BEDROCK GEOLOGIC MAP OF THE PALOUSE 7 ½ MINUTE QUADRANGLE, WHITMAN COUNTY, WASHINGTON AND LATAH COUNTY, IDAHO

JOHN H. BUSH, CHRIS H. DUNCAN, AND DEAN L. GARWOOD

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INTRODUCTION

The bedrock geologic map of the Palouse quadrangle was constructed primarily from examination of major outcrops and water well drill logs. Much of the information was obtained from the work of Duncan (1998) and Duncan and Bush (1999). Regional maps by Swanson and others (1980) and Gulick (1994) were also used. Detailed examination of chips from the city of Palouse well No. 2, drilled in 1999, provided important information. Basalt chemistry was used to assist in the determination of stratigraphic units in the Columbia River Basalt Group (CRBG). The chemistry results used for stratigraphic correlations were reported in Duncan (1998) and Bush and others (2001). Samples were analyzed at the GeoAnalytical Laboratory at Washington State University.

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 also not shown. However, alluvium and colluvium associated with the major streams is illustrated, because their map patterns help interpret bedrock contacts and structural relationships in basalt terrains (Bush and others, 1998). Continuous outcrops are rare and contacts between basalt and the older units are covered with loess and colluvium.

The lack of deep wells on the Palouse quadrangle makes interpretations of structure difficult. Structural contour and isopach maps by Duncan (1998) and Teasdale (2002) were helpful. The most significant structural features in the CRBG are broad folds with shallow plunges. Such folds are difficult to detect without detailed mapping on a regional scale. Geologic work in recent years has shown that the basalts are much more structurally complex in the Pullman-

Moscow-Palouse area than previously thought (Bush and others, 2001, Teasdale and others, 2001; Teasdale, 2002; Bush and Garwood, 2003). Dip slopes and folds are illustrated wherever possible. It is suggested that knowledge of surrounding quadrangles be used to help understand the structural features illustrated on the Palouse quadrangle.

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 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 poorly rounded 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

The stratigraphic nomenclature of the Columbia River Basalt Group (CRBG) 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. On the Palouse quadrangle no units of the Imnaha and Saddle Mountains formations have been noted. At the surface, only outcrops of the Priest Rapids Member of the Wanapum have been identified (Duncan, 1998). The Roza Member of the Wanapum Basalt crops out to the southwest and northwest on the adjoining Albion and Elberton quadrangles, but has not been identified on the Palouse quadrangle. A Tgr_{N2} flow of the Grande Ronde was encountered in the city of Palouse well No. 2.

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 which have reverse magnetic polarity (Wright and others, 1973; and Swanson and others, 1979). The Priest Rapids basalt is exposed along the Palouse River and in quarries and road cuts throughout the quadrangle. A structural contour map of the base of the Priest Rapids by Duncan (1998) shows that the basalt rises in elevation towards exposures of pre-CRBG rocks. An isopach map of the Priest Rapids over the same area shows thickening away from basement highs (Duncan, 1998). These relations are not only a function of emplacement, but also reflect post-emplacement erosion and basining.

Five outcrops were sampled and analyzed for verification (Duncan, 1998), and are the Lolo chemical type of Wright and others (1973). Hooper and Webster (1982) note that in the Pullman area to the south, the Lolo chemical type underlies much of the area and that the Rosalia chemical type occurs locally. Distribution maps for the Priest Rapids by Swanson and others (1980) show the Palouse-Pullman area to be near the southern limit of the Rosalia flows.

One exposure within the eastern city limits of Palouse was interpreted as a potential near vent locality (Swanson and others, and 1980; Bush and Seward, 1992; Gulick, 1994). The exposure consists of two Priest Rapids flows or flow units separated by a sequence approximately 10 feet thick of highly weathered vesicular basalt, bedded quartzite-feldspar sand, and palagonite obsidian breccia. The presence of obsidian, lightweight vesicular material, and spindle-shaped scoria led Bush and Seward (1992) to agree with a near-vent interpretation, and suggested that the outcrop represents an eroded vent rampart. However, we now reinterpret the sand to represent a very short interval between two flow lobes of the same flow. The breccia below the upper flow probably formed from rapid cooling and alteration caused by contact with a water source. Chemical analyses of both flows above and below the bedded sequence show that they are both Lolo chemical type suggesting little time between their emplacements.

GRANDE RONDE FORMATION

Tgr_{N2} (Miocene) – Consists of flows of fine-grained to very fine-grained aphyric basalt. Though not exposed on the quadrangle, the Grande Ronde was interpreted by Duncan (1998) to occur beneath the Priest Rapids Member throughout much of the quadrangle. Regional maps by Swanson and others (1980), Hooper and Webster (1982), and Gulick (1994) all show the uppermost Grande Ronde flows (N2-normal polarity) beneath the Priest Rapids on nearby quadrangles. Rock chemical data from three intervals in the City of Palouse well No. 2, drilled in 1999, are similar in chemistry to the N2 of the Grande Ronde Formation (Bush and others, 2001). In that well, the upper Grande Ronde was encountered at approximately 2130 feet in elevation. A minimum of 139 feet of N2 flows was penetrated before the well was completed. The thickness of the Grande Ronde shown on the cross-sections (AB and CD) must be considered an estimate, since no data for maximum thickness exist for the Palouse quadrangle. However, it is likely that the Grande Ronde is thinner than in areas to the south and west.

Tl LATAH FORMATION (Miocene) – Consists of clay, silt, sand, and gravel deposits that range from a few feet to over 130 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 CRBG. On the Palouse quadrangle, there are several small outcrops of Latah Formation that occur between flow units of the Priest Rapids Member. Well data show that this interbed is not a continuous unit. Exposures of these interbeds were not large enough to illustrate on the map at the map scale. In the subsurface, a sequence of sediments is continuous between the lowermost Priest Rapids and uppermost Grande Ronde and reaches a maximum thickness of 131 feet in city of Palouse well No. 2. The term “Vantage Member” of the Latah Formation can be used for this unit in the Palouse and Pullman area (Siems and others, 1974; Bush and others, 1998). Although the name has been used for a sediment sequence in the Ellensburg Formation of western Washington (Swanson and others, 1979), it is not improper to use the term on the eastern edge of the basin where it is part of the Latah Formation. Where sediments associated with the basalts are not bounded by the Wanapum and Grande Ronde the more encompassing terms "Latah Formation" or "Latah interbeds" should be used.

PRE-CRBG UNITS

The pre-CRBG units on the Palouse quadrangle are difficult to subdivide due to the lack of exposures and the metamorphic and intrusive effects of the underlying rocks of the Idaho batholith. All of the units lack the ability to transmit large quantities of ground water and understanding their contact with the basalt units is important. All existing well, float, and outcrop data available were used in constructing the map and associated cross-sections. However, it must be understood that the contact lines represent a working basis for future researchers and are only approximations.

Cqk Quartzite of Kamiak Butte (Cambrian?) – Consists primarily 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. It 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 would typically be described as "clean" due to the very high percentage of quartz. Though recrystallized, inconspicuous relict bedding planes, laminations, and crossbeds are present locally. On the Palouse quadrangle, these rocks crop out only on Ringo Butte in the southeastern corner. However, similar rocks cap many buttes on surrounding quadrangles, including Kamiak Butte to the southwest on the Albion quadrangle (Gulick, 1994).

There has not been an accepted stratigraphic age for this quartzite sequence (Savage, 1973; Hooper and Webster, 1982; and Bush and Provant, 1998). Hooper and Webster, (1982) believed that they could be Cambrian in age based on their similarity to Cambrian quartzite in northeastern Washington and suggested the name "quartzite of Kamiak Butte". This report follows that suggestion. The quartzite lacks the feldspar of Belt Supergroup quartzite and field relations suggest it unconformably overlies 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).

BELT SUPERGROUP

Pl Libby Formation (Precambrian) – On the Palouse quadrangle, this formation consists primarily of quartzite with minor siltite and argillite. The unit is best exposed on the top of Ladow Butte in the northern part of the quadrangle. Outcrops are poor and dominated by quartzite, but in places light colored argillite and siltite are interbedded with the quartzite. Griggs (1973) placed the rocks along the northern border of the Palouse quadrangle in the Striped Peak Formation of the Belt Supergroup. In this report they are considered to belong to the Libby Formation. In either case they belong to the upper part of the Belt Supergroup. They differ from the Cambrian? units in that the quartzite is not "clean" and the very high percentage of interbedded "Belt-like" siltite and argillite.

Pasp Argillite, siltite, and phyllite (Precambrian) – Consists of greenish gray argillite and light gray siltite with minor micaceous phyllite in places. Relict bedding consists of alternating light gray siltite and dark gray argillite laminations and microlaminations. Gulick (1994) noted two occurrences to the west on the adjoining Elberton quadrangle. From those occurrences, the unit was mapped into the western edge of the Palouse quadrangle by examining small exposures, float, and shallow water well data. This sequence and the quartzite unit exposed on Kamiak Butte located to the southwest form a pre-CRBG high that the Palouse River flows around to the north-northwest. The laminations and microlaminations of this unit are typical of the Belt Supergroup throughout nearby northern Idaho.

Pgasq Gneiss, argillite, siltite, and quartzite (Precambrian) – This unit consists of interlayered units of gneiss, argillite, siltite, and quartzite. These rocks crop out in the vicinity of Viola Ridge in the southeastern part of the quadrangle. Most of the exposures in the southwestern part of section 18, (T41N, R.6W) consist of gneiss with minor siltite. A dark laminated argillite unit is exposed in the very northeastern part of section 18 along the Palouse River. These outcrops extend eastward into the adjoining Potlatch quadrangle were they are best exposed. The laminated unit is believed to belong to the Belt Supergroup, but its relation to the other units is not clear. Quartzite float is common on Viola Ridge. These rocks were combined due to the lack of exposures and our inability to subdivide and correlate them to any specific unit.

GENERAL GEOLOGIC DISCUSSION

The Palouse quadrangle is located on a regional westward-tilted block of the CRBG along the eastern edge of the Columbia Plateau referred to as the Palouse Slope (Reidel and others, 2002). However, the basalt units dip away from pre-CRBG rocks and form a shallow basin with its center near the city of Palouse. The northern boundary of this basin is defined by a ridge of Belt Supergroup rocks that extends westward from Latah and Benewah counties in Idaho. The southern boundary is defined by a ridge of several different pre-CRBG rock units that also extend westward from Idaho. This southern ridge is overlain by the Priest Rapids Member between Ringo Butte (Palouse quadrangle) and Angel Butte (Viola quadrangle) on the east and Kamiak Butte on the west (Albion quadrangle). The depth of the basalt in the gap area is not well known, gravity data suggests the presence of only Wanapum Formation and Miocene sediments (Holom, 2006). The primary rock that is exposed on the ridges is quartzite. However, the basement rock in the gap area is interpreted to be part of the Pasp or Pgasq units. The quartzite of Kamiak Butte appears to overlie these units and dips steeply in a southerly direction. The nature of this contact is not known, but is interpreted to be an unconformity between Cambrian and Precambrian rocks.

The western edge of the basalt basin on the Palouse quadrangle is defined on its southwestern edge by a north-south-trending series of low-lying topographic ridges that consist of poorly exposed phyllite, argillite, and schist on the adjoining Elberton quadrangle. These rocks extend northeastward from Kamiak Butte for over three miles and are crossed by the Palouse River, which flows northeastward around these exposures before turning southwest towards Colfax. Although overlain by both the Priest Rapids and Grande Ronde Basalt, there is considerable evidence for a continuation of this ridge to the north forming part of the western edge of an internal "Palouse" basin. The top of the Grande Ronde surface rises slightly (150 feet) to the west and forms a high between the towns of Elberton and Palouse. The Roza flow pinches out against this rise and an outcrop of pre-CRBG rocks is present in the middle of the basalt along the high.

The eastern edge of the internal basin on the Palouse quadrangle is located near the north-south-trending Highway 95 (approximately 7 miles east of Palouse) on the Potlatch quadrangle in Idaho where the Priest Rapids flows pinch out against the pre-CRBG Onaway basalt. Most of the wells in the eastern end of this basin are in the Priest Rapids or the top of the Vantage interbed and, therefore, the true nature of the subsurface in the eastern part of the basin is not known.

The basalt basin on the Palouse quadrangle is crossed by at least three northwest-trending folds. The city of Palouse is interpreted to be located in the center of a syncline bounded on the west and east by monoclinal features. The evidence for this structure is the thick Vantage interbed in the center of the syncline, the low elevation of the Grande Ronde top, the sharp northwest turn of the Palouse River, isopach, and structural contour maps by Duncan (1998), and sedimentation patterns of modern drainages.   Bush and others (1998) previously noted the sedimentation patterns of Palouse River, Duffield Creek, and Cedar Creek define a northwest-trending structure.

GENERAL HYDOGEOLOGIC DISCUSSION

The domestic water resources of the Palouse quadrangle are easily understood. The best domestic wells occur almost entirely in the Priest Rapids Member of the Wanapum Formation and the underlying Vantage Member of the Latah Formation. There are very few wells in the pre-CRBG units and those that do exist have very low capacity. The water supply in the Wanapum and underlying interbeds is consistent and productive across much of the quadrangle and for that reason there are a lack of deep wells across the quadrangle is very little information on the underlying Grande Ronde.

The city of Palouse well No. 2 is a high production well that is located in the upper 139 feet of the Grande Ronde. The elevation on top of the Grande Ronde (2161 feet) is lower than Pullman wells and lower than the upper Grande Ronde to the west. As noted earlier, the city is located in a syncline which probably explains the high production at shallow depths.

In terms of ground-water movement, some interpretations can be made. The primary movement is likely to be towards the basin centered near the city of Palouse. Part of this pattern would be western flow following the Palouse River from its upper drainage areas in Idaho. The eastward dipping basalt units near the western boundary could be causing eastward flow although the Palouse River is flowing westward. It is not uncommon for ground-water movement in the Grande Ronde of the Columbia Plateau to be opposite the direction of stream flow (Whiteman and others, 1994).

The nature of ground-water flow through the gap on the southwestern part of the quadrangle is not well understood. Work by Holom (2006) suggests the lack of a hydrologic connection through this gap. The top of the Grande Ronde surface in Palouse is low in comparison to surrounding areas. The interpretation is that ground-water movement in the upper Grande Ronde is north from the gap into the Palouse River were it meets east-west flow from Idaho and then continues to the west through Elberton.

REFERENCES CITED

Bush, J.H. and D.L. Garwood, 2003, Interpretation and use of well data in the Columbia River Basalt Group, Pullman, Washington: Geological Society of America Abstracts with programs, vol. 34, no. 7, p. 551.

Bush, J.H., and A.P. Provant, 1998, Bedrock Geologic Map of the Viola Quadrangle, Latah County, Idaho and Whitman County, Washington: Idaho Geological Survey, Geologic Map 25, scale 1:24,000.

Bush, J.H., and W.P. Seward, 1992, Guide to the Columbia River Basalts in the Moscow-Pullman area: Idaho Geological Survey Informational Circular 49, 35 p.

Bush, J.H., D.L. Garwood, W.L. Oakley III, and T.W. Erdman, 2001, Geological Report for Pullman City Well No. Seven: Report for City of Pullman, Washington, 34 p.

Bush, J.H., R.M., Breckenridge, K.L. Othberg, and C.H. Duncan, 1998b, Paleogeomorphic evolution of the Columbia River Basalt embayments, western margin of the northern Rocky Mountains: Part III, Holocene drainage control by Miocene basalts: Geological Society of America Abstracts with programs, vol. 30, no. 6, p. 6.

Duncan, C.H., 1998, Geology of the Potlatch and Palouse 7 ½ Minute Quadrangles, Idaho and Washington: M.S. Thesis, University of Idaho, 98 p.

Duncan, C.H., and J. H. Bush, 1999, Bedrock Geologic Map of the Palouse Quadrangle, Whitman County, Washington, and Latah County, Idaho: Idaho Geological Survey Technical Report 99-7, scale 1:24,000.

Ellis, J.R., M.C. Pope, W.C. McClelland, and J.D. Vervoort, 2004, Quartzite buttes in the Palouse region, SE Washington; their relationship to the Belt Basin on the basis of U-Pb LA-ICPMS detrital zircon data: Geological Society of America Abstracts with programs, vol. 36, no. 4, p. 7.

Gulick, C.W., 1994, Geologic Map of the Pullman 1:100,000 Quadrangle, Washington-Idaho: Washington Division of Geology and Earth Resources Open-File Report 94-6.

Griggs, A.B., 1973, Geologic Map of the Spokane Quadrangle, Washington, Idaho, and Montana: U.S. Geological Survey Miscellaneous Investigations, Map I-768, scale 1:125,000.

Holom, D., 2006, Ground water flow conditions related to the pre-basalt basement geometry delineated by gravity measeurements near Kamiak Butte, Eastern Washington: M.S. Thesis, University of Idaho, 84 p.

Hooper, P.R., and G.D. Webster, 1982, Geology of the Pullman, Moscow West, Colton, and Uniontown 7 ½ minute quadrangles, Washington and Idaho: State of Washington, Department of Natural Resources, Division of Geology and Earth Resources Geologic Map GM-26, scale 1:62,000.

Reidel, S.P., V.G. Johnson, and F.A. Spane, 2002, Natural Gas Storage in Basalt Aquifers of the Columbia Basin, Pacific Northwest USA: A Guide of Site Characterization, Pacific Northwest National Laboratory, Richland, Washington, 550 p.

Savage, C.N., 1973, A geological field trip in Benewah and Whitman counties, Idaho and Washington, respectively, *in* Belt Symposium, v. 1: Idaho Bureau of Mines and Geology, p. 253-307.

Siems, B.A., J.H. Bush, and J.W. Crosby III, 1974, TiO_2 and geophysical logging criteria for Yakima Basalt correlation, Columbia Plateau: Geological Society of America Bulletin, vol. 85, p. 1061-1068.

Swanson, D.A., T. L. Wright, P.R. Hooper, and R.D. Bentley, 1979, Revisions in stratigraphic nomenclature of the Columbia River Basalt Group: U.S. Geological Survey Bulletin 1457-G, 59 pp.

Swanson, D.A., T.L. Wright, V.E. Camp, R.T. Helz, S.A. Price, and M.E. Ross, 1980, Reconnaissance geologic map of the Columbia River Basalt Group, Pullman and Walla Walla quadrangles, southeast Washington and adjacent Idaho: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-1139, scale 1:250,000.

Teasdale, E.W., 2002, Hydrogeologic Sub-Basins in the Palouse area of Idaho and Washington, M.S. thesis: University of Idaho, 63 p.

Teasdale, E.W., J.H. Bush, and D.L. Garwood, 2001, Evidence for Structural Partitioning of Ground Water Resources in Moscow, Idaho Pullman, Washington and surrounding areas (abs.): American Geophysical Union Fall Meeting 2001, San Francisco, CA.

Whiteman, K.J., J.J. Vaccaro, J.B. Gonthier and H.H. Bauer, 1994, The Hydrogeologic Framework and Geochemistry of the Columbia Plateau Aquifer System, Washington, Oregon, and Idaho, U.S. Geological Survey Professional Paper 1413-B, 73 p.

Wright, T. L., M. J. Grolier, and D.A. Swanson, 1973, Chemical variation related to the stratigraphy of the Columbia River basalt: Geological Society of America Bulletin, vol. 84, no. 2, p. 371-385.

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

Well No.	Original Owners Name	Total Depth (ft)	Overburder Thinkness (ft)	Geologic & Other Comments	Sources
W-1	J. Cochran	125	1	Drill hole in weathered pre-basalt material, useful to estimate contact location.	Duncan (1998)
W-2	B. Wolterings	180	23	Drill hole in weathered pre-basalt material, useful to estimate contact location.	Duncan (1998)
W-3	D. Scoville	80	64	Top of Priest Rapids at 2566 ft. elevation.	Duncan (1998)
W-4	J. Kerns	190	47	All weathered pre-basalt rocks.	Duncan (1998)
W-5	R. Parson	103	34	Top of Priest Rapids at 2536 ft. elevation.	Duncan (1998)
W-6	J. Leendersten	230	6	Top of Grande Ronde at approx. 230 ft., Vantage member at least 56 ft. thick.	Duncan (1998)
W-7	B. Dawdy	103	21	Top of Grande Ronde at approx. 2414 ft. in elevation.	Duncan (1998)
W-8	D. Schoepflin	300	58	Vantage member at least 44 ft. in thickness.	Duncan (1998)
W-9	B. Reiber	205	25	Vantage member at least 17 ft. in thickness.	Duncan (1998)
W-10	T. Boone	180	14	Vantage member at least 20 ft. in thickness.	Duncan (1998)
W-11	D. Rogers	375	15	Pre-basalt estimated at 2189 ft. in elevation.	Duncan (1998)
W-12	Q. Hellinger	230	22	Top of Priest Rapids 2513 ft. in elevation.	Duncan (1998)
W-13	E. Schill	55	11	Top of Priest Rapids 2464 ft. in elevation.	Duncan (1998)
W-14	Zakarison	130	106	Top of Priest Rapids 2514 ft. in elevation.	Duncan (1998)
W-15	S. Parish	220	61	Vantage member at least 24 ft. in thickness.	Duncan (1998)
W-16	J. Dunning	240	31	Vantage member at least 95 ft. in thickness.	Duncan (1998)
W-17	A. FlannBurg	233	51	Top of Priest Rapids 2544 ft. in elevation.	Duncan (1998)
W-18	Siebert	185	3	Example of interbed between Priest Rapids basalt, possible pre-basalt at 165 ft.	Duncan (1998)
W-19	Hodson	220	22	Base of Priest Rapids at 206 ft.	Duncan (1998)
W-20	A. Burns	212	83	Priest Rapids at least 212 ft. thick.	Duncan (1998)
W-21	D. Schoepflin	255	29	Base of Priest Rapids at 250 ft.	Duncan (1998)
W-22	Shoemaker	421	90	Possible Grande Ronde top at 270 ft.	Duncan (1998)
W-23	A. Barabasz	255	13	Base of Priest Rapids at 218 ft.	Duncan (1998)
W-24	Lay	280	84	No basalt, well begins and ends in pre-basaltrocks.	Duncan (1998)
W-25	Standar	128	14	No basalt, well begins and ends in pre-basaltrocks.	Duncan (1998)
W-26	B. Beeson	135	37	Priest Rapids basalt at least 100 ft. thick.	Duncan (1998)
W-27	City of Palouse	458	3	Priest Rapids 3 - 188 ft. Vantage 188 - 319 ft., weathered Grande Ronde 318 - 395 ft., Grande Ronde 395 - 458 ft.	Visual inspection of well cuttings