

Proposal for Geologic Map Updates and New Work for the Palouse Basin

Submitted to the Palouse Basin Aquifer Committee
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February 16, 2016

Premise

There are numerous hydrological tests, studies, and observations that are used to understand the complexities of an aquifer system. Those complexities are controlled, in part, by the rocks and architecture of the rock units. Both the upper and lower aquifer systems in the Palouse Basin are comprised of a three-dimensional mosaic of interbedded units of sediments and basalts. In addition, both the basalts and the sediments contain internal lateral and vertical changes. The better the understanding of these geologic relationships the more reliable the interpretations of the hydrologic data.

Previous Geologic Work

Prior to 1995, the Palouse Basin subsurface was modeled primarily as horizontal basalt flows with local sequences of sediments in the Moscow area. The basalt flows were considered to be overlain throughout the basin by loess. Geologic research by Brown (1976), Swanson and others (1980), and Hooper and Webster (1982) was rarely incorporated into the geologic thinking.

In the early 1990s, the Palouse Basin Aquifer Committee (PBAC) funded summer salaries of two students to work on four 1:24,000-scale geologic maps covering the eastern end of the basin, and the Idaho Geological Survey subsequently published the four maps for the Moscow West (Bush, Provant and Gill, 1998), Robinson Lake (Bush, Pierce and Potter, 1998), Moscow East (Bush, Pierce and Potter, 2000), and Viola quadrangles (Bush and Provant, 1998). In 2002–2003, PBAC funded student irregular help to collect data for John Bush and Dean Garwood. From that work numerous geologic cross sections and five 1:24,000-scale geologic maps and reports for the Albion (Bush and Garwood, 2005a [2006]), Pullman (Bush and Garwood, 2005b [2006]), Palouse (Bush, Duncan and Garwood, 2005 [2006]), Colfax North (Bush, Garwood and Oakley, 2005 [2006]), and Elberton (Bush, Garwood and Halver, 2005 [2006]) quadrangles were constructed. In addition, a preliminary subsurface topographic map of the top of the Grande Ronde Basalt was produced (Bush and Garwood, 2005c). These 1995–2006 maps, reports, and cross sections presented new ideas, such as the sediments

of Bovill positioned between the loess and basalt, irregular contacts, and correlation of Grande Ronde units. These products have become the geologic basis for subsequent hydrological studies and thinking. Figure 1 illustrates the location of our maps with respect to the 1:24,000-scale topographic quadrangles in the Palouse Basin.

In the past five years, Rick Conrey at Washington State University has refined the east-west stratigraphic cross sections from Moscow to Pullman (Conrey and Wolff, 2010), expanded on the structural concepts (Conrey and Crow, 2014; Crow and Conrey, 2014), and identified stratigraphic contacts (contacts of basalt and sediment sequences) in the Washington Department of Ecology monitoring wells completed in 2012 (Conrey and others, 2013). Conrey made several presentations to PBAC between 2010 and 2014 to explain his results.

Many new water wells have been drilled since 2005 when the last of the geologic maps were constructed by Bush and his students for PBAC. Locations for all known wells are being tabulated by PBAC at the present time. We have reviewed about 250 well logs and incorporated our findings into a geologic road guide being published (by the Geological Society of America in May of 2016) that correlates the Conrey data to surface exposures for the upper Grande Ronde and Wanapum basalts. The road guide also discusses the hydrological implications of those correlations for the upper aquifer.

Proposed Work

Our proposal consists of four parts. First, in Part 1, we propose to prepare a file of at least 125 well logs, located by latitude and longitude, with up-to-date geologic data and interpretations in a geographic information system (GIS) that also would be useable in Google Earth. Second, in Part 2, we propose to revise the five geologic maps along with accompanying cross sections and reports that are currently available on the PBAC Web page. Third, from the data organized in Part 2, we propose to construct ten new geologic cross-sections (for Part 3). Fourth, from all of these data we propose to construct a paleotopographic map on the top of the Grande Ronde Basalt for much of the Palouse Basin (for Part 4).

All of the proposed work is interconnected, however, the products are expected, in general, to be completed in sequence, as listed below, in the Deliverables section. Instead of the usual grant procedure, if PBAC is interested, we prefer payment for Parts 2, 3, and 4 when the products are finalized and accepted. And payment for Part 1 would be for each group of 25 well files completed, as five products. Discussion of products and costs are provided below.

Deliverables

Part 1. Well Location and Consolidation of Geologic Information

We have reviewed the status of the well log and geologic information over the last six months. We were assisted by Steve Robischon and also made considerable use of the PBAC Web page. PBAC has improved their data base 1,000-fold in the last decade, especially on government wells, but the information needed to perform further geologic work at acceptable and improved levels is very difficult to obtain. Some of the difficulties we have encountered are listed below.

- Township and Range data on drillers' logs are unreliable.
- Rock information on drillers' logs can be very useful, misleading, or of no use at all. Thus, an expert in basalt stratigraphy and the local geology needs to examine each log.
- Computer-generated locations (using the centroid of the Public Land Survey System location, with respect to closest known elevation, if provided) of wells has provided thousands of potential wells for analysis, but many are based on poor, original location data.
- After considerable sorting, a small percentage of wells with useful data can be found, but for roughly half of these the error in vertical elevation data is often greater than the ± 20 ft needed to do proper geologic correlations.
- Geologic data for many wells are scattered amongst various cross-sections, consulting and government well reports, theses, and publications. It is rare to find all of this information in one document for any one well.
- Much of the well data tabulated in University of Idaho and Washington State University theses is incomplete, and many of the well logs that were used in the students' works are no longer available, not even in the state data bases.
- Some government well reports did not properly identify the basalt units.

We have concluded that, before proceeding to the work proposed in Parts 3 and 4, at least 125 useful wells need to be properly located, and that associated geologic research and interpretations should be centralized with the location data in one file. As about 40 wells are government wells, the data already available from PBAC will make this part of the compilation possible without having to do field work and extensive computer work. However, the remaining wells are domestic, and we estimate that field and computer work to incorporate good geologic data for 85 will be extensive. We will sort through the well logs, select important ones, and provide stratigraphic interpretations. The next step will be locating the wells. Some can be located by cross checking theses, reports, and maps. Others will require onsite visitations.

Five interim products for Part 1 would be delivered, one at a time for payment, to each include (1) a file of 25 wells with longitude and latitude (x, y coordinates) and a vertical (z coordinate) for elevation (within ± 20 ft), with all references to geologic work included, for use in a GIS, and (2) associated PDF files with the original well log, as well as a typed version

with geologic interpretations. These data will be provided in a file geodatabase for use in ArcGIS and in shapefile format for use in GoogleEarth. The well logs with interpretations will also be provided as standalone PDF file(s).

The five datasets then will be combined into one for a final set of deliverables for 125 wells. We believe an initial database of 125 wells will be sufficient to fulfill the work effort proposed in Parts 2, 3 and 4, and to provide a starting point for a future effort to continue adding well data and updating interpretive products.

Special Note: Locating wells is time consuming. Our experience indicates that finding and recording coordinates for wells, on average, requires one day for every two wells. This includes time spent making personal contacts with owners.

Cost: \$37,500.00, at \$7,500 per set of 25 wells, for 5 sets of well files.

Part 2. Revision of Geologic Maps

Five geologic maps are currently served on the PBAC Web page for the Albion, Pullman, Palouse, Colfax North, and Elberton 1:24,000-scale quadrangles. Structural symbols, cross sections, and report need to be revised for these maps to incorporate new data, including the work of Rick Conrey. With the exception of Colfax North, no new field work and (or) analytical geochemistry will be performed. Mapped extent of rock units on the Colfax North quadrangle may need to be updated. The products will be delivered as Portable Document Format (PDF) files to replace the ones currently available.

Cost: \$7,000.00

Part 3. Construction of New Geologic Cross Sections

We believe that at least ten more geologic cross sections could be drawn. They would provide considerable insights into the three-dimensional aspects of the Palouse Basin once a major portion of the work outlined in Part 1 is completed. Some block diagrams will also be constructed to help visualize the subsurface in three dimensions. Figure 2 shows both existing cross sections and approximate locations of the proposed new cross-sections. A few of the new cross sections would be at a greater resolution than the existing ones, especially in areas of hydrological interest. All products will be delivered as PDF files.

Cost: \$9,000.00

Part 4. Subsurface topographic map of the top of the Grande Ronde Basalt

We are presently updating the existing preliminary subsurface topographic map (Bush and Garwood, 2005c), currently available from PBAC's Web page, as part of our research connected to preparation of a geologic field guide for the Geological Society of America meeting in May 2016 and this proposal. The initial map was produced in 2005 and is being used by numerous workers to determine actual depth to the Grande Ronde. The problem is that the first map was an "arm wave" type of map for thinking purposes only and many of the control points were not field checked. We believe a revised map of the subsurface topography is an important and useful map that we can provide to PBAC. A good working map would use the well data gathered in Part 1 and averaged data for clusters of other wells. For this type of map, once the 125 control points are in the system, other well logs can be used to ascertain if the geologic interpretations follow regional trends, thereby increasing the accuracy and reliability of the map.

The map will be provided as a PDF file; well logs with geologic interpretations will be provided as a PDF file; well site and geologic downhole data will be provided in ArcGIS formats (file geodatabase and shapefiles) for use in a geographic information system (GIS) and in Google Earth Pro.

Cost: \$9,500.00

Total Cost

The total cost of all products is \$62,500. Payment for each product would be made at time of acceptance of the delivered item.

For Part 1, five sets of products will be delivered at a cost of \$7,500 per group of 25 well log files with the first delivery about July 2016 and the last by July 2017. For Parts 2, 3, and 4, three sets of products will be delivered. We expect the products for Parts 2 and 3 to be completed by December 2016 and those for Part 4 by March 2017.

Staff expertise

We are not a consulting firm, but we have a rare mixture of basalt expertise and computer abilities and are affiliated with the University of Idaho (Bush), Spokane Community College (Garwood), and the U.S. Geological Survey (Dunlap). A considerable portion of Bush's and Garwood's experience is in the Pullman-Moscow area; Dunlap's is in database design and geographic information systems (GIS) with respect to minerals around the world and digital

geologic maps. Our curricula vitae are included herewith; you will see that we have the experience to do this work.

References Cited

Brown, J.C., 1976, Well construction and stratigraphic information—Pullman Test and Observation Well, Pullman, Washington: Pullman, Wash., Washington State University, College of Engineering Research Report 76/15-6, 35 p.

Bush, J.H., Duncan, C.H., and Garwood, D.L., 2005 [2006], Bedrock geologic map of the Palouse 7.5-minute quadrangle, Whitman County, Washington, and Latah County, Idaho: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, [11] p., scale 1:24,000. (Also available at <http://www.webpages.uidaho.edu/pbac/GeologicMaps/palouse.pdf> and at http://www.webpages.uidaho.edu/pbac/GeologicMaps/PALOUSE_DESCRIPTION.pdf.)

Bush, J.H., and Garwood, D.L., 2005a [2006], Bedrock geologic map of the Albion 7.5-minute quadrangle, Whitman County, Washington, and Latah County, Idaho: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, [12] p., scale 1:24,000. (Also available at <http://www.webpages.uidaho.edu/pbac/GeologicMaps/albion.pdf> and at http://www.webpages.uidaho.edu/pbac/GeologicMaps/ALBION_DESCRIPTION.pdf.)

Bush, J.H., and Garwood, D.L., 2005b [2006], Bedrock geologic map of the Pullman 7.5-minute quadrangle, Whitman County, Washington, and Latah County, Idaho: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, [13] p., scale 1:24,000. (Also available at <http://www.webpages.uidaho.edu/pbac/GeologicMaps/pullman.pdf> and at http://www.webpages.uidaho.edu/pbac/GeologicMaps/PULLMAN_DESCRIPTION.pdf.)

Bush, J.H., and Garwood, D.L., 2005c, Preliminary structural contour map on the upper Grande Ronde surface in the Palouse Basin of Idaho and Washington: Moscow, Idaho, Palouse Basin Aquifer Committee, scale about 1:100,000. (Also available at http://www.webpages.uidaho.edu/pbac/GeologicMaps/100k_struct_contour.pdf.)

Bush, J.H., Garwood, D.L., and Halver, B.A., 2005 [2006], Bedrock geologic map of the Elberton 7.5-minute quadrangle, Whitman County, Washington: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, [8] p., scale 1:24,000. (Also available at <http://www.webpages.uidaho.edu/pbac/GeologicMaps/elberton.pdf> and at http://www.webpages.uidaho.edu/pbac/GeologicMaps/ELBERTON_DESCRIPTION.pdf.)

Bush, J.H., Garwood, D.L., and Oakley, W.L., III, 2005 [2006], Bedrock geologic map of the Colfax North 7.5-minute quadrangle, Whitman County, Washington: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, [7] p., scale 1:24,000. (Also available at http://www.webpages.uidaho.edu/pbac/GeologicMaps/colfax_north.pdf and at http://www.webpages.uidaho.edu/pbac/GeologicMaps/COLFAX_NORTH_DESCRIPTION.pdf.)

Bush, J.H., Pierce, J.L., and Potter, G.N., 1998, Bedrock geologic map of the Robinson Lake quadrangle, Latah County, Idaho: Moscow, Idaho, Idaho Geological Survey Geologic Map 24, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/GM-24-m.pdf](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/GM-24-m.pdf).)

Bush, J.H., Pierce, J.L., and Potter, G.N., 2000, Bedrock geologic map of the Moscow East quadrangle, Latah County, Idaho: Moscow, Idaho Geological Survey Geologic Map 27, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/GM-27-m.pdf](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/GM-27-m.pdf).)

Bush, J.H., and Provant, A.P., 1998, Bedrock geologic map of the Viola quadrangle, Latah County, Idaho, and Whitman County, Washington: Moscow, Idaho Geological Survey Geologic Map 25, scale 1:24,000. (Also available at

[http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/GM-25-m.pdf](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/GM-25-m.pdf).)

Bush, J.H., Provant, A.P., and Gill, S.W., 1998, Bedrock geologic map of the Moscow West quadrangle, Latah County, Idaho, and Whitman County, Washington: Moscow, Idaho Geological Survey Geologic Map 23, scale 1:24,000. (Also available at

[http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/GM-23-m.pdf](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/GM-23-m.pdf).)

Conrey, Rick; Beard, Chris; and Wolff, John, 2013, Geology of the Palouse Basin DOE test wells: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished presentation, [22] p., accessed September 8, 2015, at

http://www.webpages.uidaho.edu/pbac/Presentations/2013/130321_Conrey_Geology_of_Palouse_Basin_WDOE_Monitoring_Wells.pdf.

Conrey, Rick, and Crow, Kyler, 2014, Basalt stratigraphy of Moscow #9 and UI #4 wells—Evidence for the Moscow Fault: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished presentation, [10] p., accessed September 8, 2015, at

http://www.webpages.uidaho.edu/pbac/Presentations/2014/140619_Conrey_Moscow_Fault.pdf.

Conrey, R.M., and Wolff, J.A., 2010, Basalt lava stratigraphy beneath Pullman and Moscow—Implications for the flow of groundwater: Moscow, Idaho, Palouse Basin Aquifer Committee, 1 sheet, accessed September 8, 2015, at

http://www.webpages.uidaho.edu/pbac/pubs/100331_Conrey_Wolff_Basalt_Stratigraphy_Poster.pdf.

Crow, Kyler, and Conrey, Rick, 2014, The Clear Creek fault at Glenwood Springs, WA: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished presentation, [13] p., accessed September 18, 2015, at

http://www.webpages.uidaho.edu/pbac/Presentations/2014/140515_Conrey_Clear_Creek_Fault.pdf.

Hooper, P.R., and Webster, G.D., 1982, Geology of the Pullman, Moscow West, Colton, and Uniontown 7.5-minute quadrangles, Washington and Idaho: Washington Division of Geology and Earth Resources Geologic Map 26, scale 1:62,000. (Also available at

http://www.dnr.wa.gov/Publications/ger_gm26_geol_map_pullman_moscow_colton_uniontown_62k.pdf.)

Swanson, D.A., Wright, T.L., Camp, V.E., Gardner, J.N., Helz, R.T., Price, S.M., Reidel, S.P., and Ross, M.E., 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 Investigations Map I-1139, scale 1:250,000, 2 sheets. (Also available at http://ngmdb.usgs.gov/Prodesc/proddesc_8987.htm.)

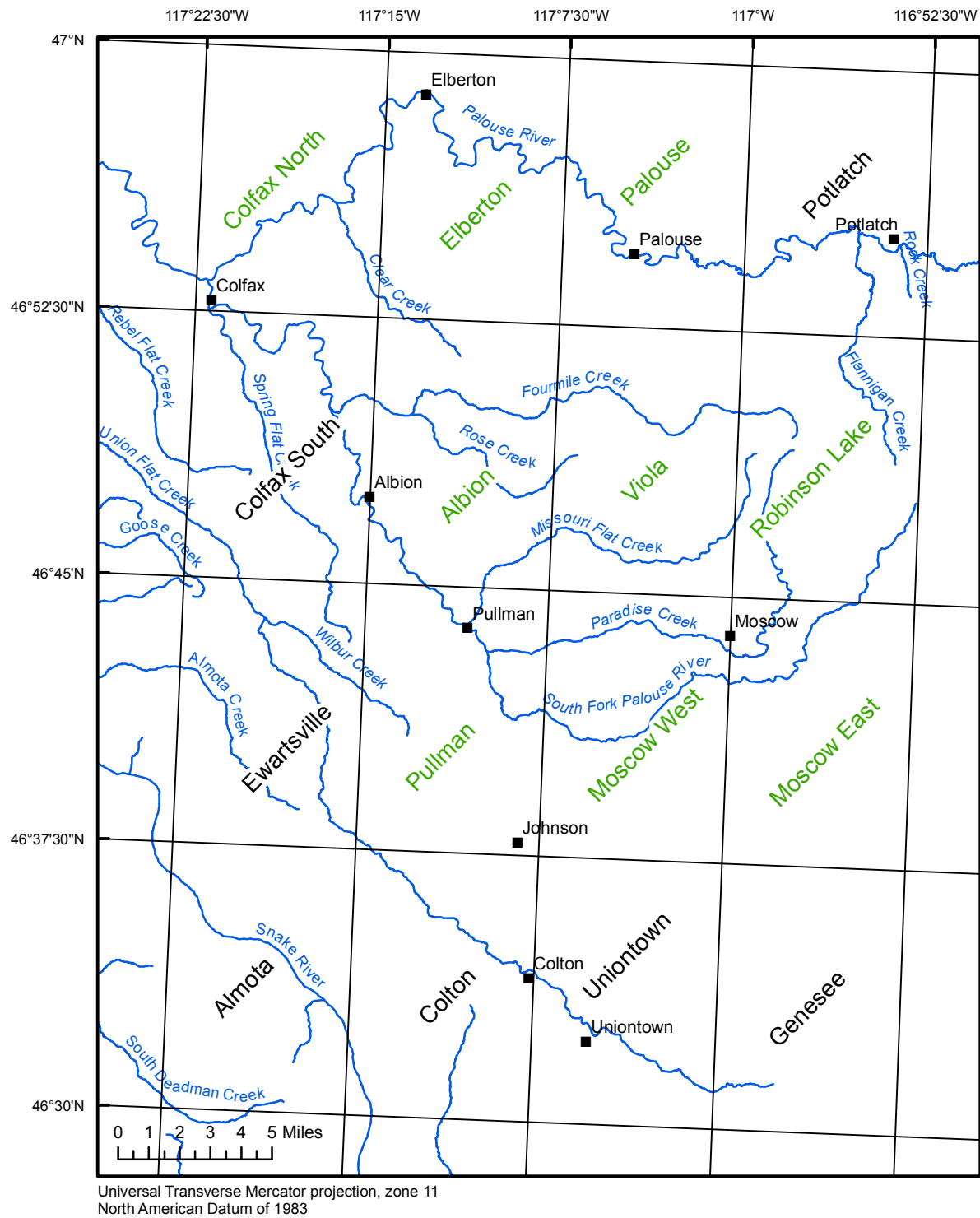
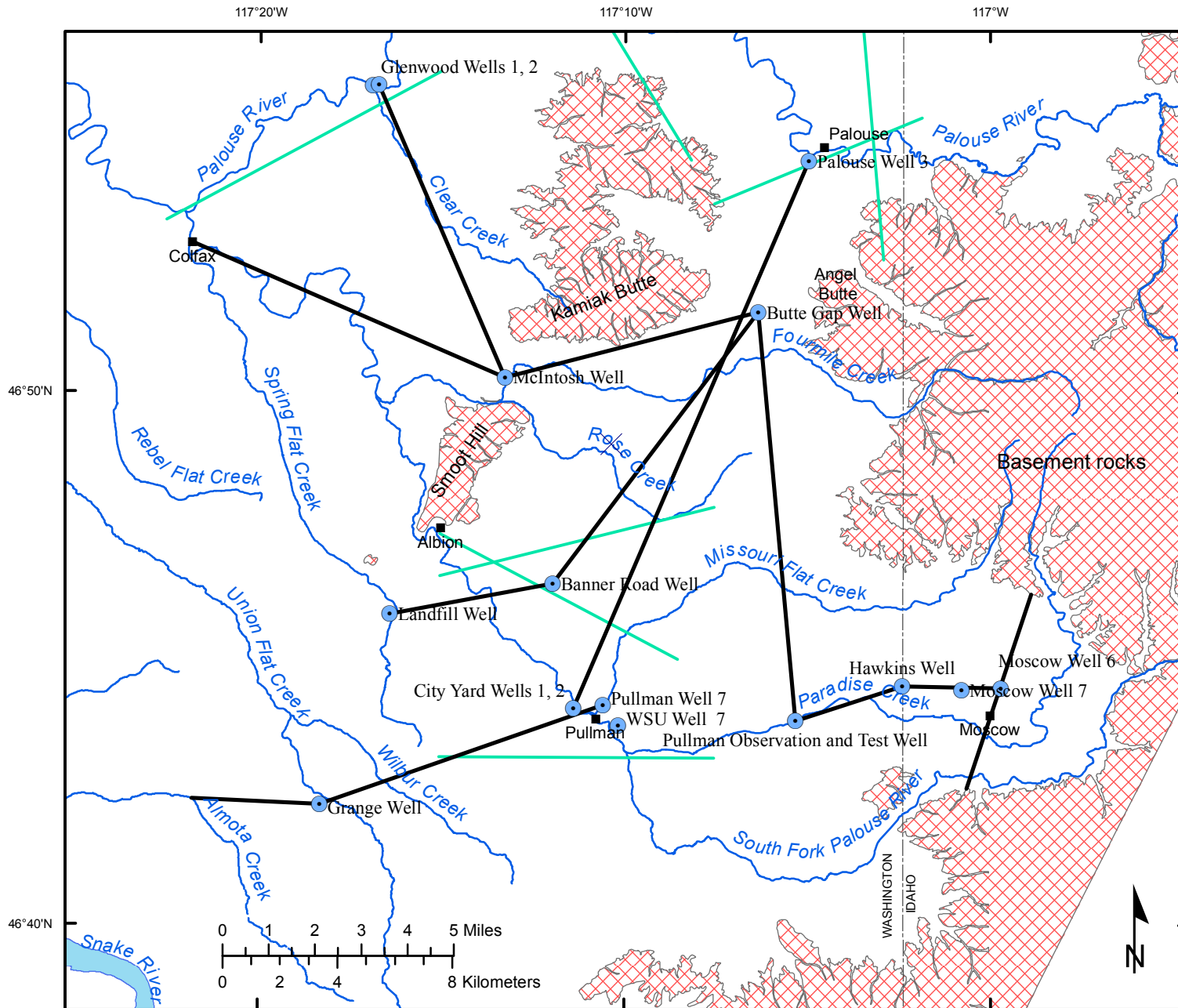


Figure 1. Index map showing 1:24,000-scale quadrangles in the Palouse Basin area. Name, in green, represents quadrangle with corresponding geologic map.



Universal Transverse Mercator projection, zone 11
 North American Datum of 1983

Figure 2. Map showing lines of existing (green) and proposed (black) geologic cross sections. Well, blue filled circle with dot; pre-Columbia River Basalt Group basement rocks, red cross hachure.

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Academic Background

Bowling Green State University, Ohio, 1965, B.S. in Geology

Montana State University, Bozeman, Mont., 1967, M.S. in Geology

Washington State University, Pullman, Wash. 1972, Ph.D. in Geology

Assistant Professor of Geology, 1972–1982, University of Idaho, Moscow, Idaho

Associate Professor of Geology, 1982–2004, University of Idaho, Moscow, Idaho

Department Head, Geology, 1983–1990, University of Idaho, Moscow, Idaho

Emeritus Professor, 2004–present, University of Idaho, Moscow, Idaho

Research

Research centered primarily on Cambrian stratigraphy of Idaho, Montana, and Washington, and on Columbia River Basalt Group stratigraphy of eastern Washington and northern Idaho. See attached list for publications and reports.

Teaching

Taught 17 different undergraduate and graduate courses with continued year-by-year focus in stratigraphy, sedimentology, sedimentary petrology, and geology field camp.

Graduate Advising

Major professor for 42 graduate theses. Served as committee member on more than 250 Ph.D. and M.S. theses at University of Idaho and Washington State University.

Public Service

Taught workshops and lead field trips for adults out of Moscow and Clark Fork, Idaho, for more than 20 years. Wrote geologic reports and provided advice for Palouse Basin Aquifer Committee for 15 years.

Other Employment

In the early 1970s (1970–1974), worked as hydrogeologist at Washington State University, and as driller and consultant for drilling firms. This work was related to the Columbia River Flood Basalt Province. Once employed by the University of Idaho, consulted occasionally for government and private entities in Columbia River Basalt Group stratigraphy related to hydrogeological problems.

John H. Bush

List of Publications

Anderson, J.V., Bush, J.H., Crosby, J.W., III, Kiesler, J.P., and Siems, B.A., 1973, Correlation of Columbia River Basalt by geophysical techniques [abs.]: Geological Society of America Abstracts with Programs (Cordilleran Section), v. 5, no. 1, p. 3.

Anderson, J.V., Bush, J.H., Crosby, J.W., III, and Siems, B.A., 1973, Geophysical investigation of Washington's ground-water resources, in Box 16 of Washington State University Libraries, Manuscripts, Archives, and Special Collections, College of Engineering Research Division Reports, 1936–1987 (UA 266): Pullman, Wash., Washington State University, College of Engineering Research Division Report 73/11-13.

Breckenridge, R.M., Othberg, K.L., and Bush, J.H., 1997, Stratigraphy and paleogeomorphology of Columbia River basalt, eastern margin of the Columbia River Plateau [abs.]: Geological Society of America Abstracts with Programs, v. 29, no. 5, p. 6.

Bush, J.H., Jr., 1973, Test-Observation well near Walla Walla, Washington—Description, stratigraphic relationships, and preliminary results, in Box 16 of Washington State University Libraries, Manuscripts, Archives, and Special Collections, College of Engineering Research Division Reports, 1936–1987 (UA 266): Pullman, Wash., Washington State University, College of Engineering Research Division Report 73/15-66.

Bush, J.H., 1977, Lithologic units of the Lakeview Limestone, Bonner County, Idaho [abs.]: Geological Society of America, Abstracts with Programs, Rocky Mountain Section, v. 9, no. 6, p. 712–713.

Bush, John, 1986, Road log for field trip along portions of the Snake, Clearwater and Potlatch Rivers, Washington and Idaho, in Beaver, P.C., ed., Cenozoic geology of Moscow Idaho and surrounding areas: Dillon, Mont., Tobacco Root Geological Society, Annual Field Conference, 11th, Moscow, Idaho, August 6–9, 1986, p. 19–31.

Bush, J.H., 1989, The Cambrian system of northern Idaho and northwestern Montana, in Chamberlain, V.E., Breckenridge, R.M., and Bonnicksen, Bill, eds., Guidebook to the geology of northern and western Idaho and surrounding area: Idaho Bureau of Mines and Geology Bulletin 28, p. 103–121. (Also available at http://www.idahogeology.org/PDF/Bulletins_%28B%29/B-28.pdf.)

Bush, J.H., 1991, Cambrian paleogeographic framework of northeastern Washington, northern Idaho, and western Montana, in Cooper, J.D., and Stevens, C.H., eds., Paleozoic paleogeography of the western United States, v. 2: Society of Economic Paleontologists and Mineralogists, Pacific Section, p. 463–473.

Bush, John, 1996, The geologic history of Moscow and a model for Moscow's ground water recharge: Unpublished report submitted to Palouse Basin Aquifer Committee, [unknown] p. and figures.

Bush, J.H., 2001, Bedrock geologic map of the Genesee quadrangle, Latah and Nez Perce counties, Idaho: Idaho Geological Survey Geologic Map 30, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/GM-30-M.PDF](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/GM-30-M.PDF).)

Bush, John, 2005, Comments on constructing lithologic logs for CRBG wells: Unpublished report submitted to Palouse Basin Aquifer Committee, [unknown] p.

Bush, John, 2005, Moscow Pullman regional cross section: Unpublished poster submitted to Palouse Basin Aquifer Committee.

Bush, John, 2005, The Columbia River Basalt Group of the Palouse Basin with hydrological interpretations, western Latah County, Idaho, and eastern Whitman County, Washington: Unpublished report submitted to Palouse Basin Aquifer Committee, [unknown] p. and figures.

Bush, John, 2006, Geologic report on Moscow monitoring wells: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, 15 p., and 1 sheet, scale 1:24,000. (Also available at http://www.webpages.uidaho.edu/pbac/pubs/061207_IDWR_Monitoring_Wells_Geology_Report_Bush_V3.pdf.)

Bush, John, 2006, Three-day short course on the Palouse Basin geology and hydrology.

Bush, John, 2007, Stratigraphic units of the Palouse Basin: Unpublished report submitted to Palouse Basin Aquifer Committee, [34] p.

Bush, John, 2008, Geologic report on Pullman Well No. 8: Unpublished report submitted to Golder Associates Inc., [10] p., and 3 figs., [unknown] tables, and 2 plates.

Bush, J.H., Jr., Anderson, J.V., Crosby, J.W., III, and Siems, B.A., 1972, Test-observation well near Mansfield, Washington—Description, stratigraphic relationships, and preliminary results, in Box 16 of Washington State University Libraries, Manuscripts, Archives, and Special Collections, College of Engineering Research Division Reports, 1936–1987 (UA 266): Pullman, Wash., Washington State University College of Engineering Research Division Report 72/11–128.

Bush, J.H., Breckenridge, R.M., Othberg, K.L., and Duncan, C.H., 1998, Paleogeomorphic evolution of the Columbia River Basalt embayments, western margin of the northern Rocky Mountains—Part 3, Holocene drainage control by Miocene basalts [abs.]: Geological Society of America Abstracts with Programs, Rocky Mountain Section, v. 30, no. 6, p. 6.

Bush, J.H., Cochran, B.D., Breckenridge, R.M., Hall, W.B., 1979, Palouse-Cheney tract of the channeled scablands, eastern Washington—A one-day field trip from Moscow, Idaho: American Association for the Advancement of Science, Pacific Division meeting, Moscow, Idaho, May 3–7, 1979 [Field guide]. (Also available as Idaho Bureau of Mines and Geology Reprint 10, 31 p., at [http://www.idahogeology.org/PDF/Reprints_\(R\)/R-10.pdf](http://www.idahogeology.org/PDF/Reprints_(R)/R-10.pdf).)

Bush, J.H., Duncan, C.H., and Garwood, D.L., 2005 [2006], Bedrock geologic map of the Palouse 7.5-minute quadrangle, Whitman County, Washington, and Latah County, Idaho: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, [11] p., scale 1:24,000. (Also available at <http://www.webpages.uidaho.edu/pbac/GeologicMaps/palouse.pdf> and at http://www.webpages.uidaho.edu/pbac/GeologicMaps/PALOUSE_DESCRIPTION.pdf.)

Bush, J.H., and Fischer, H.J., 1981, Stratigraphic and depositional summary for Middle and Upper Cambrian strata in northwestern Montana, northeastern Washington, and northern Idaho, in Taylor, M.E., ed., Short papers for the second international symposium on the Cambrian system: U.S. Geological Survey Open-File Report 81-743, p. 42–46. (Also available at <http://pubs.usgs.gov/of/1981/0743/report.pdf>.)

Bush, J.H., Fischer, H.J., and Aadland, R.K., 1980, The importance of a Middle and Upper Cambrian algal shoal-tidal barrier over northern Idaho [abs.]: Geological Society of America, Abstracts with Programs, Cordilleran Section, v. 12, no. 3, p. 100. (Also available at http://content.libraries.wsu.edu/index.php/utills/getfile/collection/palouse_dig/id/1415/filename/1410.pdf.)

Bush, J.H., and Garwood, D.L., 2001, Bedrock geologic map of the Lapwai quadrangle, Nez Perce County, Idaho: Idaho Geological Survey Technical Report 01-1, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TR-2001-1.pdf](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TR-2001-1.pdf).)

Bush, J.H., and Garwood, D.L., 2003, Interpretation and use of well data in the Columbia River Basalt Group, Pullman, Washington [abs.]: Geological Society of America Abstracts with Programs, v. 35, no. 6, p. 550. (Also available at https://gsa.confex.com/gsa/2003AM/finalprogram/abstract_63709.htm.)

Bush, J.H., and Garwood, D.L., 2005 [2006], Bedrock geologic map of the Albion 7.5-minute quadrangle, Whitman County, Washington: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, [12] p., scale 1:24,000. (Also available at <http://www.webpages.uidaho.edu/pbac/GeologicMaps/albion.pdf> and at http://www.webpages.uidaho.edu/pbac/GeologicMaps/ALBION_DESCRIPTION.pdf.)

Bush, J.H., and Garwood, D.L., 2005 [2006], Bedrock geologic map of the Pullman 7.5-minute quadrangle, Whitman County, Washington, and Latah County, Idaho: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, [13] p., scale 1:24,000. (Also available at <http://www.webpages.uidaho.edu/pbac/GeologicMaps/pullman.pdf> and at http://www.webpages.uidaho.edu/pbac/GeologicMaps/PULLMAN_DESCRIPTION.pdf.)

Bush, J.H., and Garwood, D.L., 2005, Geologic cross section of the Moscow-Pullman area, Idaho-Washington: Moscow, Idaho, Palouse Basin Aquifer Committee, scale 1:63,360. (Also available at http://www.webpages.uidaho.edu/pbac/GeologicMaps/E_W_regional.pdf.)

Bush, J.H., Garwood, D.L., and Halver, B.A., 2005 [2006], Bedrock geologic map of the Elberton 7.5-minute quadrangle, Whitman County, Washington: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, [8] p., scale 1:24,000. (Also available at <http://www.webpages.uidaho.edu/pbac/GeologicMaps/elberton.pdf> and at http://www.webpages.uidaho.edu/pbac/GeologicMaps/ELBERTON_DESCRIPTION.pdf.)

Bush, J.H., Garwood, D.L., and Kauffman, J.D., 2005, Geologic map of the Lapwai quadrangle, Nez Perce County, Idaho: Idaho Geological Survey Digital Web Map 41, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Lapwai_DWM-41-M.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Lapwai_DWM-41-M.pdf).)

Bush, J.H., Garwood, D.L., Kauffman, J.D., and Sprenke, K.F., 2003, Bedrock geologic map of the Weippe North 7.5-minute quadrangle, Clearwater County, Idaho: Idaho Geological Survey Digital Web Map 19, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/weippenorth-DWM-19.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/weippenorth-DWM-19.pdf).)

Bush, J.H., Garwood, D.L., Lewis, R.S., and McClelland, 2001, Bedrock geologic map of the Green Knob quadrangle, Latah and Nez Perce counties, Idaho: Idaho Geological Survey Geologic Map 31, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/GM-31-M.PDF](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/GM-31-M.PDF).)

Bush, J.H., Garwood, D.L., and Oakley, W.L., III, 2005 [2006], Bedrock geologic map of the Colfax North 7.5-minute quadrangle, Whitman County, Washington: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, [7] p., scale 1:24,000. (Also available at http://www.webpages.uidaho.edu/pbac/GeologicMaps/colfax_north.pdf and at http://www.webpages.uidaho.edu/pbac/GeologicMaps/COLFAX_NORTH_DESCRIPTION.pdf.)

Bush, J.H., Garwood, D.L., Oakley, W.L., III, and Erdman, T.W., 2001, Geologic report for Pullman City well no. 7: Unpublished report submitted to City of Pullman, Washington, 34 p.

Bush, J.H., Garwood, D.L., and Potter, G.N., 1999, Bedrock map of the Texas Ridge quadrangle, Latah County, Idaho: Idaho Geological Survey Technical Report 99-5, 3 sheets, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TR-99-5.pdf](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TR-99-5.pdf).)

Bush, J.H., Gill, S.W., Petrich, C.R., and Pierce, Jack, comps., 1999, Geological and hydrogeological references—Palouse region: Moscow, Idaho, Palouse Basin Aquifer Committee Technical Report 99-02, 46 p. (Also available at <http://www.webpages.uidaho.edu/pbac/pubs/biblio99.pdf>.)

Bush, J.H., and Hayden, L.L., 1987, Middle and Upper Cambrian platform evolution and paleogeography, northwestern Montana, northern Idaho and northeastern Washington [abs.]: Association of American Petroleum Geologists, Abstracts with Programs, v. 71, no. 8, p. 1002. (Also available at <http://www.searchanddiscovery.com/abstracts/html/1987/rocky/abstracts/1002b.htm>.)

Bush, John, and Hayden, Linda, 1987, W.S.U. Test Well Number 7: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished stratigraphic column, scale 1:1,200.

Bush, John, and Hooper, P.R., 1986, Road log for Columbia River Basalt vent trip, southeastern Washington, in Beaver, P.C., ed., Cenozoic geology of Moscow Idaho and surrounding areas: Dillon, Mont., Tobacco Root Geological Society, Annual Field Conference, 11th, Moscow, Idaho, August 6–9, 1986, p. 40–51.

Bush, J.H., Kachek, D.C., and Webster, G.D., 1985, Newly discovered Ordovician strata, Libby Trough, northwestern Montana [abs.]: Geological Society of America, Abstracts with Programs, v. 17, no. 4, p. 211.

Bush, J.H., Kauffman, J.D., and Schmidt, K.L., 2004, Geologic map of the Craigmont quadrangle, Lewis and Idaho counties, Idaho: Idaho Geological Survey Digital Web Map 27, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/DWM-27-M.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/DWM-27-M.pdf).)

Bush, J.H., Lewis, R.S., and Priebe, K.L., 2007, Geologic map of the Troy quadrangle, Latah County, Idaho: Idaho Geological Survey Geologic Map 46, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/troy_GM-46-m.pdf](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/troy_GM-46-m.pdf).)

Bush, J.H., Morton, J.A., and Seward, P.W., 1992, Depositional and stratigraphic interpretations of the Cambrian and Ordovician Metaline Formation, northeastern Washington: Washington Department of Natural Resources, Division of Geology and Earth Resources, Washington Geology, v. 20, no. 1, p. 27–35.

Bush, J.H., Odenborg, L.J., and Odenborg, N.D., 1999, Bedrock geologic map of the Deary quadrangle, Latah County, Idaho: Idaho Geological Survey Technical Report 99-3, 3 sheets, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TR-99-3.pdf](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TR-99-3.pdf).)

Bush, J.H., Othberg, K.L., and Priebe, K.L., 1995, Onaway Member intracanyon Columbia River basalt flows, Latah County, Idaho [abs.]: Geological Society of America Abstracts with Programs, v. 27, no. 4, p. 5.

Bush, J.H., Pierce, J.L., and Potter, G.N., 1998, Bedrock geologic map of the Robinson Lake quadrangle, Latah County, Idaho: Idaho Geological Survey Geologic Map 24, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/GM-24-m.pdf](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/GM-24-m.pdf).)

Bush, J.H., Pierce, J.L., and Potter, G.N., 2000, Bedrock geologic map of the Moscow East quadrangle, Latah County, Idaho: Idaho Geological Survey Geologic Map 27, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/GM-27-m.pdf](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/GM-27-m.pdf).)

Bush, J.H., and Priebe, K.L., 1995, Geologic map of the Troy quadrangle, Latah County, Idaho: Idaho Geological Survey Technical Report 95-5, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TR-95-5.pdf](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TR-95-5.pdf).)

Bush, J.H., Priebe, K.L., and Othberg, K.L., 1995, Priest Rapids vents near Troy, Joel, and Spring Valley Reservoir, Latah County, Idaho [abs.]: Geological Society of America Abstracts with Programs, v. 27, no. 4, p. 5.

Bush, J.H., and Provent, A.P., 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. (Also available at [http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/GM-25-m.pdf](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/GM-25-m.pdf).)

Bush, J.H., Provent, A.P., and Gill, S.W., 1998, Bedrock geologic map of the Moscow West quadrangle, Latah County, Idaho, and Whitman County, Washington: Idaho Geological Survey Geologic Map 23, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/GM-23-m.pdf](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/GM-23-m.pdf).)

Bush, J.H., and Ralston, D.R., 1997, Geologic setting of the eastern margin of the Columbia Plateau aquifer system [abs.]: Inland Northwest Water Resources Conference, Spokane, Wash., 1997, p. 15.

Bush, J.H., Jr., and Seward, W. P., 1992, Geologic field guide to the Columbia River Basalt, northern Idaho and southeastern Washington: Idaho Geological Survey Informational Circular 49, 35 p. (Also available at [http://www.idahogeology.org/PDF/Information_Circulars_\(I\)/IC-49.pdf](http://www.idahogeology.org/PDF/Information_Circulars_(I)/IC-49.pdf).)

Cochran, B.D., and Bush, J.H., 1986, Road log for a channeled scabland field trip, road log in Beaver, P.C., ed., Cenozoic geology of Moscow Idaho and surrounding areas: Dillon, Mont., Tobacco Root Geological Society, Annual Field Conference, 11th, Moscow, Idaho, August 6–9, 1986, p. 52–67.

Duncan, C.H., and Bush, J.H., 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. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TR-99-7.pdf](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TR-99-7.pdf).)

Duncan, C.H., and Bush, J.H., 1999, Bedrock geologic map of the Potlatch quadrangle, Latah County, Idaho: Idaho Geological Survey Technical Report 99-6, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TR-99-6.pdf](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TR-99-6.pdf).)

Fairley, J.P., Solomon, M.D., Hinds, J.J., Grader, G.W., Bush, J.H., and Rand, A.L., 2006, Latah County hydrologic characterization project—Final report: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report submitted to Idaho Department of Water Resources, 27 p. (Also available at http://www.webpages.uidaho.edu/pbac/pubs/HCP_FinalReport.pdf and http://www.latah.id.us/documents/HCP_FinalReport.pdf.)

Garwood, D.L., and Bush, J.H., 2001, Bedrock geologic map of the Lewiston Orchards North quadrangle, Nez Perce County, Idaho: Idaho Geological Survey Technical Report 01-2, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TR-2001-2.pdf](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TR-2001-2.pdf).)

Garwood, D.L., and Bush, J.H., 2005, Geologic map of the Lewiston Orchards North quadrangle and part of the Clarkston quadrangle, Nez Perce County, Idaho: Idaho Geological Survey Digital Web Map 40, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Lewiston_north-clarkston_DWM-40-M.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Lewiston_north-clarkston_DWM-40-M.pdf).)

Garwood, D.L., Bush, J.H., Kauffman, J.D., and Jones, T.E., 2003, New interpretations of structures in the Columbia River Basalt Group of the Clearwater Embayment, Idaho [abs.]: Geological Society of America Abstracts with Programs, v. 35, no. 6, p. 551. (Also available at https://gsa.confex.com/gsa/2003AM/finalprogram/abstract_63960.htm.)

Garwood, D.L., Bush, J.H., and Potter, G.N., 1999, Bedrock geologic map of the Juliaetta quadrangle, Latah County, Idaho: Idaho Geological Survey Technical Report 99-4, 3 sheets, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TR-99-4.pdf](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TR-99-4.pdf).)

Hayden, L.L., and Bush, J.H., 1987, Stratigraphy and depositional environment of the Upper Cambrian Red Lion Formation, southwestern Montana [abs.]: Association of American Petroleum Geologists, Abstracts with Programs, v. 71, no. 8, p. 1007. (Also available at <http://www.searchanddiscovery.com/abstracts/html/1987/rocky/abstracts/1007b.htm>.)

Hayden, L.L., and Bush, J.H., 1988, Description and significance of three isolated Cambrian outcrops in northern Idaho and northwestern Montana [abs.]: Geological Society of America, Abstracts with Programs, Rocky Mountain Section, v. 20, no. 6, p. 420.

Kauffman, J.D., Bush, J.H., and Lewis, R.S., 2003, Newly identified Oligocene alkali volcanics along the eastern margin of the Columbia Plateau, Latah and surrounding counties, Idaho [abs.]: Geological Society of America Abstracts with Programs, v. 35, no. 6, p. 549. (Also available at https://gsa.confex.com/gsa/2003AM/finalprogram/abstract_60720.htm.)

Kauffman, J.D., Bush, J.H., and Lewis, R.S., 2006, Oligocene alkaline volcanic rocks along the eastern margin of the Columbia Plateau, northern Idaho: Idaho Geological Survey Technical Report 06-7, 9 p. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TechRpt06-7_B.pdf](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TechRpt06-7_B.pdf).)

Kauffman, J.D., Schmidt, K.L., and Bush, J.H., 2004, Geologic map of the Nezperce quadrangle, Lewis and Idaho counties, Idaho: Idaho Geological Survey Digital Web Map 28, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/DWM-28-M.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/DWM-28-M.pdf).)

Kauffman, J.D., Schmidt, K.L., Garwood, D.L., and Bush, J.H., 2004, Geologic map of the Cottonwood quadrangle, Idaho County, Idaho: Idaho Geological Survey Digital Web Map 29, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/DWM-29-M.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/DWM-29-M.pdf).)

Lewis, R.S., Bush, J.H., Burmester, R.F., Kauffman, J.D., Garwood, D.L., Myers, P.E., and Othberg, K.L., 2005, Geologic map of the Potlatch 30- x 60-minute quadrangle, Idaho: Idaho Geological Survey Geologic Map 41, 30 p., scale 1:100,000. (Also available at <http://www.idahogeology.org/Products/MapCatalog/default.asp?switch=title&value=GM-41>.)

Lewis, R.S., Kauffman, J.D., Burmester, R.F., Bush, J.H., and Garwood, D.L., 2005, Geologic map of the Rudo quadrangle, Clearwater County, Idaho: Idaho Geological Survey Geologic Map 27, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/Rudo_GM-37_M.pdf](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/Rudo_GM-37_M.pdf).)

Potter, G.N., Bush, J.H., and Garwood, D.L., 1999, Bedrock map of the Little Bear Ridge quadrangle, Latah County, Idaho: Idaho Geological Survey Technical Report 99-1, 2 sheets, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TR-99-1.pdf](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TR-99-1.pdf).)

Priebe, K.L., and Bush, J.H., 1999, Bedrock geologic map of the Stanford quadrangle, Latah County, Idaho: Idaho Geological Survey Technical Report 99-8, 2 sheets, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TR-99-8.pdf](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TR-99-8.pdf).)

Reidel, S.P., J.H. Bush, D.L. Garwood, J.D. Kauffman, and B.S. Martin, 2005, The tectonic evolution of the northern Columbia River flood-basalt province [abs.]: Geological Society of America Abstracts with Programs, v. 37, no. 7, p.126.

Siems, B.A., Bush, J.H., and Crosby, J.W., III, 1974, TiO₂ and geophysical logging criteria for Yakima Basalt correlation, Columbia Plateau: Geological Society of America Bulletin, v. 85, p. 1061–1068. (Also available at <http://gsabulletin.gsapubs.org/content/85/7/1061.full.pdf+html>, and at [http://dx.doi.org/10.1130/0016-7606\(1974\)85<1061:TAGLCF>2.0.CO;2](http://dx.doi.org/10.1130/0016-7606(1974)85<1061:TAGLCF>2.0.CO;2).)

Siems, B.A., Crosby, J.W., III, Anderson, J.V., Bush, J.H., and Weber, T., 1973, Final report, Geophysical investigation of Washington's ground-water resources, in Box 16 of Washington State University Libraries, Manuscripts, Archives, and Special Collections, College of Engineering Research Division Reports, 1936–1987 (UA 266): Pullman, Wash., Washington State University, College of Engineering Research Division Report 73/15-58.

Smiley, C.J., and Bush, J.H., 1986, Road log for Miocene fossil trip Clarkia area, Idaho, in Beaver, P.C., ed., Cenozoic geology of Moscow Idaho and surrounding areas: Dillon, Mont., Tobacco Root Geological Society Annual Field Conference, 11th, Moscow, Idaho, August 6–9, 1986, p. 32–39.

Teasdale, E.W., Bush, J.H., and Garwood, D.L., 2001, Structural partitioning of ground water resources in Moscow, Idaho and Pullman, Washington [abs.], in American Geophysical Union Fall Meeting, San Francisco, Calif., December 10–14, 2001, Proceedings: Eos, v. 82, no. 47, Fall Meeting Supplement, Abstract H32D-0335. (Also available at <http://abstractsearch.agu.org/meetings/2001/FM/H32D-0335.html>.)

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February 16, 2016

Academic Background

University of Rochester, Rochester, New York, 1975, B.A. in Geology

University of Idaho, Moscow, Idaho, 1977, M.S. in Geology

Employment

Worked as exploration geologist in late 1970s for The Anaconda Company (Denver, Colo.) and Noranda Exploration (Missoula, Mont.). Designed and managed property submittal database in late 1980s and early 1990s for Pegasus Gold Corporation (Butte, Mont.).

Worked as a geologist for various state geological surveys (Idaho, 1979–1982; Montana, 1982–1987; Washington, 1990–1991). Spent the past 23 years working as a geologist for the U.S. Geological Survey (1992–2015) in Spokane, Wash., and Tucson, Ariz., where I managed the Databases and Information Analysis Project for the Minerals Program in the Western Region of the U.S. for 20 years. I designed custom databases for geologic maps in the Pacific Northwest and for mineral resources of potash and porphyry copper around the world.

List of Publications

Ten publications for identification and calculation of phosphate resources in the southern Idaho Phosphate Field, 1983–1985 (under former name, P.D. Derkey)

U.S. Geological Survey Mineral Resource Maps MR-71 through MR-82, also available at <http://www.idahogeology.org/Products/reverselook.asp?switch=usgspubs&value=MR>. Each product contains a pamphlet of about 6 pages, and 3 map sheets at a scale of 1:24,000 showing selected geology and phosphate resources.

Six publications for estimating oil shale and coal resources, for generating mineral occurrence databases, and for a geologic map, all in Montana, 1985–1989 (under former name, P.D. Derkey)

Derkey, P.D., 1986, Coal stratigraphy of the Lame Deer quadrangle, southeastern Montana: Butte, Montana Bureau of Mines and Geology Geologic Map 43, 4 sheets, scale 1:100,000.

Derkey, P.D., Abercrombie, F.N., Vuke, S.M., and Daniel, J.A., 1985, Geology and oil shale resources of the Heath Formation, Fergus County, Montana: Butte, Montana Bureau of Mines and Geology Memoir 57, 100 p., 2 sheets, scale 1:48,000.

Derkey, P.D., and Bartholomew, M.J., 1988, Geologic map of the Ramsay quadrangle, Montana: Butte, Montana Bureau of Mines and Geology Geologic Map 47, 1 sheet, scale 1:24,000.

Derkey, R.E., and Derkey, P.D., 1987, Mine and mineral occurrence database for Madison County, Montana: Butte, Montana Bureau of Mines and Geology Open-File Report 207, 536 p.

Derkey, R.E., and Derkey, P.D., 1987, Mine and mineral occurrence database for Silver Bow County, Montana (exclusive of the Butte district): Butte, Montana Bureau of Mines and Geology Open-File Report 185.

Sholes, M.A., Vuke-Foster, S.M., and Derkey, P.D., 1989, Coal stratigraphy and correlation in the Glendive 30x60-minute quadrangle, eastern Montana and adjacent North Dakota: Butte, Montana Bureau of Mines and Geology Geologic Map 49, 9 p., 4 sheets, scale 1:100,000.

Many publications which involved designing and attributing custom databases for use in a geographic information system (GIS), 1995–2015 (under former name, P.D. Derkey, and current name)

Bookstrom, A.A., Box, S.E., Jackson, B.L., Brandt, T.R., Derkey, P.D., and Munts, S.R., 1999, Digital map of surficial geology, wetlands, and deepwater habitats, Coeur d'Alene River valley, Idaho: U.S. Geological Survey Open-File Report 99-548, 186 p. and 11 digital plates, scale: 1:24,000 (plates 1 and 2) and 1:50,000 (plates 3-11), and spatial data. . (Also available at [http://pubs.usgs.gov/of/1999/of99-548/.](http://pubs.usgs.gov/of/1999/of99-548/))

Bookstrom, A.A., Zientek, M.L., Box, S.E., Derkey, P.D., Elliott, J.E., Frishman, David, Ashley, R.P., Evarts, R.C., Stoesser, D.B., Moyer, L.A., Cox, D.P., and Ludington, Steve, 1996, Status and metal content of significant metallic mineral deposits in the Pacific Northwest—A contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-688, 98 p., 1 plate, scale 1:2,000,000, and spatial data. (Also available at [http://pubs.usgs.gov/of/1995/of95-688/.](http://pubs.usgs.gov/of/1995/of95-688/))

Box, S.E., Bookstrom, A.A., Zientek, M.L., Derkey, P.D., Ashley, R.P., Elliott, J.E., and Peters, S.G., 1996, Assessment of undiscovered mineral resources in the Pacific Northwest—A contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-682, 432 p., and spatial data. (Also available at [http://pubs.usgs.gov/of/1995/of95-682/.](http://pubs.usgs.gov/of/1995/of95-682/))

Cossette, P.M. and Derkey, P.D., 2003, Readme and metadata for geologic map of the Bonners Ferry 30' X 60' quadrangle, Idaho and Montana in Miller, F.K. and Burmester, R.F., Geologic map of the Bonners Ferry 30' X 60' quadrangle, Idaho and Montana: U.S. Geological Survey, Miscellaneous Field Investigations MF-2426, 28 p., and spatial data. (Also available at [http://pubs.usgs.gov/mf/2003/2426/readme.pdf.](http://pubs.usgs.gov/mf/2003/2426/readme.pdf))

Derkey, P.D., and Johnson, B.R., 1995, Digital maps of low- to moderate-temperature geothermal springs and wells in the Pacific Northwest—A contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-689, 11 p., 3 plates, scale 1:2,000,000, and spatial data. (Also available at [http://pubs.usgs.gov/of/1995/of95-689/.](http://pubs.usgs.gov/of/1995/of95-689/))

Derkey, P.D., Johnson, B.R., and Carver, Michael, 1996, Digital geologic map of the Coeur d'Alene district, Idaho and Montana: U.S. Geological Survey Open-File Report 96-299, 6 p., 1 digital plate, scale 1:62,500, and spatial data. (Also available at [http://pubs.usgs.gov/of/1996/of96-299/.](http://pubs.usgs.gov/of/1996/of96-299/))

Derkey, P.D., Johnson, B.R., Lackaff, B.B., and Derkey, R.E., 1998, Digital geologic map of the Rosalia 1:100,000 quadrangle, Washington and Idaho—A digital database for the 1990 S.Z. Waggoner map: U.S. Geological Survey Open-File Report 98-357, 27 p., and spatial data. (Also available at [http://pubs.usgs.gov/of/1998/of98-357/.](http://pubs.usgs.gov/of/1998/of98-357/))

Graybeal, F.T., Moyer, L.A., Vikre, P.G., Dunlap, Pamela, and Wallis, J.C., 2015, Geologic map of the Patagonia Mountains, Santa Cruz County, Arizona: U.S. Geological Survey Open-File Report 2015-1023, pamphlet 10 p., and spatial data, scale 1:48,000, <http://dx.doi.org/10.3133/ofr20151023>.

Harrison, J.E., Cressman, E.R., Whipple, J.W., Kayser, H.Z., Derkey, P.D., and EROS Data Center, 2000, Geologic and structure maps of the Kalispell 1- x 2-degree quadrangle, Montana, and Alberta and British Columbia—A digital database: U.S. Geological Survey Miscellaneous Investigations Series Map I-2267, 22 p., 1 digital plate, scale 1:250,000, and spatial data. (Also available at [http://pubs.usgs.gov/imap/i2267/.](http://pubs.usgs.gov/imap/i2267/))

Harrison, J.E., Griggs, A.B., Wells, J.D., Kelley, W.N., Derkey, P.D., and EROS Data Center, 2000, Geologic and structure maps of the Wallace 1- x 2-degree quadrangle, Montana and Idaho—A digital database: U.S. Geological Survey Miscellaneous Investigations Series Map I-1509-A, 21 p., 1 digital plate, scale 1:250,000, and spatial data. . (Also available at [http://pubs.usgs.gov/imap/i1509a/.](http://pubs.usgs.gov/imap/i1509a/))

Johnson, B.R., Derkey, P.D., Frost, T.P., Derkey, R.E., and Lackaff, B.B., 1998, Digital geologic map of Spokane County and vicinity, Washington and Idaho: U.S. Geological Survey Open-File Report 98-503, 44 p., and spatial data. (Also available at [http://pubs.usgs.gov/of/1998/of98-503/.](http://pubs.usgs.gov/of/1998/of98-503/))

Johnson, B.R., Derkey, P.D., Frost, T.P., Lackaff, B.B. ,and Derkey, R.E., comps., 1998, Digital geologic map of Spokane County and vicinity, Washington and Idaho: U.S. Geological Survey Open-File Report 98-503, 42 p., and 1 digital plate, scale 1:100,000, and spatial data. (Also available at [http://pubs.usgs.gov/of/1998/of98-503/.](http://pubs.usgs.gov/of/1998/of98-503/))

Lewis, R.S., Burmester, R.F., McFaddan, M.D., Derkey, P.D., and Oblad, J.R., 1999, Digital geologic map of the Wallace 1:100,000 quadrangle, Idaho: U.S. Geological Survey Open-File Report 99-390, 46 p., 1 digital plate, scale 1:100,000, and spatial data. (Also available at [http://pubs.usgs.gov/of/1999/of99-390/.](http://pubs.usgs.gov/of/1999/of99-390/))

Lewis, R.S., and Derkey, P.D., 1999, Digital geologic map of part of the Thompson Falls 1:100,000 quadrangle, Idaho: U.S. Geological Survey, Open-File Report 99-438, 32 p., 1 digital plate, scale 1:100,000, and spatial data. (Also available at [http://pubs.usgs.gov/of/1999/0438/.](http://pubs.usgs.gov/of/1999/0438/))

Lund, Karen, Derkey, P.D., Brandt, T.K., and Oblad, Jon, 1999, Digital geologic map database of the Payette National Forest and vicinity, Idaho: U.S. Geological Survey Open-File Report 98-219B, 45 p., 10 digital plates, scale 1:100,000, and spatial data. (Also available at [http://pubs.usgs.gov/of/1998/ofr-98-0219-b/.](http://pubs.usgs.gov/of/1998/ofr-98-0219-b/))

Miller, F.K., Burmester, R.F., Powell, R.E., Miller, D.M., and Derkey, P.D., 1999, Digital geologic map of the Sandpoint 1- by 2-degree quadrangle, Washington, Idaho, and Montana: U.S. Geological Survey Open-File Report 99-144, 11 p., 1 digital plate, scale 1:250,000, and spatial data. (Also available at [http://pubs.usgs.gov/of/1999/0144/.](http://pubs.usgs.gov/of/1999/0144/))

Miller, F.K., Cossette, P.M., and Derkey, P.D., 2001, Geologic map of the Chewelah 30' by 60' quadrangle, Washington and Idaho: U.S. Geological Survey Miscellaneous Field Studies Map MF-2354, 20 p., 1 plate, scale 1:100,000, and spatial data. (Also available at <http://pubs.usgs.gov/mf/2001/2354/README.pdf>.)

Orris, G.J., Cocker, M.D., Dunlap, Pamela, Wynn, Jeff, Spanski, G.T., Briggs, D.A., and Gass, Leila, with contributions from Bliss, J.D., Bolm, K.S., Yang, Chao, Lipin, B.R., Ludington, Steve, Miller, R.J., and Slowakiewicz, Miroslaw, 2014, Potash—A global overview of evaporite-related potash resources, including spatial databases of deposits, occurrences, and permissive tracts: U.S. Geological Survey Scientific Investigations Report 2010-5090-S, 76 p., and spatial data, <http://dx.doi.org/10.3133/sir20105090s>.

Zientek, M.L., Derkey, P.D., Miller, R.J., Causey, J.D., Bookstrom, A.A., Carlson, M.H., Green, G.N., Frost, T.P., Boleneus, D.E., Evans, K.V., Van Gosen, B.S., Wilson, A.B., Larsen, J.C., Kayser, H.Z., Kelley, W.N., and Assmus, K.C., 2005, Spatial databases for the geology of the Northern Rocky Mountains—Idaho, Montana, and Washington: U.S. Geological Survey Open-File Report 2005-1235, 206 p., and spatial data. (Also available at <http://pubs.usgs.gov/of/2005/1235/>.)

Zürcher, Lukas, Bookstrom, A.A., Hammarstrom, J.M., Mars, L.C., Ludington, Steve, Zientek, M.L., Dunlap, Pamela, and Wallis, J.C., 2015, Porphyry copper assessment of the Tethys region of western and southern Asia: U.S. Geological Survey Scientific Investigations Report 2010-5090-V, 232 p., and spatial data, <http://dx.doi.org/10.3133/sir20105090v>.

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Academic Background

University of Idaho, Moscow, Idaho, 1997, B.S. in Geology

University of Idaho, Moscow, Idaho, 2001, M.S. in Geology

University of Idaho, Moscow, Idaho, 2004, GIS certification

Employment

Worked as a geologist, first as a consultant (1998–2000), then for the Idaho Water Resources Research Institute (2002–2003) and the Idaho Geological Survey (2004–2014), primarily mapping Columbia River Basalt Group and other volcanic rocks in Idaho, Washington, and Oregon.

Taught geology classes and labs at Spokane Community College, Spokane, Wash. (2015–present).

List of Publications

Breckenridge, R.M., and Garwood, D.L., 2014, Geologic guide of the Hoodoo Valley area: Moscow, Idaho, Idaho Geological Survey Staff Report 14-3, 23 p., and map. (Also available at [http://www.idahogeology.org/PDF/Staff_Reports_\(S\)/2014/IGS_S-14-3.pdf](http://www.idahogeology.org/PDF/Staff_Reports_(S)/2014/IGS_S-14-3.pdf).)

Breckenridge, Roy, Garwood, Dean, and Hersley, Chad, 2012, Idaho well headers: AASG Geothermal Data Repository Web page, digital data, accessed January 18, 2016, at <http://repository.stategeothermaldata.org/repository/resource/dc2950e94fd12022579c7307b63f779f/>.)

Breckenridge, R.M., Garwood, D.L., Nisbet, Jack, 2014, Mapping the deluge—Sandpoint to Cabinet Gorge Dam, Idaho: Moscow, Idaho, Idaho Geological Survey Staff Report 14-1, 21 p., and map. (Also available at [http://www.idahogeology.org/PDF/Staff_Reports_\(S\)/2014/IGS_S-14-1.pdf](http://www.idahogeology.org/PDF/Staff_Reports_(S)/2014/IGS_S-14-1.pdf).)

Bush, J.H., Duncan, C.H., and Garwood, D.L., 2005 [2006], Bedrock geologic map of the Palouse 7.5-minute quadrangle, Whitman County, Washington, and Latah County, Idaho: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, [11] p., scale 1:24,000. (Also available at <http://www.webpages.uidaho.edu/pbac/GeologicMaps/palouse.pdf> and at http://www.webpages.uidaho.edu/pbac/GeologicMaps/PALOUSE_DESCRIPTION.pdf.)

Bush, J.H., and Garwood, D.L., 2001, Bedrock geologic map of the Lapwai quadrangle, Nez Perce County, Idaho: Idaho Geological Survey Technical Report 01-1, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TR-2001-1.pdf](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TR-2001-1.pdf).)

Bush, J.H., and Garwood, D.L., 2003, Interpretation and use of well data in the Columbia River Basalt Group, Pullman, Washington [abs.]: Geological Society of America Abstracts with Programs, v. 35, no. 6, p. 550. (Also available at https://gsa.confex.com/gsa/2003AM/finalprogram/abstract_63709.htm.)

Bush, J.H., and Garwood, D.L., 2005 [2006], Bedrock geologic map of the Albion 7.5-minute quadrangle, Whitman County, Washington: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, [12] p., scale 1:24,000. (Also available at <http://www.webpages.uidaho.edu/pbac/GeologicMaps/albion.pdf> and at http://www.webpages.uidaho.edu/pbac/GeologicMaps/ALBION_DESCRIPTION.pdf.)

Bush, J.H., and Garwood, D.L., 2005 [2006], Bedrock geologic map of the Pullman 7.5-minute quadrangle, Whitman County, Washington, and Latah County, Idaho: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, [13] p., scale 1:24,000. (Also available at <http://www.webpages.uidaho.edu/pbac/GeologicMaps/pullman.pdf> and at http://www.webpages.uidaho.edu/pbac/GeologicMaps/PULLMAN_DESCRIPTION.pdf.)

Bush, J.H., and Garwood, D.L., 2005, Geologic cross section of the Moscow-Pullman area, Idaho-Washington: Moscow, Idaho, Palouse Basin Aquifer Committee, scale 1:63,360. (Also available at http://www.webpages.uidaho.edu/pbac/GeologicMaps/E_W_regional.pdf.)

Bush, J.H., Garwood, D.L., and Halver, B.A., 2005 [2006], Bedrock geologic map of the Elberton 7.5-minute quadrangle, Whitman County, Washington: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, [8] p., scale 1:24,000. (Also available at <http://www.webpages.uidaho.edu/pbac/GeologicMaps/elberton.pdf> and at http://www.webpages.uidaho.edu/pbac/GeologicMaps/ELBERTON_DESCRIPTION.pdf.)

Bush, J.H., Garwood, D.L., and Kauffman, J.D., 2005, Geologic map of the Lapwai quadrangle, Nez Perce County, Idaho: Idaho Geological Survey Digital Web Map 41, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Lapwai_DWM-41-M.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Lapwai_DWM-41-M.pdf).)

Bush, J.H., Garwood, D.L., Kauffman, J.D., and Sprenke, K.F., 2003, Bedrock geologic map of the Weippe North 7.5-minute quadrangle, Clearwater County, Idaho: Idaho Geological Survey Digital Web Map 19, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/weippenorth-DWM-19.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/weippenorth-DWM-19.pdf).)

Bush, J.H., Garwood, D.L., Lewis, R.S., and McClelland, 2001, Bedrock geologic map of the Green Knob quadrangle, Latah and Nez Perce counties, Idaho: Idaho Geological Survey Geologic Map 31, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/GM-31-M.PDF](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/GM-31-M.PDF).)

Bush, J.H., Garwood, D.L., and Oakley, W.L., III, 2005 [2006], Bedrock geologic map of the Colfax North 7.5-minute quadrangle, Whitman County, Washington: Moscow, Idaho, Palouse Basin Aquifer Committee, unpublished report, [7] p., scale 1:24,000. (Also available at http://www.webpages.uidaho.edu/pbac/GeologicMaps/colfax_north.pdf and at http://www.webpages.uidaho.edu/pbac/GeologicMaps/COLFAX_NORTH_DESCRIPTION.pdf.)

Bush, J.H., Garwood, D.L., Oakley, W.L., III, and Erdman, T.W., 2001, Geologic report for Pullman City Well No. 7: Unpublished report submitted to City of Pullman, Washington, 34 p.

Bush, J.H., Garwood, D.L., and Potter, G.N., 1999, Bedrock map of the Texas Ridge quadrangle, Latah County, Idaho: Idaho Geological Survey Technical Report 99-5, 3 sheets, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TR-99-5.pdf](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TR-99-5.pdf).)

Cash, J.R., and Garwood, D.L., Road guide to the Columbia River Basalt Group of the Lewiston, Kendrick, Deary, Moscow area, Idaho: Moscow, Idaho, Idaho Geological Survey Staff Report S-10-6, 20 p. (Also available at [http://www.idahogeology.org/PDF/Staff_Reports_\(S\)/2010/S-10-6.pdf](http://www.idahogeology.org/PDF/Staff_Reports_(S)/2010/S-10-6.pdf).)

Feeney, D.M., Garwood, D.L., and Phillips, W.M., 2014, Geologic map of the Drummond quadrangle, Fremont and Teton counties, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 167, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Drummond_DWM-167_m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Drummond_DWM-167_m.pdf).)

Feeney, D.M., Garwood, D.L., Phillips, W.M., and Cooley, S.W., 2014, Geologic map of the Mann Creek SE quadrangle, Washington County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 169, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Mann_Creek_SE_DW-M-169_m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Mann_Creek_SE_DW-M-169_m.pdf).)

Garwood, D.L., 2012, BHT information for permitted oil and gas wells in Idaho: AASG Geothermal Data Repository Web page, digital data, accessed January 18, 2016, at <http://repository.stategeothermaldata.org/repository/resource/50ec3aefb656b70647f32e38bc891149/>.)

Garwood, D.L., 2012, Idaho well logs: AASG Geothermal Data Repository Web page, digital data, accessed January 18, 2016, at <http://repository.stategeothermaldata.org/repository/resource/caad517515720208ad5e01bce4027651/>.)

Garwood, D.L., 2012, Well header information for permitted oil and gas exploration wells in Idaho: AASG Geothermal Data Repository Web page, digital data, accessed January 18, 2016, at <http://repository.stategeothermaldata.org/repository/resource/50ec3aefb656b70647f32e38bc890677/>.)

Garwood, D.L., 2012, Well log information for permitted oil and gas exploration wells in Idaho: AASG Geothermal Data Repository Web page, digital data, accessed January 18, 2016, at <http://repository.stategeothermaldata.org/repository/resource/50ec3aefb656b70647f32e38bc890c85/>.)

Garwood, D.L., and Breckenridge, R.M., 2012, Idaho well tests: AASG Geothermal Data Repository Web page, digital data, accessed January 18, 2016, at <http://repository.stategeothermaldata.org/repository/resource/90e5aa8a743c04160c055efb026faf9f/>.)

Garwood, D.L., and Breckenridge, R.M., 2014, Geological Society of the Oregon Country—Lewiston Basin field trip: Moscow, Idaho, Idaho Geological Survey Staff Report 14-2, 14 p. (Also available at [http://www.idahogeology.org/PDF/Staff_Reports_\(S\)/2014/IGS_S-14-2.pdf](http://www.idahogeology.org/PDF/Staff_Reports_(S)/2014/IGS_S-14-2.pdf).)

Garwood, D.L., and Bush, J.H., 2001, Bedrock geologic map of the Lewiston Orchards North quadrangle, Nez Perce County, Idaho: Idaho Geological Survey Technical Report 01-2, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TR-2001-2.pdf](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TR-2001-2.pdf).)

Garwood, D.L., and Bush, J.H., 2005, Geologic map of the Lewiston Orchards North quadrangle and part of the Clarkston quadrangle, Nez Perce County, Idaho: Idaho Geological Survey Digital Web Map 40, scale 1:24,000. (Also available at

[http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Lewiston_north-clarkston_DWM-40-M.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Lewiston_north-clarkston_DWM-40-M.pdf).)

Garwood, D.L., Bush, J.H., Kauffman, J.D., and Jones, T.E., 2003, New interpretations of structures in the Columbia River Basalt Group of the Clearwater Embayment, Idaho [abs.]: Geological Society of America Abstracts with Programs, v. 35, no. 6, p. 551. (Also available at

https://gsa.confex.com/gsa/2003AM/finalprogram/abstract_63960.htm.)

Garwood, D.L., Bush, J.H., and Potter, G.N., 1999, Bedrock geologic map of the Juliaetta quadrangle, Latah County, Idaho: Moscow, Idaho, Idaho Geological Survey Technical Report 99-4, 3 sheets, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TR-99-4.pdf](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TR-99-4.pdf).)

Garwood, D.L., Cash, J.R., Daly, R.G., Feeney, D.M., Lewis, R.L., Pixley, S.E., and Breckenridge, R.M., 2013, Historical oil and gas data for Idaho, 1903–1988: Moscow, Idaho, Idaho Geological Survey Digital Database DD-3, GIS data, ver. 12.2013.2, available at

http://www.idahogeology.org/Products/reverselook.asp?switch=title&value=Historical_Oil_and_Gas_data_for_Idaho:_1903-1988.)

Garwood, D.L., Feeney, D.M., Phillips, W.M., and Cooley, S.W., 2014, Geologic map of the Nutmeg Flat quadrangle, Washington County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 168, scale 1:24,000. (Also available at

[http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Nutmeg_Flat_DWM-168_m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Nutmeg_Flat_DWM-168_m.pdf).)

Garwood, D.L., Kauffman, J.D., and Othberg, K.L., 2011, Geologic map of the Picabo quadrangle, Blaine County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 131, scale 1:24,000. (Also available at

[http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Picabo_DWM-131-m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Picabo_DWM-131-m.pdf).)

Garwood, D.L., Kauffman, J.D., Othberg, K.L., and Lewis, R.S., 2014, Geologic map of the Fairfield 30 x 60 minute quadrangle, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 171, 24 p., scale 1:100,000. (Also available at

[http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Fairfield_DWM-171_m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Fairfield_DWM-171_m.pdf) and

[http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Fairfield_30x60_DWM-171_b.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Fairfield_30x60_DWM-171_b.pdf).)

Garwood, D.L., Lewis, R.S., Daly, R.G., and Breckenridge, R.M., 2011, Oil and gas map of Idaho–2011 revision: Moscow, Idaho, Idaho Geological Survey Digital Web Map 142, scale 1:750,000, and GIS data. (Also available at

http://www.idahogeology.org/Products/reverselook.asp?switch=title&value=Oil_and_Gas_Map_of_Idaho:_2011_Revision.)

Garwood, D.L., and Othberg, K.L., 2009, Geologic map of the Fruitvale quadrangle, Adams County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 106, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Fruitvale_DWM-106-m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Fruitvale_DWM-106-m.pdf).)

Garwood, D.L., and Othberg, K.L., 2009, Geologic map of the Tamarack quadrangle, Adams County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 105, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Tamarack_DWM-105-m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Tamarack_DWM-105-m.pdf).)

Garwood, D.L., Othberg, K.L., and Kauffman, J.D., 2009, Geologic map of the Council quadrangle, Adams County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 104, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Council_DWM-104-m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Council_DWM-104-m.pdf).)

Garwood, D.L., Othberg, K.L., and Kauffman, J.D., 2010, Geologic map of the Gannett quadrangle, Blaine County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 117, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Gannett_DWM-117-m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Gannett_DWM-117-m.pdf).)

Garwood, D.L., Othberg, K.L., and Kauffman, J.D., 2010, Geologic map of the Indian Valley quadrangle, Adams County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 121, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Indian_Valley_DWM-121-m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Indian_Valley_DWM-121-m.pdf).)

Garwood, D.L., Schmidt, K.L., Kauffman, J.D., Stewart, D.E., Lewis, R.S., Othberg, K.L., and Wampler, P.J., 2008, Geologic map of the White Bird quadrangle, Idaho County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 101, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/White_Bird_DWM-101-m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/White_Bird_DWM-101-m.pdf).)

Garwood, D.L., and Welhan, John, 2012, Idaho borehole temperatures: AASG Geothermal Data Repository Web page, digital data, accessed January 18, 2016, at <http://repository.stategeothermaldata.org/repository/resource/50b3a9b3bec98d3d491e2187c52ef6f1/>.)

Kauffman, J.D., Garwood, D.L., and Othberg, K.L., 2013, Geologic map of the Davis Mountain SW quadrangle, Gooding County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 159, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/DavisMtnSW-DWM-159_m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/DavisMtnSW-DWM-159_m.pdf).)

Kauffman, J.D., Lewis, R.S., Schmidt, K.L., Stewart, D.E., Garwood, D.L., and Othberg, K.L., 2011, Geologic map of the Dairy Mountain quadrangle, Idaho County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 129, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Dairy_mtn_pub_129-m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Dairy_mtn_pub_129-m.pdf).)

Kauffman, J.D., Othberg, K.L., and Garwood, D.L., 2010, Geologic map of the McHan Reservoir quadrangle, Camas and Gooding counties, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 116, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/McHan_DWM-116-m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/McHan_DWM-116-m.pdf).)

Kauffman, J.D., Schmidt, K.L., Garwood, D.L., and Bush, J.H., 2004, Geologic map of the Cottonwood quadrangle, Idaho County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 29, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/DWM-29-M.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/DWM-29-M.pdf).)

Kauffman, J.D., Schmidt, K.L., Lewis, R.S., Stewart, D.E., Othberg, K.L., and Garwood, D.L., 2011, Geologic map of the McKinzie Creek quadrangle, Idaho County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 127, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/McKinzie_pub_DWM-127-m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/McKinzie_pub_DWM-127-m.pdf).)

Kauffman, J.D., Schmidt, K.L., Lewis, R.S., Stewart, D.E., Othberg, K.L., and Garwood, D.L., 2014, Geologic map of the Idaho part of the Grangeville 30 x 60 minute quadrangle, and adjoining areas of Washington and Oregon: Moscow, Idaho, Idaho Geological Survey Geologic Map 50, 23 p., scale 1:100,000. (Also available at [http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/Grangeville_30x60_GM-50_m.pdf](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/Grangeville_30x60_GM-50_m.pdf) and [http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/Grangeville_GM-50_b.pdf](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/Grangeville_GM-50_b.pdf).)

Lewis, R.S., Bush, J.H., Burmester, R.F., Kauffman, J.D., Garwood, D.L., Myers, P.E., and Othberg, K.L., 2005, Geologic map of the Potlatch 30- x 60-minute quadrangle, Idaho: Moscow, Idaho, Idaho Geological Survey Geologic Map 41, 30 p., scale 1:100,000. (Also available at <http://www.idahogeology.org/Products/MapCatalog/default.asp?switch=title&value=GM-41>.)

Lewis, R.S., Kauffman, J.D., Burmester, R.F., Bush, J.H., and Garwood, D.L., 2005, Geologic map of the Rudo quadrangle, Clearwater County, Idaho: Moscow, Idaho, Idaho Geological Survey Geologic Map 27, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Maps_\(M\)/Geologic_Maps_\(GM\)/PDF/Rudo_GM-37_M.pdf](http://www.idahogeology.org/PDF/Maps_(M)/Geologic_Maps_(GM)/PDF/Rudo_GM-37_M.pdf).)

Phillips, W.M., Embree, G.F., and Garwood, D.L., 2013, Geologic map of the Tetonia quadrangle, Teton County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 157, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Tetonia_DWM-157_m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Tetonia_DWM-157_m.pdf).)

Phillips, W.M., Garwood, D.L., and Embree, G.F., 2013, Geologic map of the Packsaddle Lake quadrangle, Teton County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 155, scale 1:24,000. (Also available at

<http://www.idahogeology.org/Products/MapCatalog/default.asp?switch=title&value=DWM-155.>)

Phillips, W.M., Garwood, D.L., and Feeney, D.M., 2014, Geologic map of the Lamont quadrangle, Fremont and Teton counties, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 166, scale 1:24,000. (Also available at

[http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Lamont_DWM-166-m.pdf.](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Lamont_DWM-166-m.pdf.))

Phillips, W., Garwood, D., and Stewart, R., 2008, Landslide hazards of Idaho: Moscow, Idaho, Idaho Geological Survey GeoNote G-44. (Also available at

http://www.idahogeology.org/uploads/Hazards/Landslides/landSld_bro_final.pdf.)

Phillips, W.M., Lewis, R.S., Gillerman, V.S., Garwood, D.L., and Stewart, D.E., 2012, Geologic map of the Mayfield area, Ada and Elmore counties, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 144, scale 1:24,000. (Also available at

[http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/Mayfield_DWM-144-m.pdf.](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/Mayfield_DWM-144-m.pdf.))

Potter, G.N., Bush, J.H., and Garwood, D.L., 1999, Bedrock map of the Little Bear Ridge quadrangle, Latah County, Idaho: Moscow, Idaho, Idaho Geological Survey Technical Report 99-1, 2 sheets, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Technical_Reports_\(T\)/TR-99-1.pdf.](http://www.idahogeology.org/PDF/Technical_Reports_(T)/TR-99-1.pdf.))

Reidel, S.P., Camp, V.E., Tolan, T.L., Kauffman, J.D., and Garwood, D.L., 2013, Tectonic evolution of the Columbia River flood basalt province, *in* Reidel, S.P., Camp, V.E., Ross, M.E., Wolff, J.A., Martin, B.S., Tolan, T.L., and Wells, R.E., eds., *The Columbia River flood basalt province: Geological Society of America Special Paper 497*, p. 293–324. (Also available at [http://dx.doi.org/10.1130/2013.2497\(12\).](http://dx.doi.org/10.1130/2013.2497(12).))

Reidel, S.P., Bush, J.H., Garwood, D.L., Kauffman, J.D., and Martin, B.S., 2005, The tectonic evolution of the northern Columbia River flood-basalt province [abs.]: *Geological Society of America Abstracts with Programs*, v. 37, no. 7, p.126.

Schmidt, K.L., Garwood, D.L., and Kauffman, J.D., 2005, Geologic map of the Keuterville quadrangle, Lewis and Idaho counties, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 38, scale 1:24,000. (Also available at

[http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/DWM-38-M.pdf.](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/DWM-38-M.pdf.))

Schmidt, K.L., Kauffman, J.D., Stewart, D.E., Garwood, D.L., Othberg, K.L., and Lewis, R.S., 2009, Geologic map of the Grave Point quadrangle, Idaho County, Idaho, and Wallowa County, Oregon: Moscow, Idaho, Idaho Geological Survey Digital Web Map 111, scale 1:24,000. (Also available at

[http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/GravePoint_DWM-111-m.pdf.](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/GravePoint_DWM-111-m.pdf.))

Schmidt, K.L., Kauffman, J.D., Stewart, D.E., Lewis, R.S., Othberg, K.L., and Garwood, D.L., 2009, Geologic map of the Slate Creek quadrangle, Idaho County, Idaho: Moscow, Idaho, Idaho Geological Survey Digital Web Map 110, scale 1:24,000. (Also available at [http://www.idahogeology.org/PDF/Digital_Data_\(D\)/Digital_Web_Maps_\(DWM\)/SlateCreek_DWM-110-m.pdf](http://www.idahogeology.org/PDF/Digital_Data_(D)/Digital_Web_Maps_(DWM)/SlateCreek_DWM-110-m.pdf).)

Stanford, L.R., Breckenridge, R.M., Lewis, R.S., Adema, G.W., Garwood, D.L., Welhan, John, 2012, Idaho active faults: AASG Geothermal Data Repository Web page, digital data, accessed January 18, 2016, at <http://repository.stategeothermaldata.org/repository/resource/50b3a9b3bec98d3d491e2187c52e8175/>.)

Teasdale, E.W., Bush, J.H., and Garwood, D.L., 2001, Structural partitioning of ground water resources in Moscow, Idaho and Pullman, Washington [abs.], in American Geophysical Union Fall Meeting, San Francisco, Calif., December 10–14, 2001, Proceedings: Eos, v. 82, no. 47, Fall Meeting Supplement, Abstract H32D-0335. (Also available at <http://abstractsearch.agu.org/meetings/2001/FM/H32D-0335.html>.)