BEDROCK GEOLOGIC MAP OF THE PULLMAN 7 ½ MINUTE QUADRANGLE, WHITMAN COUNTY, WASHINGTON

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INTRODUCTION

The bedrock geologic map of the Pullman quadrangle was constructed primarily from examination of major outcrops and water well drill logs (Table 1). Much of the outcrop information on the Columbia River Basalt Group (CRBG) was obtained from the work of Hooper and Webster (1982). Regional maps by Swanson and others (1980) and Gulick (1994) were also used. Examination of chips and rock chemistry results from several deep wells in the Pullman area provided considerable subsurface information (Bush and others, 2001) and was used to define the stratigraphic framework for the CRBG. Earlier work by Brown (1976) formed the basis for subsurface correlation of individual units.

Distribution of loess of the Palouse Formation is not illustrated on the map in keeping with the emphasis on bedrock geology. For the same reason, colluvium next to topographic highs of pre-CRBG units is not shown. However, alluvium and colluvium associated with the major streams is illustrated because the sedimentation patterns help interpret bedrock contacts and structural relationships. Continuous outcrops are rare and contacts between basalt and the older units are covered with loess and colluvium. Therefore, the contact lines are interpretive.

Research by Brown (1976), Bush and others (2001), and Bush and Garwood (2003) has shown that the subsurface in the Pullman area is structurally and stratigraphically complex. The bedrock geologic map illustrates some of these structures. For details on the subsurface, the reader should review the report by Bush and others (2001).

DESCRIPTION OF MAP UNITS

QUATERNARY DEPOSITS

Qac Alluvium and colluvium (Holocene) – Stream, slope-wash, and debris-flow deposits in drainage areas. Composition consists of loess, basalt, and pre-CRBG materials. In the South Fork of the Palouse River mixtures of granule- and sand-sized basalt and quartz fragments are common. Locally near outcrops, cobbles and pebbles of basalt dominate. In the intermittent drainages reworked loess is more common. Close to pre-CRBG topographic highs, fragments of loess and subrounded quartz and quartzite fragments occur in poorly sorted mixtures.

Ql Palouse Formation (Pleistocene) – Silty and clayey loess of the Palouse hills. Shown in cross-section only.

COLUMBIA RIVER BASALT GROUP (CRBG)

The stratigraphic nomenclature of the Columbia River Basalt Group is based on that presented by Swanson and others (1979). The group is divided into four formations: from base upward these are the Imnaha Basalt, Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt. WSU well No. 7 in Pullman penetrated over 2200 feet of the Wanapum, Grande Ronde, and Imnaha basalts (Bush and others, 2001; Bush and Garwood, 2003). Flows of the younger Saddle Mountains Basalt crop out west and southwest of Pullman. The base of the Imnaha was not penetrated in the well. The composite sequence of CRBG is at least 2600 feet thick in the Pullman quadrangle.

SADDLE MOUNTAINS FORMATION

Tsm Saddle Mountains Basalt, undivided (Miocene) – Mapped by Hooper and Webster (1982) as intravalley flows of the Asotin and Wilbur Creek members. The Asotin Member overlies the Wilbur Creek Member. These two flows filled a shallow paleovalley or structural low developed on the surface of the Priest Rapids Member. These flows have normal magnetic polarity (Wright and others, 1973; and Swanson and others, 1979).

WANAPUM FORMATION

Tpr Priest Rapids Member (Miocene) – Medium- to coarse-grained basalt with phenocrysts of plagioclase and olivine in a groundmass of intergranular pyroxene, illmenite blades, and minor devitrified glass. Other workers have previously identified and described these flows (Wright and others, 1973; and Swanson and others, 1979). These flows have reverse magnetic polarity (Wright and others, 1973; and Swanson and others, 1979). The Priest Rapids is exposed in quarries and road cuts throughout much of the quadrangle. Hooper and Webster (1982) have examined most outcrops and note that the Lolo chemical type underlies much of the area and that the Rosalia chemical type occurs locally.

The Priest Rapids typically ranges from 180 to 250 feet in thickness on surrounding quadrangles. The Priest Rapids in the city of Pullman thins to less than 100 feet and it thickens to the east towards Moscow and also to the west. This thinning occurred in response to the development of a paleogeographic high just southwest of the Pullman area after the emplacement of the Grande Ronde (Bush and Garwood, 2003).

Hooper and Webster (1982) noted the presence of Priest Rapids dikes in outcrops along the South Fork of the Palouse in Pullman. Those dikes were examined for this study and we conclude from field characteristics that they may be internal dikes (rootless dikes) of the same flow. Our work showed that the Priest Rapids in Pullman consists of at least two flow units of Lolo chemical type. Slight chemical differences between analyses of one dike sample and the two flows suggest that Hooper and Webster (1982) may be correct in reporting a different chemical type for the dikes. No flow has been found on the Pullman and adjoining quadrangles to match the chemistry of the dikes.

Tr Roza Member (Miocene) – Consists of flows of basalt with abundant plagioclase phenocrysts. The phenocrysts average about 10 mm in length and occur with microphenocrysts of olivine and augite in an intergranular groundmass. The unit is not exposed on the Pullman quadrangle, but is present in the subsurface along the western margin and is illustrated on cross-section AB. The flow is 190 feet thick to the northwest at Colfax. The pinch out of the Roza in the subsurface in the western part of the quadrangle helps define the subsurface high on the upper Grande Ronde that occurs beneath Pullman.

GRANDE RONDE FORMATION

Tgr_{N2}, Tgr_{R2}, Tgr_{N1}, Tgr_{R1} magnetostratigraphic units (Miocene) – Consists of flows of fine-grained to very fine-grained aphyric basalt. The Grande Ronde Basalt sequence is 1773 feet thick in WSU well No. 7. Brown (1976) showed that the Grande Ronde sequence in Pullman could be subdivided into at least three chemical groups. Bush and others (2001) subdivided the sequence into four groups and related them to the four magnetostratigraphic members of the Grande Ronde. They tentatively determined the sequence in WSU well No. 7, from base upwards, to be subdivided as follows: Tgr_{R1} member (278 ft.), Tgr_{N1} member (591 ft.), Tgr_{R2} member (514 ft.), and Tgr_{N2} member (390 ft). Tgr_{R2}, Tgr_{N1}, and Tgr_{R1} shown in cross-section only.

Tl LATAH FORMATION (Miocene) – Consists of clay, silt, sand, and gravel deposits that range from a few feet to over 40 feet in thickness. The sand is angular to subrounded, poorly sorted, and consists primarily of quartz with muscovite common in places. The term “Latah Formation” is typically used for any sequence of sediments interlayered with or associated with Miocene basalt flows of the Columbia River Basalt Group. In the Pullman quadrangle, interbeds throughout the stratigraphic sequence are rarely exposed at the surface and typically comprise less than 10 percent of the sequence at any one location. Although thin in the Pullman quadrangle, the interbed between the Wanapum and the Grande Ronde has been correlated regionally. The term “Vantage Member” has been used for this interbed in the Pullman area (Siems and others, 1974; Bush and Provant, 1998), and is equivalent to the same sediment interval in the Ellensburg Formation of western Washington (Swanson and others, 1979). Where sediments associated with the basalts are not bounded by the Wanapum and Grande Ronde in the Pullman area, the more encompassing terms “Latah Formation” or “Latah interbeds” are appropriate.

WSU well No. 8, drilled in 2003, was completed in a unit of basalt pebbles and cobbles that is at least 50 feet thick. Such a thick gravel unit has not been noted in any of the other deep wells in Pullman. Correlations to surrounding wells in the Pullman area indicate that the gravel is near the base of the Tgr_{N2} unit. Chemical analyses of three samples of the gravels indicate that they are Grande Ronde and show similarities to the underlying Tgr_{R2} Member.

PRE-CRBG UNITS

Prebasalt rocks are poorly exposed in parts of the southeastern corner of the quadrangle. These rocks extend eastward into Idaho and define part of the southern boundary of the Palouse basin.

Kgr Undifferentiated intrusive rocks (Cretaceous) – Compositions include tonalite, hornblende monzodiorite, and hornblende granodiorite. Foliation is common in places. Mineral sizes range from medium-grained equigranular to coarse-grained equigranular. Hooper and Webster (1982) report a biotite K-Ar date of 69.8 ±2.6 Ma from rocks collected at the western end of the exposures near the old community of Chambers.

CqK Quartzite of Kamiak Butte (Cambrian?) – Consists mostly of massive-bedded quartzite with minor schist and phyllite (Gulick, 1994). The quartzite is white to creamy white, light gray to bluish purplish gray, pink, and reddish brown, and consists primarily of recrystallized quartz with small amounts of feldspar, muscovite, and biotite locally. The quartz grains, where visible, range from well sorted to poorly sorted and are typically described as “clean” due to the very high percentage of quartz. Though recrystallized, inconspicuous relict bedding planes, laminations, and cross-beds are present in places.

There has not been an accepted stratigraphic age for this quartzite (Savage, 1973; Hooper and Webster, 1982; and Bush and Provant, 1998). Similar quartzites to the east have been mapped as Prichard Formation of the Belt Supergroup (Tullis, 1944), pre-Belt prebasalt rocks (Bond, 1978), and Revett Formation of the Belt Supergroup (Anderson, 1991). Hooper and Webster (1982) suggest a Cambrian age for these quartzites based on the lack of laminations, which are common in Belt Supergroup rocks, and on their similarity to Cambrian quartzites in northeast Washington. The outcrop illustrated in section 33 (T14N, R45E) was not examined for this report and was compiled from Hooper and Webster (1982). The quartzite lacks the feldspar of Belt Supergroup quartzite and field relations suggest they overlie the Belt rocks, although no outcrop proving that relationship has been noted. However, detrital zircon signatures of Kamiak Butte rocks suggest they are consistent with easterly derived units of the Belt Supergroup (Ellis and others, 2004).

GENERALIZED GEOLOGIC DISCUSSION

The major structural feature on the Pullman quadrangle is an anticlinal high located just southwest of the city of Pullman (Bush and others, 2003). Deformation of the CRBG during and after emplacement of the Grande Ronde produced the northwest-trending folds on the Pullman quadrangle. The Roza flows pinched against the anticlinal high to the southwest and the Priest Rapids flows later thinned over it. Saddle Mountains basalt flowed northwest into the Uniontown syncline to the west of the anticline, but did not get into the city of Pullman area. This structure creates a difference in stratigraphic sequences between the southwestern and northeastern part of the quadrangle.

The northwest-trending folds illustrated on the map were for the most part defined by stratigraphic analyses of several wells in the Pullman subsurface (Brown, 1976; Bush and others, 2001; and Bush and Garwood, 2003). Those studies have shown that Grande Ronde units rapidly change in thickness and in some cases elevations of contacts change over short distances. We conclude that the Pullman subsurface is a deformation zone as suggested by Brown (1976). The stratigraphic correlations could be explained by faults, but folds with minor faulting are more likely. Detailed studies of well chips and overall regional mapping provide the evidence for the existence of the anticline and deformation zone. The lack of deep well geochemical data north and south of Pullman makes determination of axial trace position for each of the folds difficult in those areas. Therefore, the axial traces illustrated are approximations.

GENERALIZED HYDROGEOLOGIC DISCUSSION

The Pullman quadrangle is an excellent example of how geologic structure and stratigraphy control ground-water resources. The contact line between Saddle Mountains and Wanapum Basalt is the approximate boundary between two different geologic areas; the northeastern and southeastern parts of the quadrangle.

The northeastern part of the quadrangle, which includes the city of Pullman, is dominated by the anticlinal high and deformation zone that has been discussed. In this part of the quadrangle domestic sources are from both Wanapum and shallow Grande Ronde wells, although the Wanapum is rarely a good domestic water supply. The interbed between the Wanapum and Grande Ronde is only a source of water in a few locations. High production wells are developed in the N1 and R2 members of the Grande Ronde and are concentrated in the Pullman area. WSU well No. 7 is the only deep well in the lower Grande Ronde and upper Imnaha. This well did not penetrate any significant high production zones below 1000 feet.

Nearly all the deep wells in the Pullman area have been successful. The producing zones typically vary in depth and stratigraphic interval from well to well and pump tests have shown that not all are interconnected on a short time basis. We conclude that the differences are due to a combination of rapid changes in thicknesses, nature of flow features, and the location of Pullman in a deformation zone. However, similar water levels indicate interconnection of Grande Ronde aquifers. Unmapped dikes in the subsurface could also play a role in the complexity of the Grande Ronde aquifers beneath Pullman. All of these features are related to the development of the anticline and deformation zone during the emplacement of the entire basalt sequence.

The lack of a consistent and dependable Wanapum aquifer in the northeastern part of the quadrangle is related to several features. The most important feature is irregular nature of the Grande Ronde-Wanapum contact which dips to the east and west from the high area. That surface and the corresponding dips of basalt units may be causing movement away from the Wanapum units. Other geologic features that may be a factor are the lack of a consistent and thick interbed between the Wanapum and Grande Ronde, and the thinning of units over the anticline.

The southeastern portion of the map area is a small part of a larger northwest-trending syncline that extends from east of Uniontown to just southeast of Colfax. Other northwest trending folds control the northwest flow of the Snake River and the Uniontown drainage system. Foxworthy and Washburn (1963) note the ground-water flow is to the northwest in this area. The pinching of the Roza and Saddle Mountains flows on the western edge of the Pullman quadrangle denotes where the Grande Ronde-Wanapum contact and underlying basalt flows must steepen towards the west and southwest, causing stratigraphic and structural control of ground-water movement.

Domestic wells in the southeastern part of the map and nearby quadrangles are in the Saddle Mountains, Priest Rapids, and Roza flows. These units are often separated by interbeds of varying thickness and composition.

The anticlinal high in the upper Grande Ronde southwest of Pullman, in conjunction with the northwest trending folds west of the anticline, are believed to be of regional significance to ground-water flow. The synclines are typically broad and the anticlines are narrow. The narrow anticlines can cause impediment to ground-water flow. Fractures in axial planes of folds can also be avenues for movement locally. Recent geochemical work shows that flow of Grande Ronde water to the Snake River from the Pullman area cannot be documented (Kent Keller, personal communication, 2003). This work substantiates the concept that the folds with northwest trends west of Pullman and in Pullman may be barriers to ground-water movement towards the southwest from Pullman and Moscow.

Foxworthy and Washburn (1963) hypothesized structures being an impediment to southwest flow via Pullman. Subsequently Barker (1979) and Brown (1976) believed there was a barrier to southwest flow from Pullman. Deformation during emplacement causing onlap and offlap of stratigraphic units along the edge of the Columbia Plateau was documented in several papers and reports in the 1970's (Bush and others, 1972; Swanson and others, 1975). Swanson and others (1980) produced a geologic map of part of the Palouse Basin that showed these stratigraphic and structural features at a 1:250,000 scale. Geohydrologic modelers later dismissed the potential of such a barrier (Lum and others, 1990).

Hanford area researchers in Washington concluded that ground-water movement generally follows the dip of the basalt units (Reidel and others, 2002). Whiteman and others (1994), discusses regional ground-water movement for the Columbia Plateau and made the same conclusion. Future ground-water models must incorporate the fact that regional dips, structures, and stratigraphic relations play a major role in ground-water movement.

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Table 1 - Wells used in Construction of Bedrock Map of the Pullman 7 ½ Minute Quadrangle, Whitman County, Washington.

Well No.	Original Owners Name	Total Depth (ft)	Overburden Thinkness (ft)	Geologic & Other Comments	Sources
W-1	L.C. Staley	206	20	Data suggests Basalt at least 200 ft. thick.	Walters & Clancy (1969)
W-2	A. Fairbanks	200	13	Base of Wanapum at 106 ft., Vantage approx. 74 ft. thick, top of Grande Ronde 180 ft.	Public Well Log
W-3	B. Wagner	308	7	Base of Wanapum at 130 ft., top of Grande Ronde 130 ft. or 235 ft.?	Public Well Log
W-4	W.S.U. Ag. Farm	335	14	Base of wanapum 205 ft., top of Grande Ronde 222 ft., well log dated at 1956.	Public Well Log
W-5	B. Boyd	285	8	Base of Wanapum at 124 ft., top of Grande Ronde at 164 ft.	Public Well Log
W-6	City Cemetery	355	Data Not Obtained	Base of Wanapum at 199 ft., top of Grande Ronde at 229 ft.	Walters & Clancy (1969)
W-7	W.S.U. Dairy	600	37	Location in Saddle Mountains. Interpretation of Wanapum base at 293 ft. and top of Grande Ronde at 373 ft. is guess-work.	Walters & Clancy (1969)
W-8	Pullman # 5	712	Data Not Obtained	Top of Grande Ronde at 132 ft.	Heinemann (1994)
W-9	W.S.U. # 7	2220	5	Top of Grande Ronde at 140 ft., stratigraphic subdivision of basalt units using chemistry in Bush & others 2001.	Bush & others (2001)
W-10	W.S.U. # 8	850	90	Top of Grande Ronde at approx. 240 ft., gravels at bottom have Tgr_{r2} chemistry.	Visual inspection of well cuttings
W-11	W.S.U. # 6	702	Data Not Obtained	Top of Grande Ronde at approx. 195 ft.	Heinemann (1994)
W-12	W.S.U.	396	11	Log suggests no interbed at Wanapum-Grande Ronde contact.	Walters & Clancy (1969)
W-13	Pullman # 7	720	15	Top of Grande Ronde at 87 ft.	Bush & others (2001)
W-14	Pullman # 6	518	Data Not Obtained	Top of Grande Ronde at 90 ft.	Heinemann (1994)
W-15	V. Michaelson	300	Data Not Obtained	Top of Grande Ronde at 177 ft.	Heinemann (1994)
W-16	J. Davis	130	25	Top of basalt at 2480 ft. in elevation.	Heinemann (1994)
W-17	P Stiener	141	80	Top of basalt at 2580 ft. in elevation.	Heinemann (1994)
W-18	O. Lee	270	Data Not Obtained	Top of Grande Ronde at 218 ft.	Heinemann (1994)
W-19	C. Carbon	155	Data Not Obtained	Top of Grande Ronde at 55 ft.	Heinemann (1994)
W-20	F. Bryant	300	Data Not Obtained	Top of Grande Ronde at 170 ft.	Heinemann (1994)