Basalt lava stratigraphy beneath Pullman and Moscow: implications for the flow of groundwater

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ABSTRACT

Pullman and Moscow sit atop many hundreds of feet of 14-16 million year old basalt lava flows, and the water supplies for both cities depend upon groundwater stored in and between the basalt layers. Advances have been made in understanding the amount of water present and the very slow recharge rate of the buried aquifers (groundwater levels decline 1.5 feet per year). However, little is known of the sub-surface paths of groundwater flow chiefly because the layering and structure of the basalt layers is poorly known.

Recently the WSU GeoAnalytical Lab has recovered the glass pellets analyzed by our lab over 30 years ago when many of the existing Pullman, WSU, and UI water wells were drilled and the layers encountered were sampled. Because no agency stores the drill chips from water wells these pellets are the only remaining physical records of the basalts encountered. Re-analysis of the pellets (we still use the same basic method) with modern spectroscopy has allowed us to better understand the basalt formations.

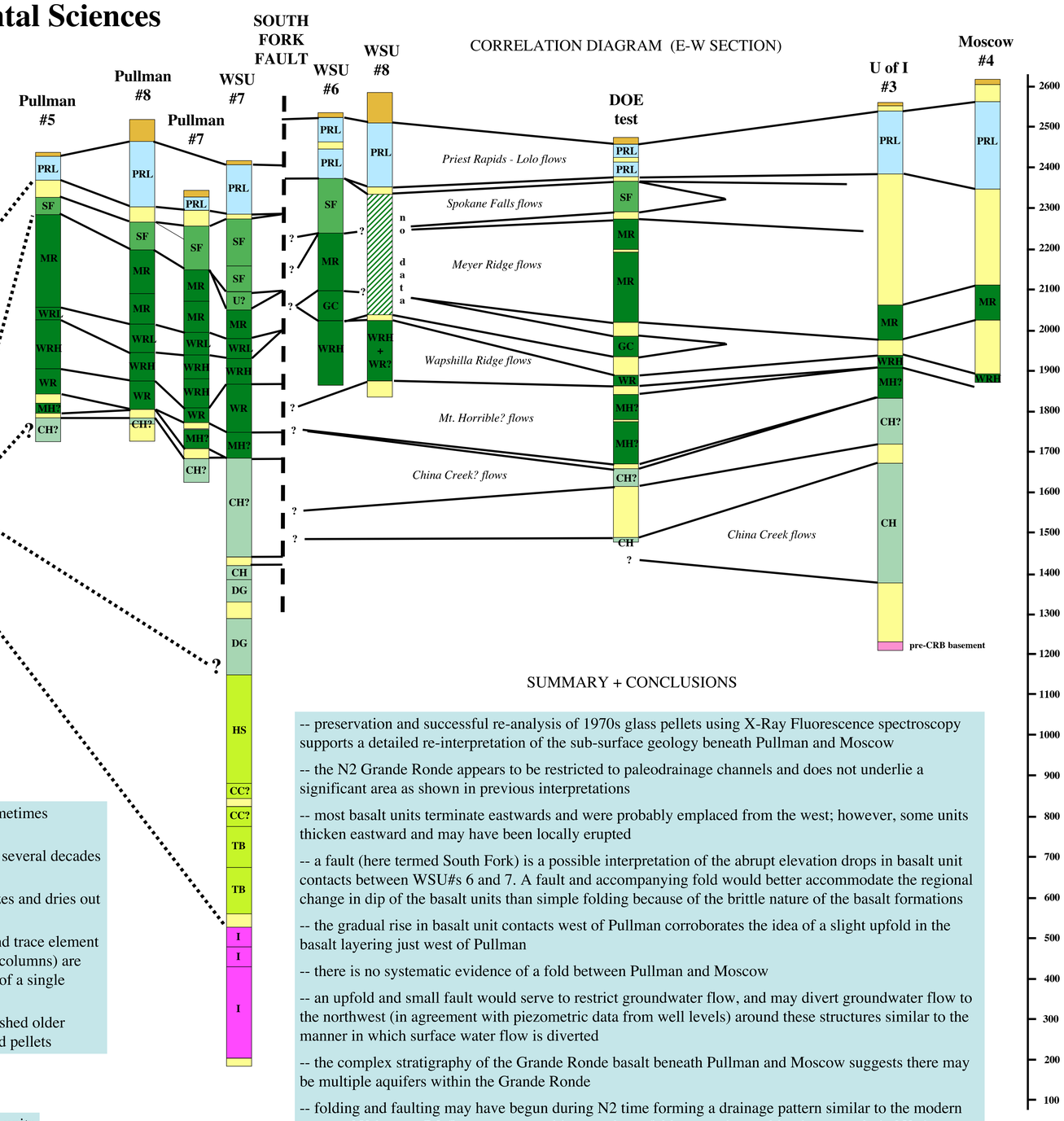
The results of our re-analysis corroborate the idea of a slight upfold in the basalt layering just west of Pullman, and the possibility of a small fault beneath WSU. Both structures would serve to restrict groundwater flow, and may divert groundwater flow to the northwest around the nose of the fold similar to the manner in which surface water flow is diverted. Folding may have developed during emplacement of the some of the younger basalt units.

Stratigraphy of the Columbia River Basalt

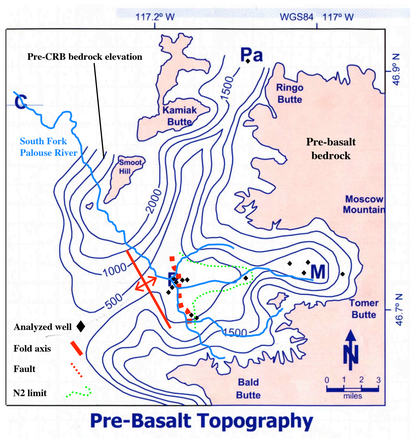
			Magnetic polarity unit**
Saddle Mountains basalt	Priest Rapids member	PRL	
Wanapum basalt	Roza member		
	Frenchman Springs member		
	Eckler Mountain member		
Grande Ronde basalt	Sentinel Bluffs unit	SF	*N2*
	Slack Canyon unit		
	Field Springs unit		
	Winter Water unit		
	Umtanum unit	U	
	Ortley unit		
	Armstrong Canyon unit		
	Meyer Ridge unit	MR	*R2*
	Grouse Creek Unit	GC	
	Wapshilla Ridge unit	WR, WRH, WRL	
	Mt. Horrible unit	MH	
	China Creek unit	CH	*N1*
	Downey Gulch unit	DG	
	unnamed High-Si unit	HS	
	Center Creek unit	CC	*R1*
	Rogersburg unit		
	Teepee Butte unit	TB	
Imnaha basalt	Buckhorn Springs unit	I	

** Magnetic polarity units are based upon magnetic directions recorded in lava. As lava cools through the Curie Point the magnetic domains of Fe- and Ti-oxide minerals grown in the cooling lava align parallel to the prevailing direction of the Earths magnetic field. The field frequently reverses itself, providing a physical time scale for cooled lava. Four polarity units are known in the Grande Ronde basalt: N1 and N2 similar in (*normal*) polarity to the modern field, and R1 and R2 of opposite (*reversed*) polarity.

CORRELATION DIAGRAM (E-W SECTION)



LOCATION MAP



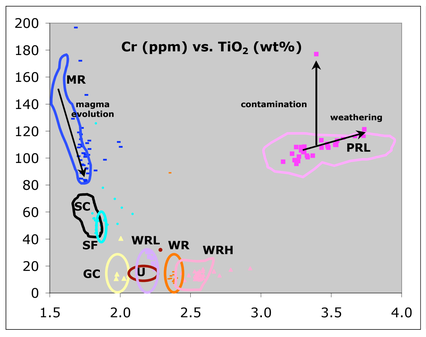
Sample	PW7-25	UIWT 17S	UIWT 20A	UIWT 20B
bead age	new	old	old	old
SiO2	50.28	50.05	55.14	55.17
TiO2	3.25	3.24	2.59	2.59
Al2O3	13.54	13.70	14.10	14.11
FeO*	13.55	13.59	11.78	11.74
MnO	0.23	0.22	0.19	0.19
MgO	5.05	5.30	3.17	3.17
CaO	9.22	9.16	7.38	7.38
Na2O	2.75	2.62	2.90	2.91
K2O	1.11	1.10	1.90	1.92
P2O5	0.77	0.76	0.52	0.52
Ni	44	45	15	15
Cr	96	98	18	16
Sc	39	38	33	33
V	374	370	402	406
Ba	544	540	938	931
Rb	27	27	81	81
Sr	290	296	352	351
Zr	194	197	207	208
Y	45	45	43	43
Nb	16	16	15	14
Ga	19	20	22	20
Cu	45	51	32	34
Zn	148	149	146	146
Pb	8	9	8	9
La	28	34	31	35
Ce	57	60	62	67
Th	7	6	4	5
Nd	36	37	33	35
U	1	1	1	2

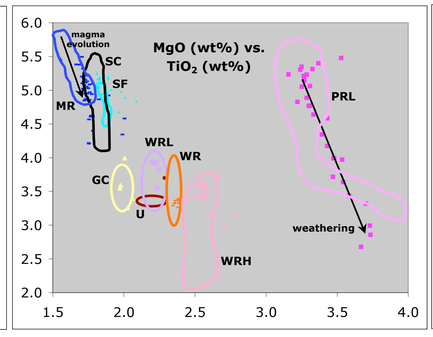
OLD VS. NEW PELLETS

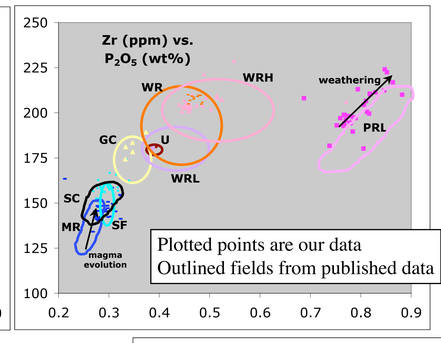
- 1970s pellets were singly fused and the flux used was sometimes contaminated with particles rich in Cr and Ni
- Older pellets (picture left) become slightly hydrated after several decades of storage
- Cleaning, regrinding to powder, and re-fusion homogenizes and dries out the glass (picture right)
- Comparison of analyses (major element oxides in wt% and trace element concentrations in ppm) of older and newer pellets (first two columns) are typically within analytical uncertainty for multiple analyses of a single basalt unit
- Analytical reproducibility (two columns right) of re-furbished older pellets is excellent, comparable to newer fluxed doubly fused pellets

CHEMICAL DISCRIMINATION OF COLUMBIA RIVER BASALT FLOWS

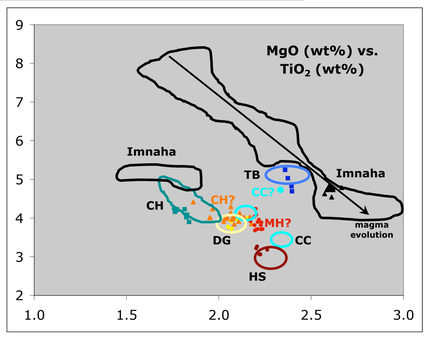
- The chemical composition of Columbia River basalt determined using X-Ray Fluorescence methods can often be used to discriminate flow units
- Compositional variation is not always diagnostic because of similarities between some units and incomplete knowledge of the total variation
- Compositions can be affected by surface weathering, and some of the older pellets are contaminated with Cr and Ni (flux impurities)
- In this case we were able to discriminate much of the stratigraphy, especially in the uppermost layers, but some questions remain
- The primary uncertainties are in the depths of the R1-N1 and N1-R2 transitions, where chemical discriminants are not completely diagnostic







- Prior workers suggested that much more N2 Grande Ronde basalt is present, especially the N2 Stember Creek (SC) sub-unit of the Sentinel Bluffs; we identify the alleged SC flows as R2 Meyer Ridge based upon their Cr content
- Strong evidence for surficial weathering (which requires significant time to develop) is found as deep as the lower R2 and may be present as low as the R1. Weathering of and sediment deposition between units is consistent with the spotty nature of the basalt section beneath our area, which is at the edge of the basalt plateau and only received the larger regional flows or those locally derived
- Regionally, some units are highly variable due to magmatic evolution, however, such variation is rather limited beneath Pullman and Moscow
- Discrimination of N1 Downey Gulch (DG) and China Creek (CH) units is difficult due to interbedding of the two compositional types
- The HS unit may be chiefly N1 and not R1 as depicted



SUMMARY + CONCLUSIONS

-- preservation and successful re-analysis of 1970s glass pellets using X-Ray Fluorescence spectroscopy supports a detailed re-interpretation of the sub-surface geology beneath Pullman and Moscow

-- the N2 Grande Ronde appears to be restricted to paleodrainage channels and does not underlie a significant area as shown in previous interpretations

-- most basalt units terminate eastwards and were probably emplaced from the west; however, some units thicken eastward and may have been locally erupted

-- a fault (here termed South Fork) is a possible interpretation of the abrupt elevation drops in basalt unit contacts between WSU#s 6 and 7. A fault and accompanying fold would better accommodate the regional change in dip of the basalt units than simple folding because of the brittle nature of the basalt formations

-- the gradual rise in basalt unit contacts west of Pullman corroborates the idea of a slight upfold in the basalt layering just west of Pullman

-- there is no systematic evidence of a fold between Pullman and Moscow

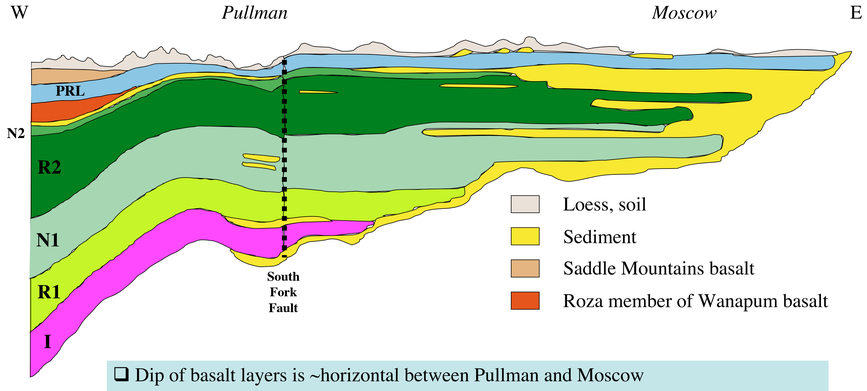
-- an upfold and small fault would serve to restrict groundwater flow, and may divert groundwater flow to the northwest (in agreement with piezometric data from well levels) around these structures similar to the manner in which surface water flow is diverted

-- the complex stratigraphy of the Grande Ronde basalt beneath Pullman and Moscow suggests there may be multiple aquifers within the Grande Ronde

-- folding and faulting may have begun during N2 time forming a drainage pattern similar to the modern pattern; N2 but not R2 flows appear to thin over the upfold suggesting arching began early in N2 time

-- detailed study of hydrogeologic problems in Columbia River basalt is possible only by preservation and analysis of well cuttings

GENERALIZED E-W GEOLOGIC CROSS SECTION



- Dip of basalt layers is ~horizontal between Pullman and Moscow
- West of Pullman the regional dip of the basalt is westward
- The change in dip beneath Pullman may be accomodated by both folding and faulting
- Roza member and Saddle Mountains basalt were unable to spread to the Pullman area
- Apparent thinning of N2 (and Lolo?), but not R2, over the upfold suggests folding began during early N2 time

ACKNOWLEDGEMENTS

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