East Fork Lewis River forms a prominent younger geomorphic feature inset into the eroded basalt of Battle Ground. The terrace height gradually lowers as it traces upstream 14 km beyond the quadrangle, indicating that the terrace-forming river had a gentler gradient than the modern river. The terrace is interpreted on this map to be composite. Part is a now-dissected constructional fluvial terrace underlain by loose, bouldery, lenticular terrace deposits (Qt), as near the mouth of Rock Creek (northeastern part of the quadrangle), and at a Pacific Rock Products quarry near the Lewisville Cemetery. Elsewhere I view the terrace as a strath terrace eroded on underlying finer grained, more consolidated gravel assigned to the alluvial-fan member of the Troutdale Formation (QTta). Mundorff (1964, 1984) interpreted the terrace as an outwash feature related to his Amboy Drift, but the terraced river valley incises and is younger than both the mapped (undivided) drift and the basalt of Battle Ground. The terrace furthermore projects lower than and, therefore, likely insets into and postdates the Amboy Drift of Mundorff (1984) that floors the Yacolt valley 10 km east of the quadrangle (Mundorff, 1964, 1984). The terrace gravel may be outwash from a post-Amboy glacier that terminated far upstream.

CATASTROPHIC FLOOD DEPOSITS

Fine-grained catastrophic flood deposits (Qf) mantle the strath terrace and much of the Fourth Plains below 310 ft (95 m) elevation. These flood deposits were described locally as deltaic alluvial or lacustrine conditions (Trimble, 1963; Mundorff, 1964). The deposits have been ascribed to temporary ponding of enormous outburst floods coursing down the Columbia River valley from glacial Lake Missoula and the scablands of eastern Washington (Bretz, 1969; Trimble, 1963; Waitt, 1994). In this quadrangle they fine northward, in the downstream direction, from medium sand to very fine sand. Substantial local erosion into underlying gravel is indicated by fresh unweathered substrate, by rip-ups of gravel enclosed within the fine sand, and by a fluted erosional trough 1 to 3 km wide at about 200-ft (60-m) elevation that exposes older gravel from near Manor north to the East Fork Lewis River. Dating of tephra in eastern Washington and of peat above the fine-grained catastrophic flood deposits in this quadrangle establish the age of the last flooding as about 13,000 years B.P. (Mullineaux and others, 1978). Topographic fluting of 2 to 11 m local relief mapped in this quadrangle on the fine-grained catastrophic flood deposits and locally on underlying gravel of the Troutdale Formation forms mostly north-trending ridges and valleys that record flood sculpting by erosion and, locally, deposition. The lowest flute valleys are about 195 ft (59 m) in elevation and the highest flute ridges in the quadrangle are about 280 ft (85 m) in elevation. The multiply-fluted Manor trough mostly lacks the fine-sand deposit and therefore records catastrophic-flood erosion into older gravels along a major flood channel. Flood depositional bed forms 15 m thick occur as large west-trending flutelike ridges where the fine-grained catastrophic flood deposits perch atop the 30-m high terrace overlooking East Fork Lewis River in the west center of the quadrangle north of Daybreak Park (NE1/4 sec. 20, T. 4 N., R. 2 E.). Rare pebbles found on the surface show that these ridges cannot be eolian features. Water-well logs indicate that the base of the fine-grained catastrophic flood deposits is nearly flat under these and other nearby west-trending ridges. These ridges are therefore interpreted as fluvial dunes deposited during the flooding. They align parallel to the terrace scarp that they drape. Catastrophic flood deposits are absent from the terrace east of the large dune.

ALLUVIUM, LANDSLIDES, AND TALUS

Older alluvium (Qoa) underlies sloping terraces that ramp down the inside of meander bends of the East Fork Lewis River toward the river. This morphology suggests that the older alluvium was deposited by the river while the river sequentially lowered itself while it cut outward in meander bends, leaving ramps of older alluvium. The age of the older alluvium relative to the catastrophic flood deposits is uncertain.

Bouldery young alluvium along the modern floodplain, up to 9 m thick, forms the youngest extensive deposits in the quadrangle. Landslides and basalt talus (Ql) concentrate on steep slopes where drift or the fine-grained member of the Troutdale Formation underlie more competent material.

STRUCTURAL FEATURES

The present study aimed to evaluate tectonic setting, particularly to test for structural boundaries for the east side of the Portland basin that might relate to seismic hazards. Previously the northeast margin of the Portland basin was inferred to be a structural boundary (Yelin and Patton, 1991; Blakely and others, 1995). I map a concealed northwest-trending fault in this zone near the East Fork Lewis River at the east edge of this quadrangle based on (1) northwest projection of a fault, with apparent down-to-southwest throw, under study in the adjacent Yacolt quadrangle (fig. 1), and (2) an abrupt northeast rise of pre-Neogene bedrock in sections 13 and 14, T. 4 N., R. 2 E., as determined from water-well logs. Surface elevations on a 30-m high terrace, underlain by late Pleistocene terrace deposits, slope anomalously compared to their usual downstream gradient. The terrace surface also is possibly deformed 8 km upstream (at river mile 23) in the Yacolt quadrangle, where contours show an unusual rise of the terrace, near where dips steepen to more than 10° in the underlying Skamania Volcanics, which elsewhere nearby are subhorizontal. Whether the anomalous terrace elevations relate to sedimentary or deformation processes or are artifacts of poor photogrammetric control remains unknown. Any deformation of the late Pleistocene terrace would be of considerable interest for assessing tectonic and seismic hazards.

Structure-contour mapping of the top of the fine-grained member of the Troutdale Formation (by Mundorff, 1964; Swanson and others, 1993; and as part of the present study) indicates (1) a gentle dip to the southwest, (2) a south-trending, locally exposed syncline near the center of the quadrangle, and (3) doming beneath a symmetrical topographic domal hill 40 m high and more than 1 km wide near Dollar Corner (Mundorff, 1964). Compared to regional levels, the subsurface top of the Troutdale Formation fine-grained member domes beneath this hill, as logged in two water wells on this hill and two wells on the skirt of the hill. Possibly a cryptic intrusion of Boring Lava, not penetrated by water wells, caused the doming. Based on my assignment of the upper part of the dome to the Troutdale Formation alluvial-fan member (QTta), the age of doming may be as young as Quaternary.

A series of parallel, east-west lineaments defined by linear barbed drainages cut into flood deposits in the south part of the quadrangle suggests possible fracturing of these young deposits. The west-southwest course of nearby Salmon Creek here and in adjacent quadrangles may conceal a fault of Holocene age. The creek's valley bisects a 10-km-wide domelike rise 6 to 12 m high in the depositional surface of latest Pleistocene catastrophic flood deposits, centered just south of and extending into the Battle Ground quadrangle. The surface elevation of this dome abruptly drops as much as 6 m as it steps northward across the creek's valley (Howard and others, 2000). The east-northeast orientation of the faultlike step in the surface of the flood-deposits along Salmon Creek, together with earthquake first motions recorded by Yelin and Patton (1991), are consistent with sinistral to thrust fault motions on a fault of this strike due to north-south regional compression. Clusters of small earthquakes centered near this step (Yelin and Patton, 1991) support the possibility of ongoing faulting near or at this step. If the creek is antecedent to structural doming, and the flood-deposit surface is domed 12 m and perhaps offset 6 m, the implied Holocene deformation rate is approximately 0.5 to 1 mm/yr. Alternatively the two halves of the dome could be undeformed bar shapes left by the catastrophic flooding, and the step down to the lower north half of the dome could be some hydrodynamic effect of flood flow directly across a pre-existing Salmon Creek valley.

GEOLOGIC HISTORY

The earliest events recorded in the Battle Ground quadrangle were the accumulation and then zeolite-grade metamorphism of Paleogene lavas, the Skamania Volcanics. These rocks formed a western part of an ancestral Cascade volcanic arc, which interfingered to the west with coeval marine sedimentary rocks (Niem and others, 1992). In middle Miocene time, following burial and partial exhumation and erosion of the Skamania Volcanics, an ancestral Portland basin began to develop near the transition between the Paleogene volcanic and sedimentary strata (Beeson and others, 1989; Wells and others, 1998). Flows of the Columbia River Basalt Group erupted from vents far east of the Cascade Range, traversed the incipient range near the present course of the Columbia River, entered the nascent Portland basin, and inundated large areas of the surrounding terrain (Tolan and Beeson, 1984; Beeson and others, 1989; Wells and others, 1998). These flows are not exposed in the Battle Ground quadrangle but may be present at depth beneath its western part.

The basin subsequently served as a depocenter in late Miocene, Pliocene, and possibly Pleistocene time for fluvial deposits of the Troutdale Formation. The Troutdale Formation was derived partly from distant eastern sources, as shown by the presence of muscovite in the sand and by round quartzite pebbles, which have no local source. The source stream crossed the Cascade Range near the present Columbia River Gorge (Tolan and Beeson, 1984). Sedimentary structures in the Troutdale's lowest two members in the Battle Ground quadrangle show north- to northwest-flowing paleocurrents, paralleled later by the nearby modern Columbia River. A subsequent locally derived volcanic-clast gravel member (QTtv) now caps hills in the northwest part of the quadrangle. The fine-grained member of the Troutdale Formation was folded into a syncline in the central part of the quadrangle. After dissection of the Troutdale's lower members, west-flowing streams, possibly including Pleistocene glacial outwash, deposited the youngest (alluvial-fan) member of the Troutdale Formation across the Fourth Plains in the quadrangle.

One or more Pleistocene ice sheets moving west and south down the Lewis River valley from the Cascade Range overrode the hilly northeast part of the quadrangle and coated the Troutdale Formation and underlying Skamania Volcanics with drift, mostly bouldery till (Mundorff, 1984). The till reached elevations as low as about 200 ft or 60 m at Lewisville Park. Mundorff (1984) suggested that the ancestral upper East Fork Lewis River originally coursed northward through Yacolt Valley, east of the quadrangle, until a glacier in that valley forced the river westward across the Battle Ground quadrangle. The new recognition of drift as far as 3 km south of the East Fork Lewis River in this quadrangle implies that the ice-marginal stream passed south, probably exiting onto the Fourth Plains southwest through the site of Battle Ground.

Late Pleistocene eruptions built Pleistocene cones and flows of the basalt of Battle Ground atop the drift**.** After volcanism the river incised, near the East Fork Lewis River's present course, to a late Pleistocene bed that is now isolated as a terrace. The terrace gravel possibly is outwash from an upstream post-Amboy glacier. As further downcutting isolated the terrace 30 to 40 m above the flood plain, the river sequentially lowered itself while it cut outward in meander bends, leaving ramps of older alluvium.

In latest Pleistocene time one or more giant floods that had burst down the Columbia River valley from glacial Lake Missoula flowed northwest across the lowlands in the quadrangle, depositing fine sand as thick as 23 m and at elevations up to about 300 ft (90 m) (Bretz, 1969; Trimble, 1963; Waitt, 1994). The catastrophic flooding deposited transverse fine-sand dunes as thick as 15 m atop the northern 30-m high East Fork Lewis River terrace. Elsewhere, the northward flow fluted and eroded into the Troutdale Formation. Peat and volcanic ash have subsequently accumulated to small, unmapped thickness in some of the bogs that occupy the flute valleys (Rigg, 1958).

Subsequently the flood deposits may have undergone offset and broad doming where Salmon Creek has cut its valley and small earthquakes cluster (Yelin and Patton, 1991; Howard and others, 2000). If so, Holocene offset and uplift rates could be about 0.5 to 1 mm/yr.

Avulsion events during historic floods on the East Fork Lewis River have resulted in multiple changes in the river's course within its floodplain. The most recent avulsions were influenced by excavated gravel pits (Norman and others, 1998).

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APPENDIX

Digital database description

DIGITAL DATABASE DESCRIPTION FOR THE GEOLOGIC MAP OF THE BATTLE GROUND QUADRANGLE, CLARK COUNTY, WASHINGTON

Database by Robert W. Givler and Philip A. Dinterman

INTRODUCTION

This appendix serves to introduce and describe the digital files that are included in this publication, available for downloading at http://geopubs.wr.usgs.gov. These files include a set of ARC/INFO geospatial databases containing the geologic information as well as Adobe Acrobat Portable Document Format (PDF) and PostScript plot files containing images of the geologic map sheet and the text of an accompanying pamphlet that describes the geology of the area. For those interested only in a paper plot of the map and pamphlet, please see the section entitled "Obtaining paper plots" below.

This digital map publication, generated from new mapping by the author, shows the general distribution of bedrock and surficial deposits in the Battle Ground 7.5' quadrangle. Together with the accompanying geologic description pamphlet, it presents current knowledge of the geologic structure and stratigraphy of the area covered. The database identifies map units that are classified by general age and lithology following the stratigraphic nomenclature of the U.S. Geological Survey. The scale of the source map limits the spatial resolution (scale) of the database to 1:24,000 or smaller. The content and character of the digital publication, as well as methods of obtaining the digital files, are described below.

The databases in this report were compiled in ARC/INFO, a commercial Geographic Information System by Environmental Systems Research Institute (ESRI) in Redlands, California, with version 3.0 of the menu interface ALACARTE (Fitzgibbon and Wentworth, 1991; Fitzgibbon, 1991; Wentworth and Fitzgibbon, 1991). The files are in either GRID (ARC/INFO raster data) format or COVERAGE (ARC/INFO vector data) format. Coverages are stored in uncompressed ARC export format (ARC/INFO version 8.1.2 for Unix). ARC/INFO export files (files with the .e00 extension) can be converted into ARC/INFO coverages in ARC/INFO (see below) and can be read by some other Geographic Information Systems, such as MapInfo, via ArcLink and ESRI's ArcView (version 1.0 for Windows 3.1 to 3.11 is available for free from ESRI's web site: http://www.esri.com). The digital compilation was done in version 8.1.2 of ARC/INFO for Unix.

MF-2395 DIGITAL CONTENTS

The digital data for the Miscellaneous Field Studies Map consist of three separate packages. Choosing the most appropriate package will depend on the resources available. The **PostScript (PS) package** consists of Encapsulated PostScript files of the geologic map with explanation and a geologic description pamphlet with figures and tables. The **Portable Document Format (PDF) package** contains the same map and pamphlet as the first package as PDF files The **Digital Database package** contains ARC/INFO files that comprise the geologic map database itself and supporting data, including base map, map explanation, geologic description, and references.

Those who have computer capability can access the plot file packages in any of the three ways described below. However, it should be noted the plot file packages do require gzip and tar utilities or winzip to access the plot files. Therefore additional software, available free on the Internet, may be required to use the plot files (see section "Tar files"). In addition, the map sheet is large and requires large-format color plotters to produce a plot of the entire image, although smaller plotters can be used to plot portions of the images using the PDF plot files.

Those without computer capability can obtain plots of the map files through U.S. Geological Survey print on demand service for digital geologic maps (see section "To obtain paper plots from the U.S. Geological Survey) or from an outside vendor (see section "To obtain plots from a commercial vendor").

ENCAPSULATED POSTSCRIPT PACKAGE

For those interested in the geology of the Battle Ground 7.5' quadrangle who do not use an ARC/INFO compatible GIS system we have included a PostScript (PS) plot file created with Adobe Illustrator 9.0. This package contains:

bgmap.ps — A PS plottable file containing an image of the geologic map, base map, cross sections, correlation of map units, description of map units, and index map of the Battle Ground 7.5' quadrangle The file contains a color plot of the geologic map sheet at 1:24,000 scale. The PostScript image of the map sheet is 36 by 38 inches, so it requires a large plotter to produce paper copies at the intended scale

geoltext.pdf — A PDF file of the geologic description pamphlet with figures and an appendix containing the readme file (digital database description)

The PostScript plot files for maps were produced by the PostScript command using the uncompressed option in ARC/INFO version 7.2.1 for Unix. Encapsulated PostScript files, as well as the layout (bg.eps) contain a color plot of the geologic map, cross sections, correlation of map units, description of map units, and index map.

PORTABLE DOCUMENT FORMAT PACKAGE

Adobe Acrobat PDF files are similar to PostScript plot files in that they contain all the information needed to produce a paper copy of a map and they are platform-independent. PDF files allow printing of portions of a map image on a printer smaller than that required to print the entire map without the purchase of expensive additional software. The PDF files were created from the PostScript files using Adobe Acrobat Distiller. In test plots we have found that paper maps created with PDF files contain almost all the detail of maps created with PostScript plot files. We would, however, recommend that users with the capability to print the larger PostScript files use them in preference to the PDF files. This package contains the images described here in PDF 5.0 format:

bgmap.pdf — A PDF file containing an image of the geologic map, base map, cross sections, correlation of map units, description of map units, and index map of the Battle Ground 7.5' quadrangle

geoltext.pdf — A PDF file of the geologic description pamphlet with figures and an appendix containing the readme file (digital database description)

To use PDF files, the user must get and install a copy of Adobe Acrobat Reader. This software is available free from the Adobe website (http://www.adobe.com). Please follow the instructions given at the website to download and install this software. Once installed, the Acrobat Reader software contains an online manual and tutorial.

There are two ways to use Acrobat Reader in conjunction with the Internet. One is to use the PDF reader plug-in with your Internet browser. This allows interactive viewing of PDF file images within your browser. This is a very handy way to quickly look at PDF files without downloading them to your hard disk. The second way is to download the PDF file to your local hard disk and then view the file with Acrobat Reader. **We strongly recommend that large map images be handled by downloading to your hard disk, because viewing them within an Internet browser tends to be very slow.**

To print a smaller portion of a PDF map image using Acrobat Reader, use the crop tool to show the desired print area. This crop tool will not remove any area that is not printing, but masks the parts and can be later be changed to show the entire map or any other part of it for printing or viewing.

DIGITAL DATABASE PACKAGE

The database package includes geologic map database files for the Battle Ground 7.5' quadrangle. ARC/INFO compatible Geographic Information System (GIS) software is required to use the files of this package. The digital maps, or coverages, and associated INFO directory have been converted to uncompressed ARC/INFO export files. ARC export files promote ease of data handling and are usable by some Geographic Information Systems in addition to ARC/INFO (see below for a discussion of working with export files). Raster data are stored in ARC grid format rather than export format to reduce file size. The ARC export files and associated ARC/INFO coverages, grids, and directories, as well as the additional digital material included in the database, are described below:

ARC/INFO export file	Resultant Coverage	Description of Coverage
bg_geo.e00	bg_geo	Faults, contacts, and rock units in the quadrangle
bg_stx.e00	bg_stx	Geologic attitudes as points; include pttype, strike, and dip fields, dip values as annotation, flow directions and cross section lines
bg_ann.e00	bg_ann	Unit labels and leaders
bg_line.e00	bg_line	Ridges, valleys, flood fluting data
fnt034.e00	fnt034	ARC/INFO font used with markerset
fnt035.e00	fnt035	ARC/INFO font used with markerset
fnt038.e00	fnt038	ARC/INFO font used with markerset
fnt039.e00	fnt039	ARC/INFO font used with markerset
fnt040.e00	fnt040	ARC/INFO font used with markerset
fnt339.e00	fnt339	ARC/INFO font used with markerset
geologykrg.mrk.e00	geologykrg.mrk	ARC/INFO markerset (custom)
droid.lut.e00	droid.lut	ARC/INFO marker look up table (internal)
bg_poly.lut.e00	bg_poly.lut	ARC/INFO line look up table for polygons (internal)
bg_ln.lut.e00	bg_ln.lut	ARC/INFO line look up table for lines and fold arcs (internal)
bg_lo.lut.e00	bg_lo.lut	ARC/INFO line look up table for lines and fold arcs (internal)
bg_lm.lut.e00	bg_lm.lut	ARC/INFO line look up table for fold and fault markers (internal)

ARC/INFO grid	Description of Grid
bg_grd	Battle Ground color geology grid merged with grid of topographic base

The digital database package also includes the following files:

metadata.txt	The metadata as a text file
geoltext.pdf	Geology pamphlet including readme as a PDF file with figures
geoltext.doc	Geology pamphlet including readme as a MSWord 2000 document with figures
import.aml	ASCII text file in ARC Macro Language (AML) used to convert ARC export files to ARC coverages in ARC/INFO
bg.eps	Adobe Illustrator 9.0 Encapsulated PostScript file of the Battle Ground quadrangle (map collar)
bg_plot.aml	AML that uses the coverages and grid to generate an uncompressed PostScript file of the Battle Ground geologic map at 600 dpi., which can be combined with the other files in Adobe Illustrator to produce the entire map sheet layout

bgmap.gra	ARC Graphics Metafile for the Battle Ground quadrangle
bgmap.ps	Postscript file of Battle Ground quadrangle uncompressed
geol61r1.lin	Custom ARC lineset
johanna.txt	Custom ARC textset
landu	Parameter file in bg_plot.aml to uncompress and rotate PostScript file
bg.tab	ARC/INFO grid remap table for colors
info	ARC/INFO directory
log	ARC/INFO log file
alc1.shd	ARC/INFO shadeset (custom)

The following supporting directory is not included in the database package, but is produced in the process of reconverting the export files into ARC coverages:

info/	INFO directory containing files supporting the databases

CONVERTING ARC EXPORT FILES

ARC export files for coverages are converted to ARC coverages using the ARC command IMPORT with the option COVER. To ease conversion and maintain naming conventions, we have included an ASCII text file in ARC Macro Language that will convert all of the export files in the database into coverages, import the fonts, markersets, and lookup tables, and create the associated INFO directory. From the ARC command line type:

Arc: &run import.aml

ARC export files can also be read by some other Geographic Information Systems. Please consult your GIS documentation to see if you can use ARC export files and the procedure to import them.

TAR FILES

The two data packages described above are stored in tar (UNIX tape archive) files. A tar utility is required to extract the database from the tar file. This utility is included in most UNIX systems and can be obtained free of charge over the Internet from Internet Literacy's Common Internet File Formats Webpage (http://www.matisse.net/files/formats.html). The tar files have been compressed and may be uncompressed with **gzip**, which is available free of charge over the Internet via links from the U.S. Geological Survey Public Domain Software page (http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/public.html). When the tar file is uncompressed and the data is extracted from the tar file, a directory is produced that contains the data in the package as described above. If you are using a PC, a software package called cygwin will provide a UNIX-like environment on a PC. Using this software these files maybe untared and uncompressed. Download this software for free at *http://sources.redhat.com/cygwin/*. The specifics of the tar files are listed below:

Name of compressed tar file (size)	**Size of uncompressed tar file**	**Directory produced when extracted from tar file**	**Data package contained**

2395ps.tar.gz (6.8 Mb)	114 Mb	2395ps/	PostScript package
2395pdf.tar.gz (6.4 Mb)	6.9 Mb	2395pdf/	Portable Document Format package
2395db.tar.gz (11.8 Mb)	129 Mb	2395db/	Digital Database package

OBTAINING THE DIGITAL DATA

The digital data for this map can be obtained in any of three ways:

A. Western Region Geologic Information Web Page
B. Anonymous ftp over the Internet
C. Request for the data on a compact disk (CD)

A. TO OBTAIN TAR FILES FROM THE U.S. GEOLOGICAL SURVEY WEB PAGES

The U.S. Geological Survey supports a set of graphical pages on the World Wide Web. Digital publications (including this one) can be accessed via these pages. The location of the main Web page for the entire U.S. Geological Survey is http://www.usgs.gov. The Web server for digital publications from the Western Region is http://geopubs.wr.usgs.gov. To access files for the Battle Ground quadrangle, go to *http://geopubs.wr.usgs.gov/map-mf/mf2395/*.

B. TO OBTAIN TAR FILES BY FTP

The files in this report are stored on the U.S. Geological Survey Western Region FTP server. The Internet ftp address of this server is *ftp://geopubs.wr.usgs.gov*. The user should log in with the user name anonymous and then input their e-mail address as the password. This will give the user access to all the publications available via ftp from this server. The files in this report are stored in the subdirectory *pub/map-mf/mf2395/*.

C. TO OBTAIN TAR FILES ON A CD

The database files, EPS files, and PDF files can be obtained on a CD by sending a request and return address:

Keith Howard, Ray Wells, or Karen Wheeler
U.S. Geological Survey
345 Middlefield Road, M/S 975
Menlo Park, CA 94025

or by email: *khoward@usgs.gov*, *rwells@usgs.gov* or *kwheeler@usgs.gov*

The compressed tar file will be returned on a CD.

OBTAINING PAPER PLOTS

TO OBTAIN PLOTS FROM A COMMERCIAL VENDOR

Those interested in the geologic map of the Battle Ground 7.5' quadrangle, but who use neither a computer nor the Internet, can still obtain the information by providing the PostScript plot files to a commercial vendor who can make large-format plots. To obtain a CD with the compressed tar file, send a request and return address:

Keith Howard, Ray Wells, or Karen Wheeler
U.S. Geological Survey
345 Middlefield Road, M/S 975
Menlo Park, CA 94025

or by email: *khoward@usgs.gov*, *rwells@usgs.gov*, or *kwheeler@usgs.gov*

Make sure your vendor is capable of reading CDs and PostScript files; be certain to provide a copy of this document to your vendor.

TO OBTAIN PAPER PLOTS FROM THE U.S. GEOLOGICAL SURVEY

The U.S. Geological Survey provides a print on demand service for digital maps such as this report. To obtain plots, contact the U.S. Geological Survey:

USGS Information Services
Box 25286
Denver Federal Center
Denver, CO 80225-0046

(303) 202-4200
1-800-USA-MAPS
FAX: (303) 202-4695
e-mail: infoservices@usgs.gov

Be sure to include with your request the Miscellaneous Field Studies Map number, MF-2395.

DIGITAL COMPILATION

Several different coverages were generated during the construction of the Battle Ground quadrangle geologic map. The topographic base map remains as an image and then is converted to a grid, and is merged at the last step with the colored geology polygrids. The image was merged with the geology grid to give an apparent transparent color image of both combined. The raster geology grids were converted to vector coverages with ARC/INFO's gridline routine. Alacarte and some custom menus and AMLs (ARC Macro Language) were used to project, transform, edit, tag, and build lines, polygons, and points in the map. A digital layout or map collar was made with Adobe Illustrator. The plot AMLs run in ARC/INFO and call the coverages, grids, and Adobe Illustrator EPS files to make uncompressed PostScript files. The map is in UTM projection, zone 10, meters, and 1:24,000 scale. The pamphlet that describes the geology and readme was saved to PDF from Microsoft Word.

Base Map

The base map for the digital compilation is a Digital Raster Graphic (DRG) of the U.S. Geological Survey, 1:24,000-scale topographic map of the Battle Ground 7.5' quadrangle (1990), which has a 10-foot contour interval. The image inside the map neatline is georeferenced to the Universal Transverse Mercator projection. The horizontal positional accuracy and datum of the DRG matches the accuracy and datum of the source map. These base map/geology layers are digital images but no information other than location is attached to the lines. The base/geology maps are provided for reference only.

Spatial Resolution

Uses of this digital geologic map should not violate the spatial resolution of the data. Although the digital form of the data removes the constraint imposed by the scale of a paper map, the detail and accuracy inherent in map scale are also present in the digital data. The fact that this database was edited at a scale of 1:24,000 means that higher resolution information is not present in the dataset. Plotting at scales larger than 1:24,000 will not yield greater real detail, although it may reveal fine-scale irregularities below the intended resolution of the database. Similarly, where this database is used in combination with other data of higher resolution, the resolution of the combined output will be limited by the lower resolution of these data.

Annotation

Annotation coverages were used to label desired information to show when the map is printed. These coverages do not hold any information other than the information attached to the lines or polygons. Within the structural coverage (bg_stx) is an annotation showing dip amount associated with each attitude. An annotation coverage (bg_ann) was also used to label map units within the geology polygons. These annotation layers are called by the plot AML (bg_plot.aml) used by ARC/INFO, using a custom ARC textset, johanna.txt. The plot AML converts all coverages into a PostScript file (bgmap.ps).

DATABASE SPECIFICS

The map databases consist of ARC coverages and supporting INFO files, which are stored in a UTM (Universal Transverse

Mercator) projection (table 1). Digital tics define a 7.5' grid of projected latitude and longitude in the coverages corresponding with quadrangle corners and internal tics.

Table 1 - *Map Projection*

The map is stored in UTM projection

PROJECTION UTM	
UNITS METERS	-on the ground
ZONE 10	-UTM zone
PARAMETERS	
END	

The content of the geologic database can be described in terms of the lines, areas, and points that compose the map. Descriptions of the database fields use the terms explained in table 2.

Table 2 - *Field Definition Terms*

ITEM NAME	name of the database field (item)
WIDTH	maximum number of digits or characters stored
OUTPUT	output width
TYPE	B-binary integer, F-binary floating point number, I-ASCII integer, C-ASCII character string
N. DEC.	number of decimal places maintained for floating point numbers

Lines

The lines (arcs) are recorded as strings of vectors and are described in the arc attribute table (table 3). They define the boundaries of the map units, faults, and the map boundaries. These distinctions, including the geologic identities of the unit boundaries, are recorded in the LTYPE field according to the line types listed in table 4.

Table 3 - *Content of the Arc Attribute Tables*

ITEM NAME	**WIDTH**	**OUTPUT**	**TYPE**	**N.DEC.**	**Description**
FNODE#	4	5	B		starting node of arc (from node)
TNODE#	4	5	B		ending node of arc (to node)
LPOLY#	4	5	B		polygon to the left of the arc
RPOLY#	4	5	B		polygon to the right of the arc
LENGTH	4	12	F	3	length of arc in meters
<coverage>#	4	5	B		unique internal control number
<coverage>-ID	4	5	B		unique identification number
LTYPE	35	35	C		line type (see table 4)
SEL	1	1	I		user-defined field used to save a selected set
SYMB	3	3	I		user defined field used to save symbol assignments (such as color)

Table 4 - *Line Types recorded in the LTYPE Field (listed by coverage name, LTYPE ending with "m" or "_" is for cartographic plotting purposes to cause a symbol to plot at a specific location on that line)*

bg_geo
contact, certain
map boundary
fault, concealed
fault, concealed _m
topographic escarpment
topographic escarpment, concealed
water

bg_stx
dome, certain
f.a., syncline, concealed
f.a., syncline, certain

flow direction

bg_ann
cross section

bg_line
fluting ridge
fluting valley
lineations, inferred

Areas

Map units (polygons) are described in the polygon attribute table (table 5). The identities of the map units from compilation sources are recorded in the PTYPE field by map label (table 6). Note that ARC/INFO coverages cannot contain both point and polygon information, so only coverages with polygon information will have a polygon attribute table, and these coverages will not have a point attribute table. More complete descriptions of the various rock units can be found in the geologic report (geoltext.doc or geoltext.pdf) that precedes the dataset description.

Table 5 - *Content of the Polygon Attribute Table*

ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC.	Description
AREA	4	12	F	3	area of polygon in square meters
PERIMETER	4	12	F	3	length of perimeter in meters
<coverage>#	4	5			unique internal control number
<coverage>-ID	4	5	B		unique identification number
PTYPE	35	35	C		unit label
SEL	1	1	I		user defined field used to save a selected set
SYMB	3	3	I		user defined field used to save symbol assignments (such as color)

Table 6 - *Map Units*

bg_geo
QTta
QTtf
QTtfs
QTtq
QTtv
Qa
Qb
Qbs
Qd
Qf
Ql
Qoa
Qt
Qt?
Tsv
Tsv?

Points

Data gathered at a single locality (points) are described in the point attribute table (table 7). The identities of the points from compilation sources are recorded in the PTTYPE field by map label (table 8). Note that ARC/INFO coverages cannot contain both point and polygon information, so only coverages with point information will have a point attribute table, and these coverages will not have a polygon attribute table.

Table 7 – *Content of the Point Attribute Table*

bg_stx
Geologic attitudes

ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC.
AREA	4	12	F	3
PERIMETER	4	12	F	3
BG_STX#	4	5	B	
BG_STX-ID	4	5	B	
PTTYPE	35	35	C	
DIP	3	3	I	
STRIKE	3	3	I	
SEL	1	1	I	
SYMB	3	3	I	

ACKNOWLEDGMENTS

We thank Karen Wheeler for the digital review of this Miscellaneous Field Studies Map.

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Wentworth, C.M., and Fitzgibbon, T.T., 1991, ALACARTE user manual (version 1.0): U.S. Geological Survey Open-File Report 91-587C.