A Collection of Geologic Maps, Cross Sections, and Schematic Diagrams that Illustrate the Subsurface Geology of the Moscow-Pullman Basin and Vicinity

By John H. Bush, Pamela Dunlap, and Daisuke Kobayashi

2019

Prepared for the Palouse Basin Aquifer Committee

GEOLOGIC CROSS SECTIONS

INTRODUCTION

The Moscow-Pullman basin is filled with Miocene-age lava flows of the Columbia River Basalt Group (CRBG) and associated sediments of the Latah Formation that have a composite thickness greater than 2,700 ft (823 m). Domestic and municipal water supplies have been obtained from both the sediment and basalt units. Decades of continued water-level declines have prompted numerous hydrological studies, but accurate flow models have been difficult to construct due to the complexity of the subsurface architecture. Basalt units encountered in the subsurface were placed into a regional stratigraphic framework, and three geologic cross sections (Plates 1–3) were constructed to better understand the relationship between the sediments and individual basalt members and to assist in the interpretation of existing and future hydrological data.

SUBSURFACE GEOLOGY

The stratigraphic sequence and correlations of CRBG units were determined primarily from geochemical analyses of rock-chip cuttings collected from ten deep (700–2,250 ft [213–686 m]) wells (Bush and others, in press) and seven Washington Department of Ecology (DOE) test wells (Conrey and others, 2013). These determinations required comparisons to the regional stratigraphy as outlined by Reidel and others (2013a, b). Bush and others (2018) provided the geochemical data for the ten deep wells, discussed stratigraphic interpretations, and noted contributions by previous workers. Correlations to wells lacking whole-rock geochemical data were made using flow contacts and sediment horizons noted on drillers' reports. Sixteen members of the CRBG, made up of an estimated 25–30 lava flows, are illustrated and placed into three geologic formations; from base upward, they are the Grande Ronde, Wanapum, and Saddle Mountains Basalts. More than 90 percent of this basalt sequence belongs to the Grande Ronde Basalt which has been divided, from base upward, into the R1, N1, R2, and N2 magnetostratigraphic units (MSUs) (Swanson and others, 1980). The Latah Formation has been divided, from base upward, into the sediments of Moscow, the Vantage Member, and the sediments of Bovill (Bush and others, 1998).

Subdivision of the R1 and lower N1 MSUs into members is based only on samples from WSU well 7, and the position shown for the R1–N1 boundary should be considered tentative. The stratigraphic sequence upward from the top of the N1 is consistent from well to well. Correlations of the uppermost members of the Grande Ronde Basalt, the Vantage Member of the Latah Formation, and the Roza and Priest Rapids Members of the Wanapum Basalt were verified by comparisons to numerous drillers' reports and rare outcrops. Subsurface samples of the Latah Formation and descriptions are typically poor, and correlations of lithologies from well to well should be considered tentative.

The geologic cross section from about 4 mi (6 km) west of Pullman, Washington, to about 2 mi (3 km) east of Moscow, Idaho, (Plate 1) illustrates the nature of the subsurface dominated by slightly deformed CRBG lava flows in the western part and Latah Formation sediments in the eastern part. Most of the flows entered the basin from the west and pinch out and (or) thin near the state boundary. The folds in the Pullman area plunge to the northwest. They began to form at least as early as the R2 MSU of the Grande Ronde Basalt and, at times, acted as a barrier to lava emplacement into the basin. The Roza Member, in the western part of Plate 1, is the best example of a flow pinching out against the anticline.

The geologic cross sections in Plates 2 and 3 illustrate north-south relationships. They are more interpretive due to lack of subsurface data. Plate 2 shows the near-horizontal nature of the sequence in the central part of the basin, while Plate 3 portrays gentle folding beneath Pullman.

Hydrological Implications

The two primary groundwater systems in the Moscow-Pullman basin have been referred to as the upper and lower aquifers. The lower aquifer occurs entirely within the Grande Ronde Basalt and interbedded Latah Formation sediments, whereas the upper aquifer occurs primarily in the Vantage sediments (Latah Formation) and overlying basalt of Lolo (Wanapum Basalt). Some relationships between the subsurface geology and the aquifer systems are discussed briefly below.

LOWER AQUIFER

In Pullman, municipal water wells (Pullman 5, 7, 8; WSU 6, 8) were completed just above, in, and below sediments that separate the Cold Spring Ridge Member (CSRM) of the N1 MSU from the R2 MSU of the Grande Ronde Basalt. Primary production comes from this interval which contains gravel, hyaloclastite, sand, silt, and clay deposited by a stream system that existed in the Pullman area at the end of the N1 MSU (Bush and others, in press). Additional production comes from contacts between lava flows and flow-units of the overlying R2 MSU. All these producing zones are part of the lower aquifer. WSU well 7 was designed to obtain water from the lower aquifer (to a depth of 1,000 ft [305 m]) and then was extended to a depth of 2,225 ft (678 m) for research and exploration purposes. It subsequently was backfilled and grouted to a depth of 1,814 ft (553 m) (Wyatt-Jaykim Engineers and Ralston, 1987). Analytical modeling has indicated that, in Pullman, the lower aquifer is separated into upper and lower compartments with vertical leakage between the two (Moran, 2011; Folnagy, 2012). The lower compartment is believed to be primarily related to the sediment interbeds between the N1 and R2 MSUs and the upper compartment to flow contacts within the R2 sequence.

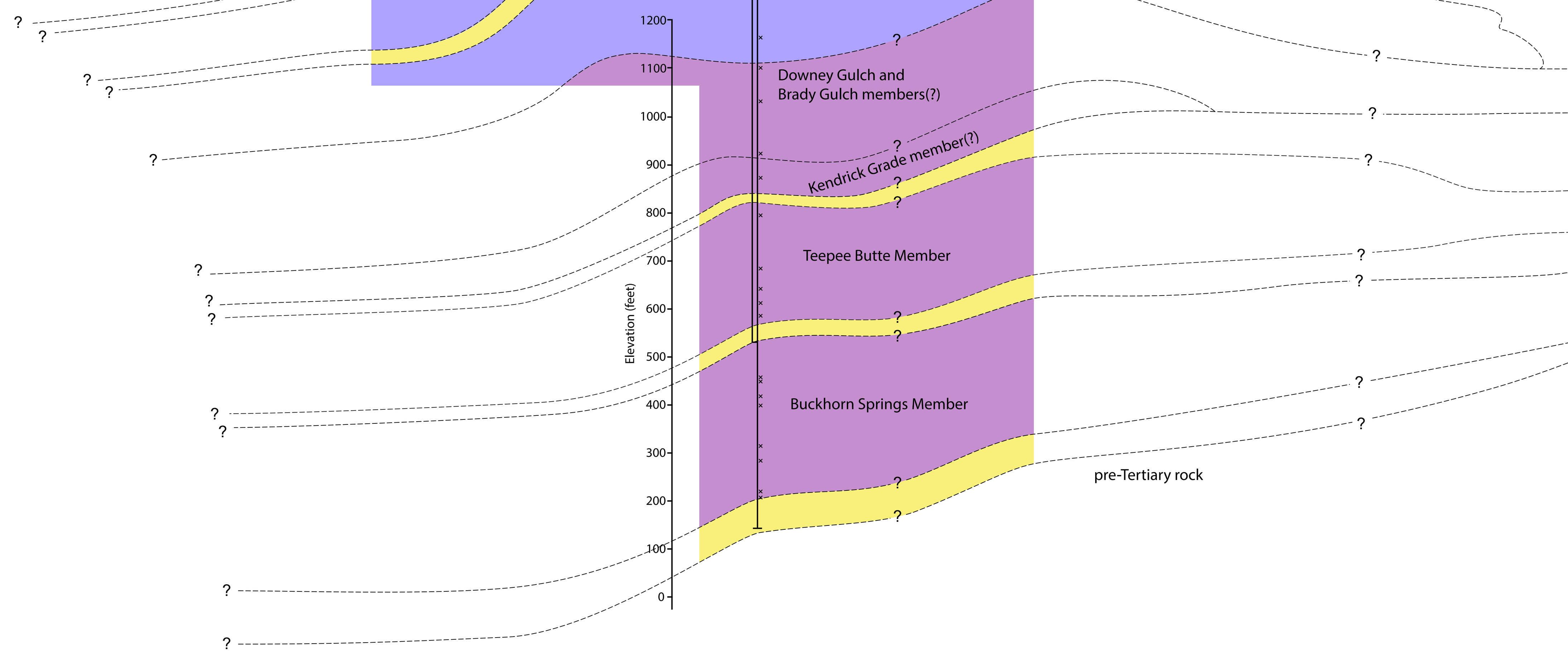
In Moscow, sediments dominate, flow contacts are not common, and the major production zones in the lower aquifer are not as consistent as they are in Pullman. Moscow city wells 9 and 10 and UI well 3 produce from the coarse-grained portions of the clay-rich sediments and the interlayered R2 basalts. In addition, Moscow city well 9 was also designed to obtain water from the base of the CSRM and the top of the underlying sediments. UI well 3 was also designed to produce water at various intervals within the CSRM and underlying sediments including weathered sands above granitic rocks. Thus, Moscow city well 9 and UI well 3 are composite wells in the sense that they obtain water from different stratigraphic horizons within the Grande Ronde Basalt and Latah Formation. Moscow city wells 6 and 8 were cased to the top of the CSRM and produce primarily from the underlying Latah sediments and to a much lesser extent from the CSRM. The CSRM is the most extensive CRBG member that can be correlated from well to well, and it ranges from 275 ft (84 m) beneath Pullman to 325 ft (99 m) below Moscow before terminating near the eastern end of the basin. At the DOE Pullman Test and Observation well, the CSRM top is a very dense basalt with rare vesicles. Beneath Moscow, where drill data and (or) well chips are available, the basalt is generally dense, not only at the top but throughout the unit, and the CSRM is considered an invasive unit in the eastern part of the basin. We believe the CSRM is a leaky aquitard throughout much of the basin. Folnagy (2012) and Fiedler (2009) determined that Moscow city wells 6 and 8 were hydrologically separated from the other Moscow city wells based on aquifer tests. In Pullman, Wyatt-Jaykim Engineers and Ralston (1987) noted that water-bearing zones below 1,000 ft (305 m) in depth in WSU well 7 likely were not as prolific as those intercepted above. Recognition of the CSRM as an aquitard is significant and should be considered in any hydrological model of the Moscow-Pullman basin.

UPPER AQUIFER

Domestic and municipal water supplies are obtained from the upper aquifer, but production varies from less than 1 gallon per minute (gpm) to more than 1,000 gpm. The variations of thicknesses and lithology of the Vantage Member of the Latah Formation are considered the primary controls on supply (Bush and others, 2016). For example, in the central part of the basin, the Vantage is thin and consists primarily of clay, thus wells are generally only capable of very low yields. Large-production wells have been developed in the Vantage Member where it is thick (> 200 ft [61 m]) by both the City of Moscow and the University of Idaho. The Vantage is clay rich, but zones of coarse-grained materials provide the necessary permeability for the high-production wells. These high-yield wells follow a north-south trend through the western part of Moscow along ancient stream channels responsible for the deposition of the Vantage Member (Bush and others, 2016, in press). These streams existed east of the pinchouts of the N2 and upper R2 MSUs of the Grande Ronde Basalt, as noted in Plate 1.

ACKNOWLEDGMENTS

The Palouse Basin Aquifer Committee provided the major part of the funds for our research. Steve Robischon provided information throughout the research project. The Department of Geological Sciences at the University of Idaho provided technical assistance. Too numerous to mention are the people who collected samples from wells over a period of five decades. We were encouraged and helped by the work of Rick Conrey and his co-authors (Conrey and Wolff, 2010; Conrey and others, 2013; Conrey and Crow, 2014) who provided data and interpretations to the Committee. Reviews by Alexis Clark, Dennis M. Feeney, Reed Lewis, and Robin Nimmer greatly improved the manuscript. Special thanks to Reed Lewis of the Idaho Geological Survey who assisted and encouraged us to submit our cross sections for publication.



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EXPLANATION

Columbia River Basalt Group
- Saddle Mountains Basalt
  - Weissenfels Ridge Member(?)
- Wanapum Basalt
- Grande Ronde Basalt
  - N_2 Magnetostratigraphic Unit (MSU)
  - R_2 MSU
  - N_1 MSU
  - R_1 MSU

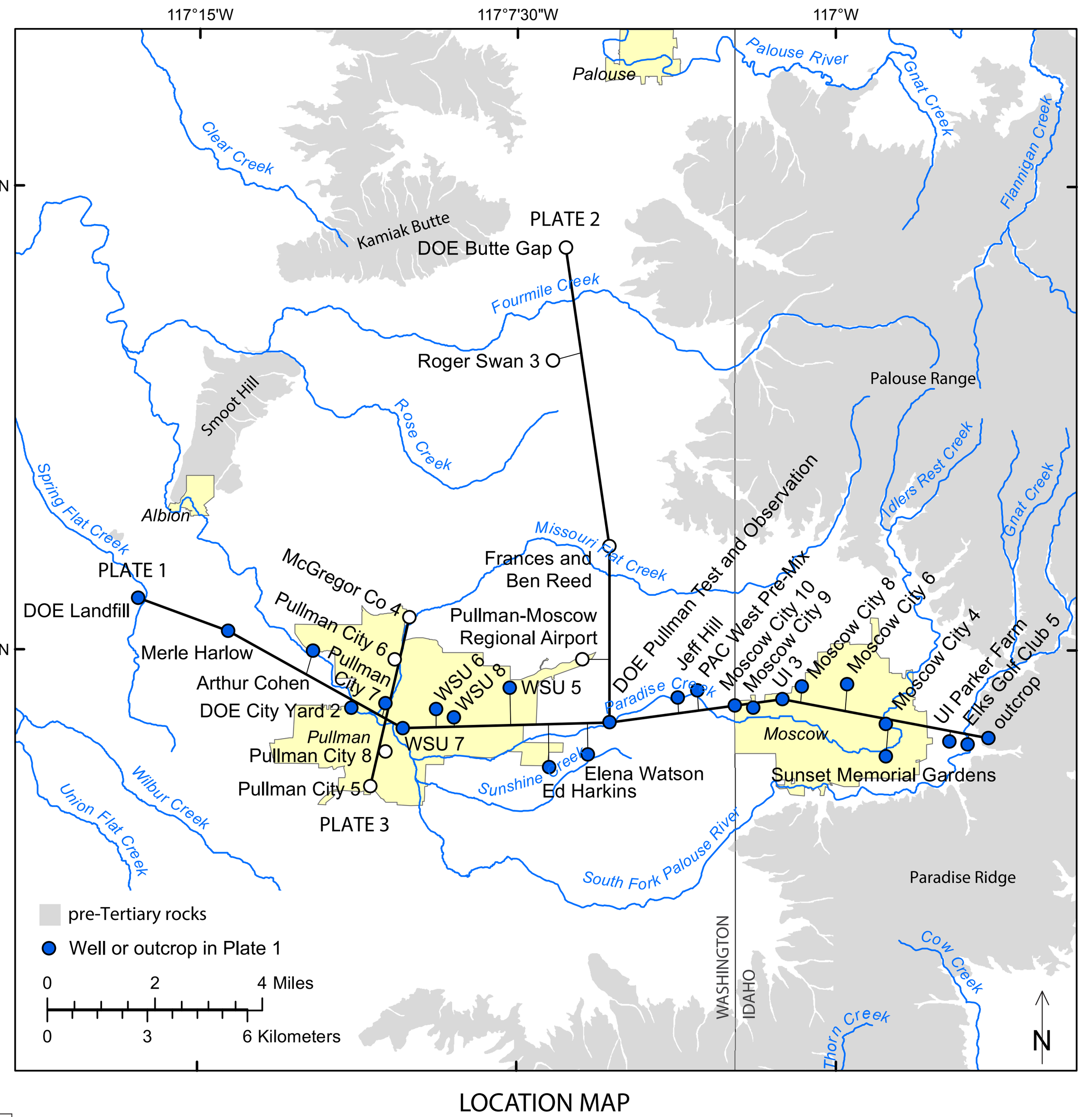
Latah Formation
- Grain size unknown
- Gravel
- Sand
- Silt and clay
- Clay
- Palagonite

x Approximate location of basalt sample analyzed for chemistry

Uncased, perforated, or screened intervals for some wells

* Well projected onto cross section

Note: Surface shown is the first Tertiary rocks encountered after drilling through the Palouse Formation (loess). The boundary between Palouse Formation and sediments of Bovill was estimated.



LOCATION MAP

Geologic Cross Section Through Pullman and Moscow

Geologic Cross Sections Across the Moscow-Pullman Basin, Idaho and Washington

By

John H. Bush[1], Pamela Dunlap[2], Stephen P. Reidel[3], and Daisuke Kobayashi[4]

2018

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[4]Department of Earth Sciences, The College at Brockport, State University of New York, Brockport, New York 14420

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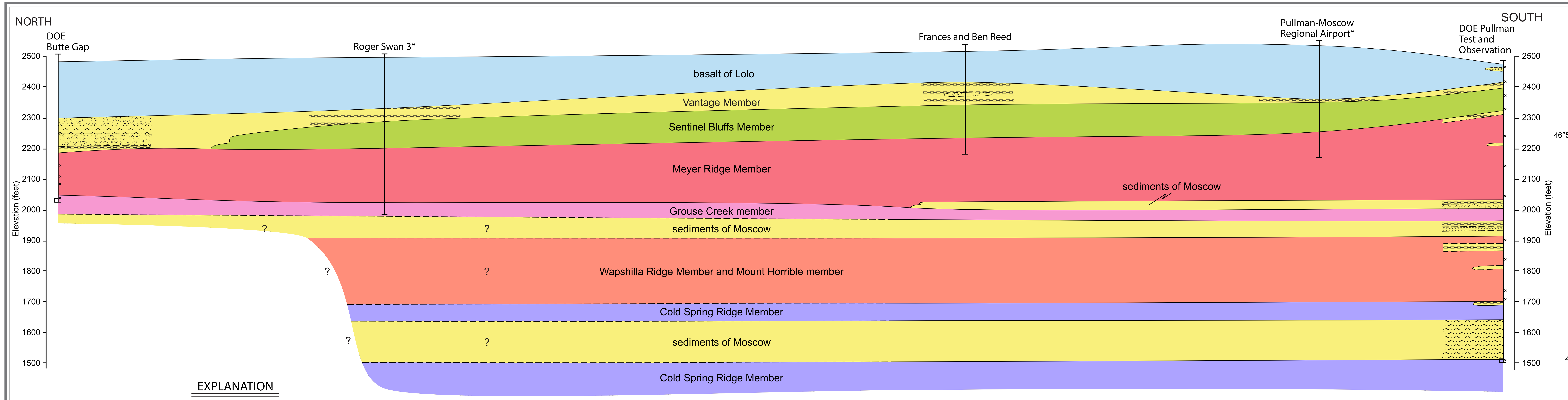
Plate 2 of 3



EXPLANATION

Columbia River Basalt Group

- Wanapum Basalt
- Grande Ronde Basalt
  - N_2 Magnetostratigraphic Unit (MSU)
  - R_2 MSU
  - N_1 MSU

Latah Formation

- Grain size unknown
- Gravel
- Sand
- Silt and clay
- Clay

x Approximate location of basalt sample analyzed for chemistry

Uncased, perforated, or screened intervals for some wells

* Well projected onto cross section

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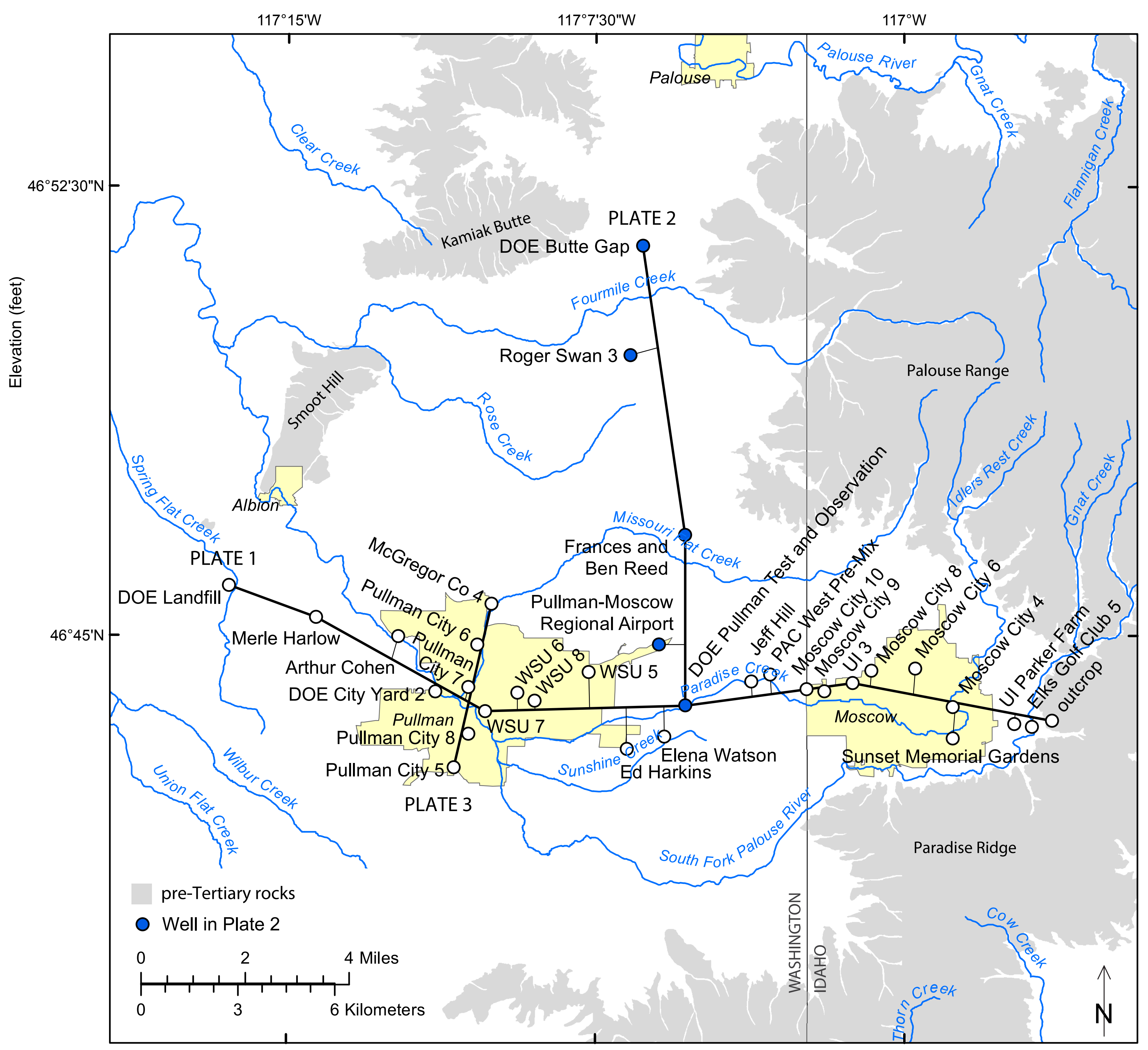
SCALE 1:24,000

0 5,000 Feet

0 2,000 Meters

10x vertical exaggeration



LOCATION MAP

Geologic Cross Section Across the Central Part of the Moscow-Pullman Basin

Geologic Cross Sections Across the Moscow-Pullman Basin, Idaho and Washington

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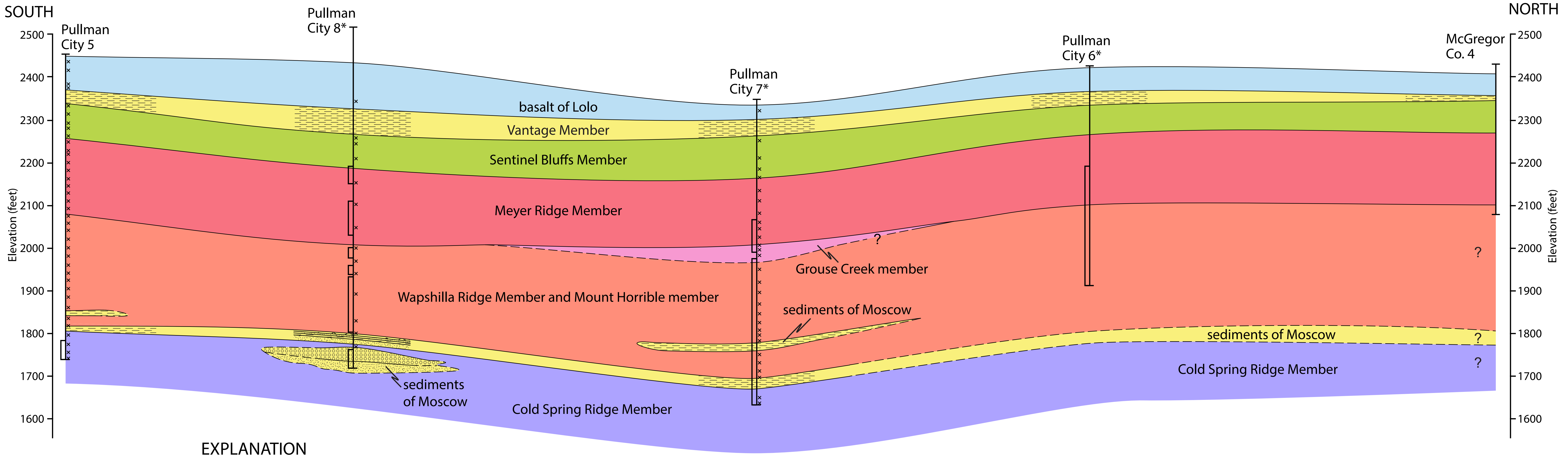


EXPLANATION

Columbia River Basalt Group

Wanapum Basalt

Grande Ronde Basalt

N_2 Magnetostratigraphic Unit (MSU)

R_2 MSU

N_1 MSU

Latah Formation

Grain size unknown

Gravel

Sand

Silt and clay

Clay

x Approximate location of basalt sample analyzed for chemistry

Uncased, perforated, or screened intervals for some wells

* Well projected onto cross section

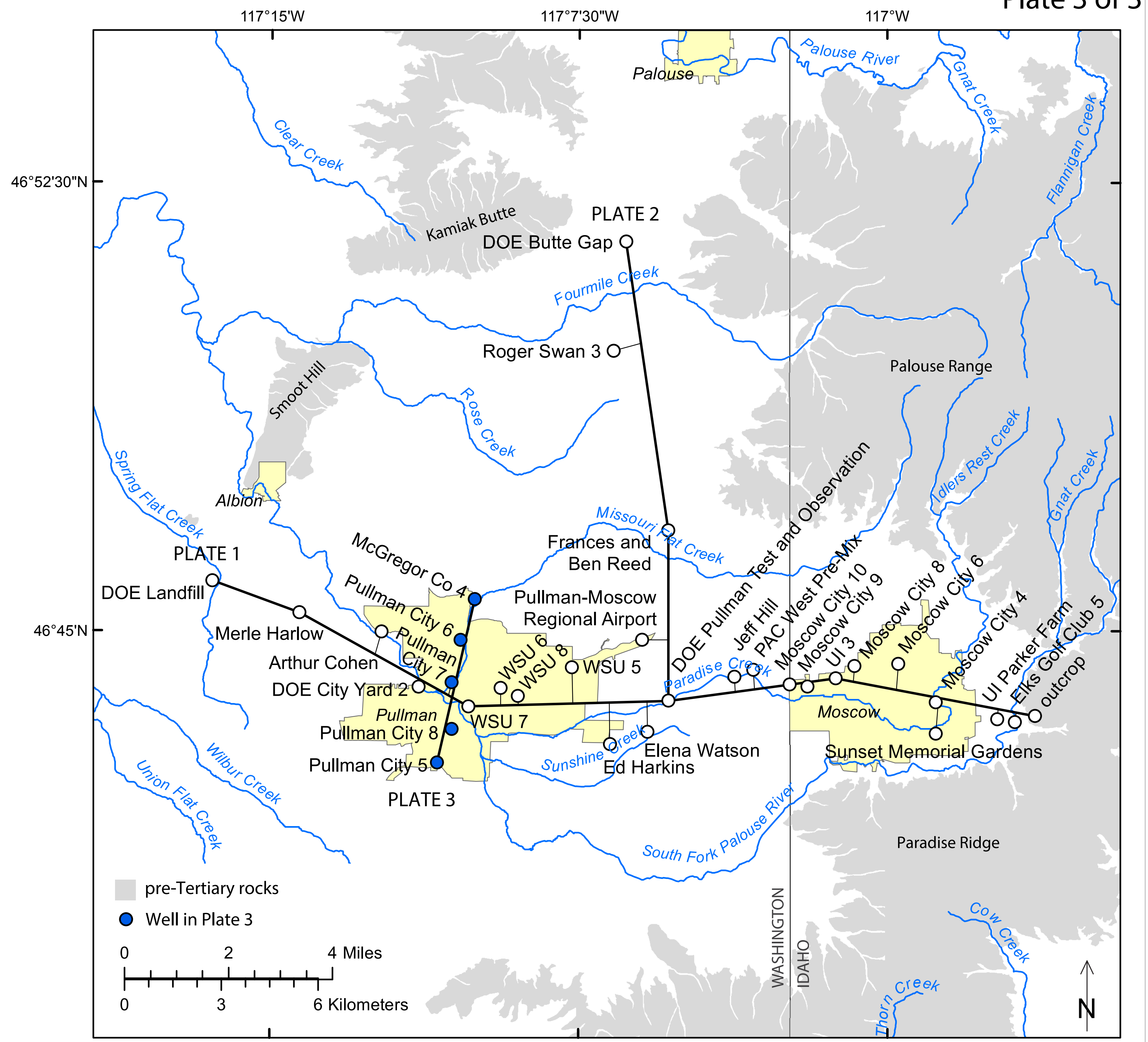
Note: Surface shown is the first Tertiary rocks encountered after drilling through the Palouse Formation (loess). The boundary between Palouse Formation and sediments of Bovill was estimated.

SCALE 1:24,000

0 — 5,000 Feet

0 — 2,000 Meters

10x vertical exaggeration



LOCATION MAP

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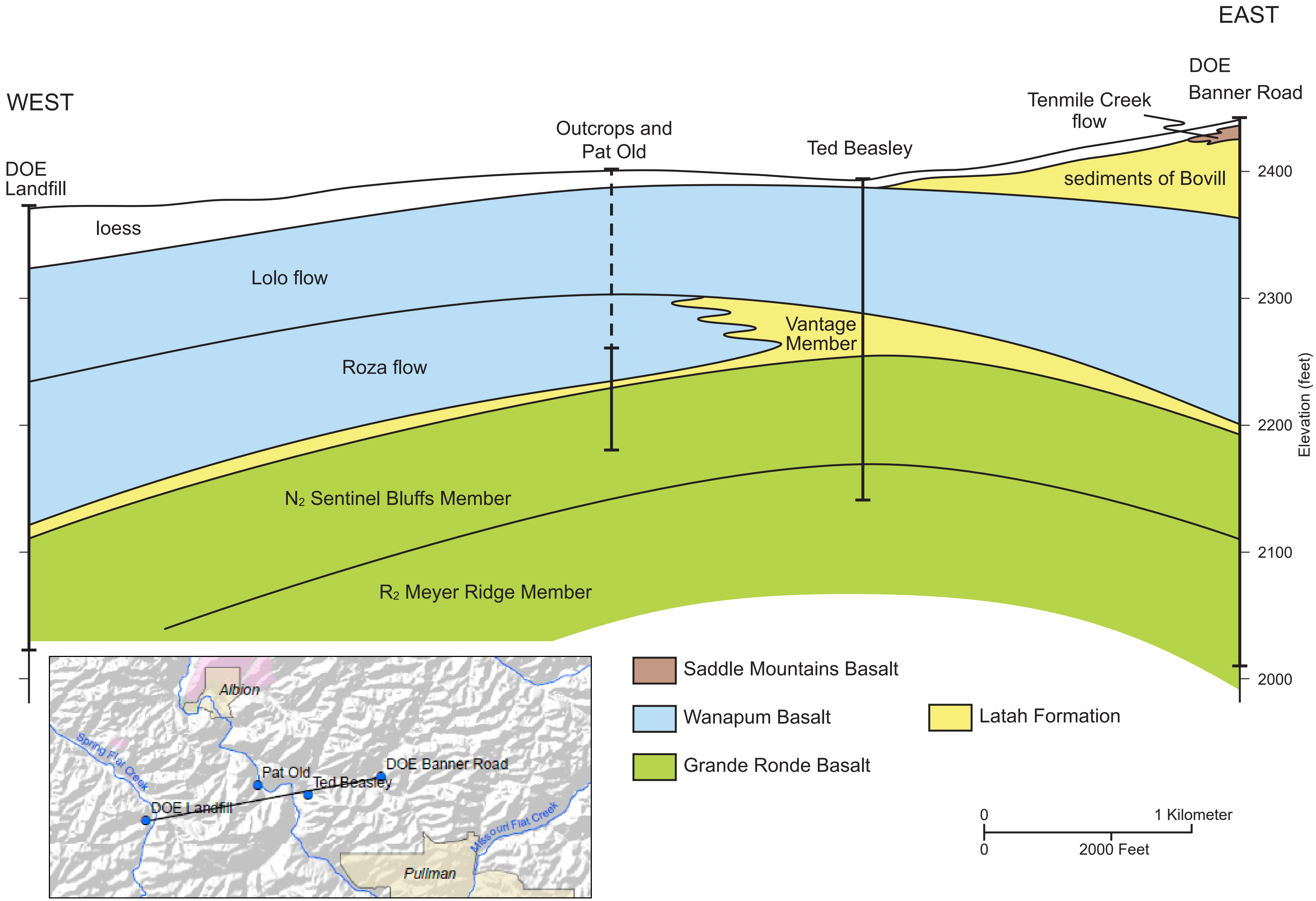
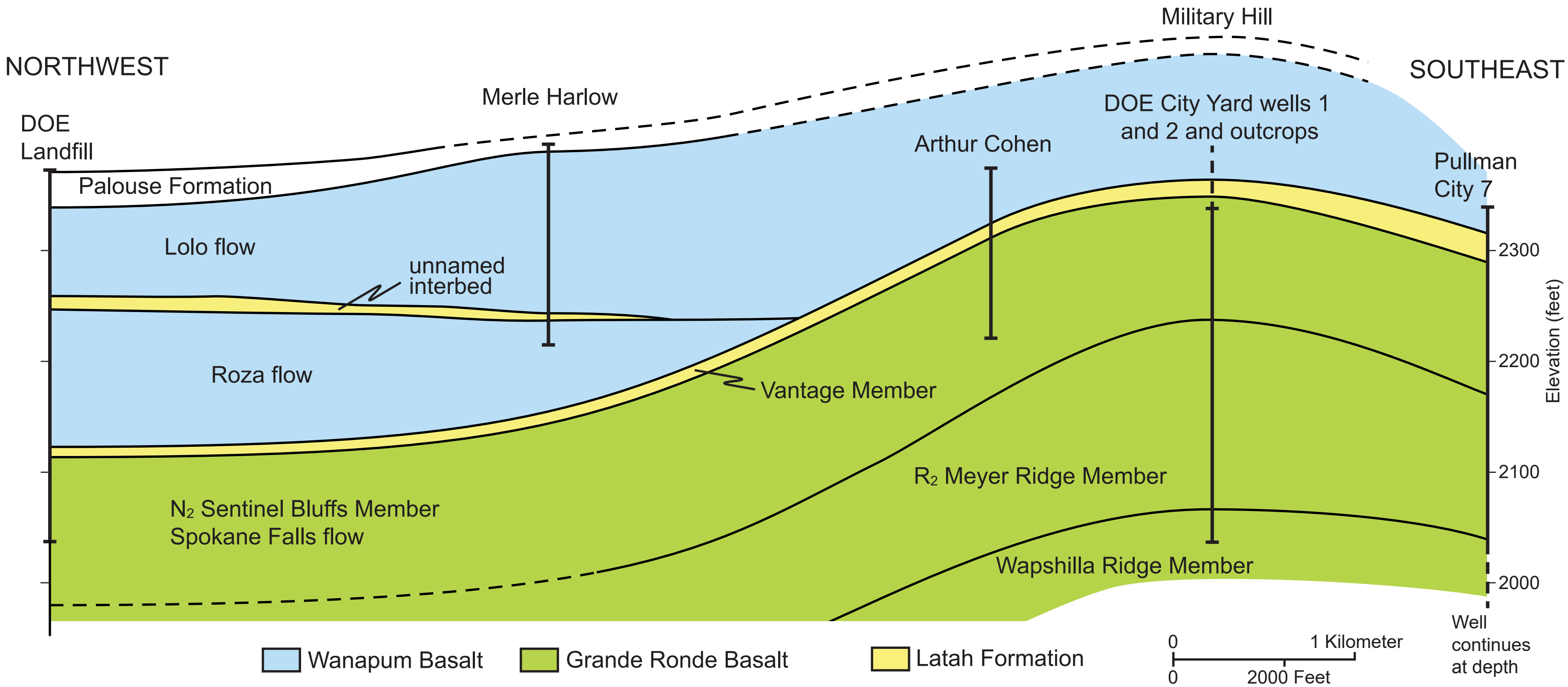
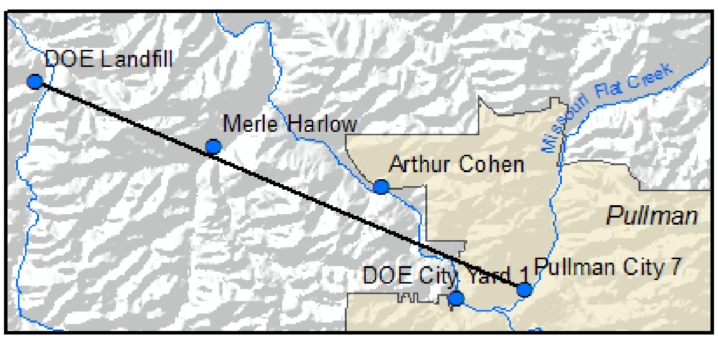


Figure 4. West-to-east geologic cross section from DOE Landfill well to DOE Banner Road well, Whitman County, Washington, showing the northwest part of the anticline at Pullman (from Bush and others, 2018, Figure 5).

Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).





By John H. Bush, Pamela Dunlap, and Daisuke Kobayashi, 2017

Figure 5. Northwest-to-southeast geologic cross section from DOE Landfill well to Pullman City well 7, Pullman, Washington.

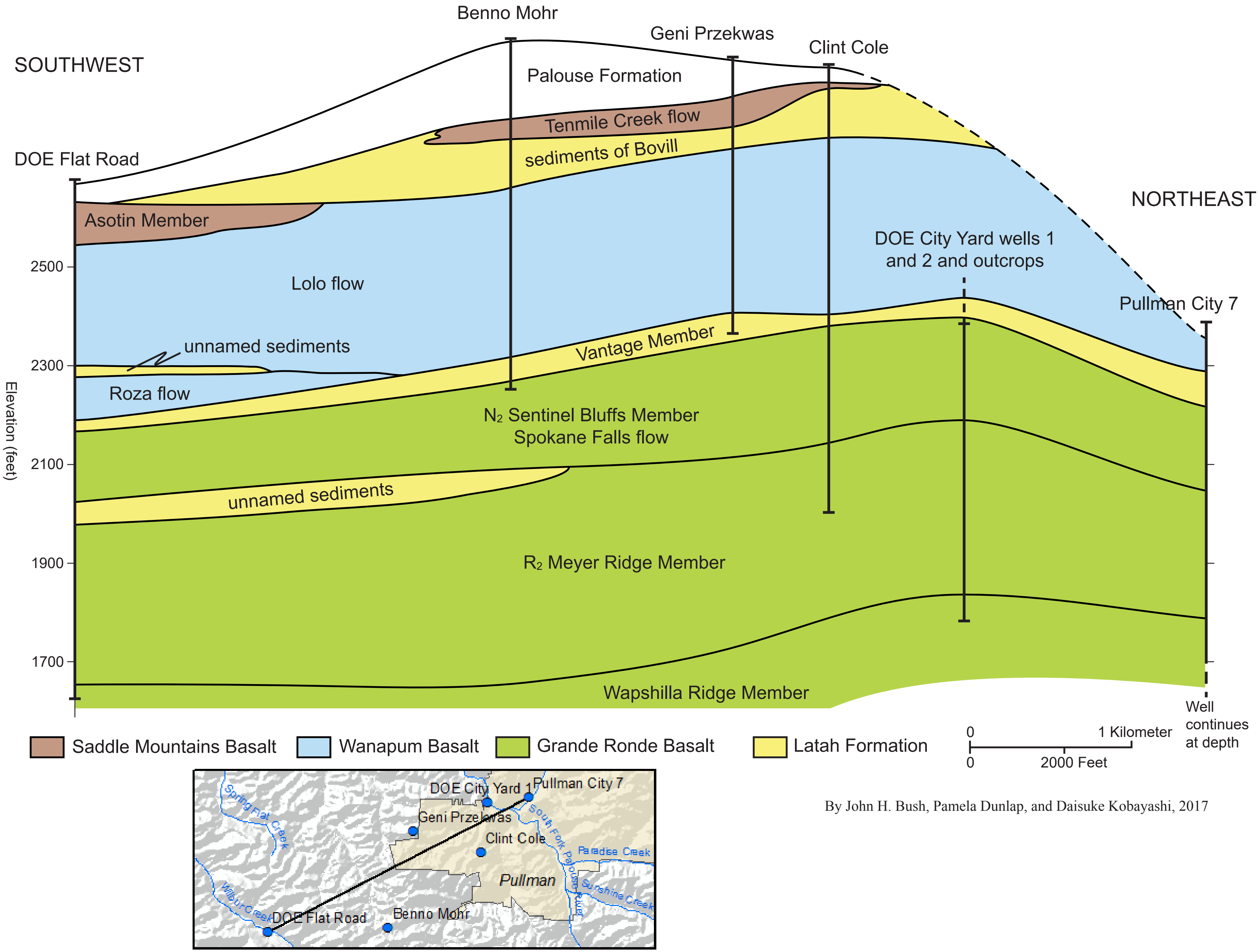


Figure 6. Southwest-to-northeast geologic cross section from DOE Flat Road well to Pullman City well 7, Whitman County, Washington.

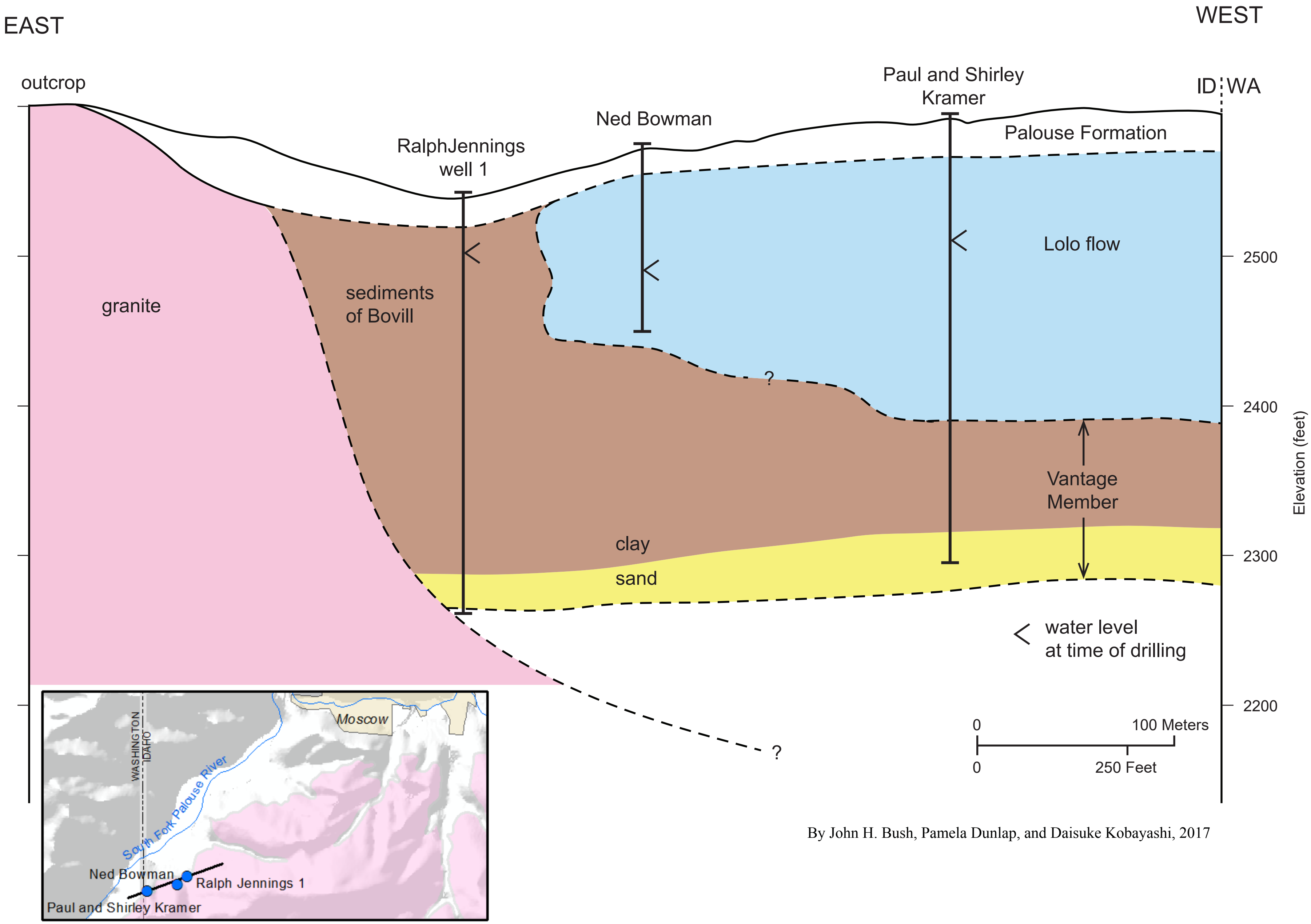


Figure 7. East-to-west geologic cross section near South Fork Palouse River, southwest of Moscow, Idaho.

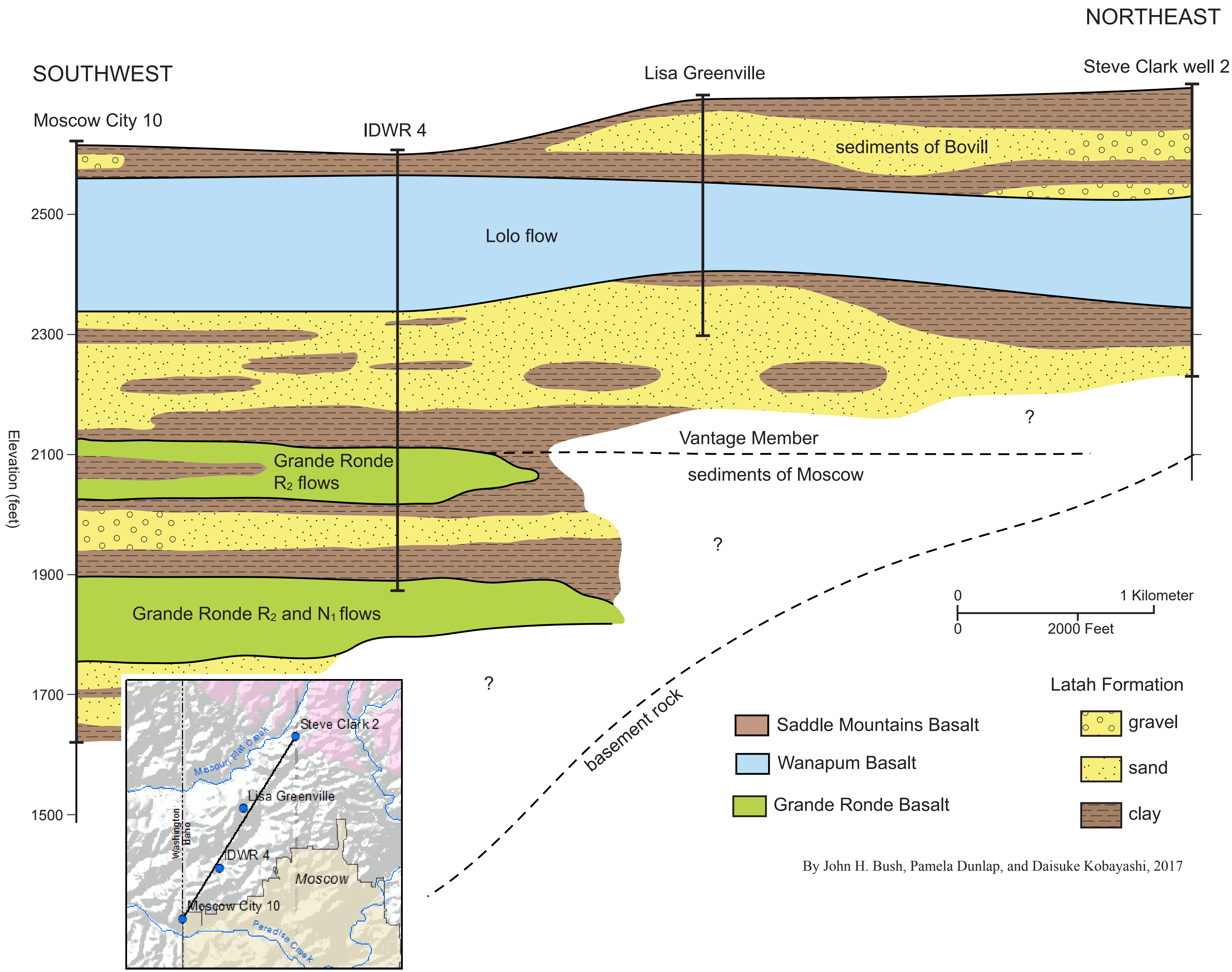


Figure 8. Southwest-to-northeast geologic cross section from Moscow City well 10 to Steve Clark well 2, Latah County, Idaho.

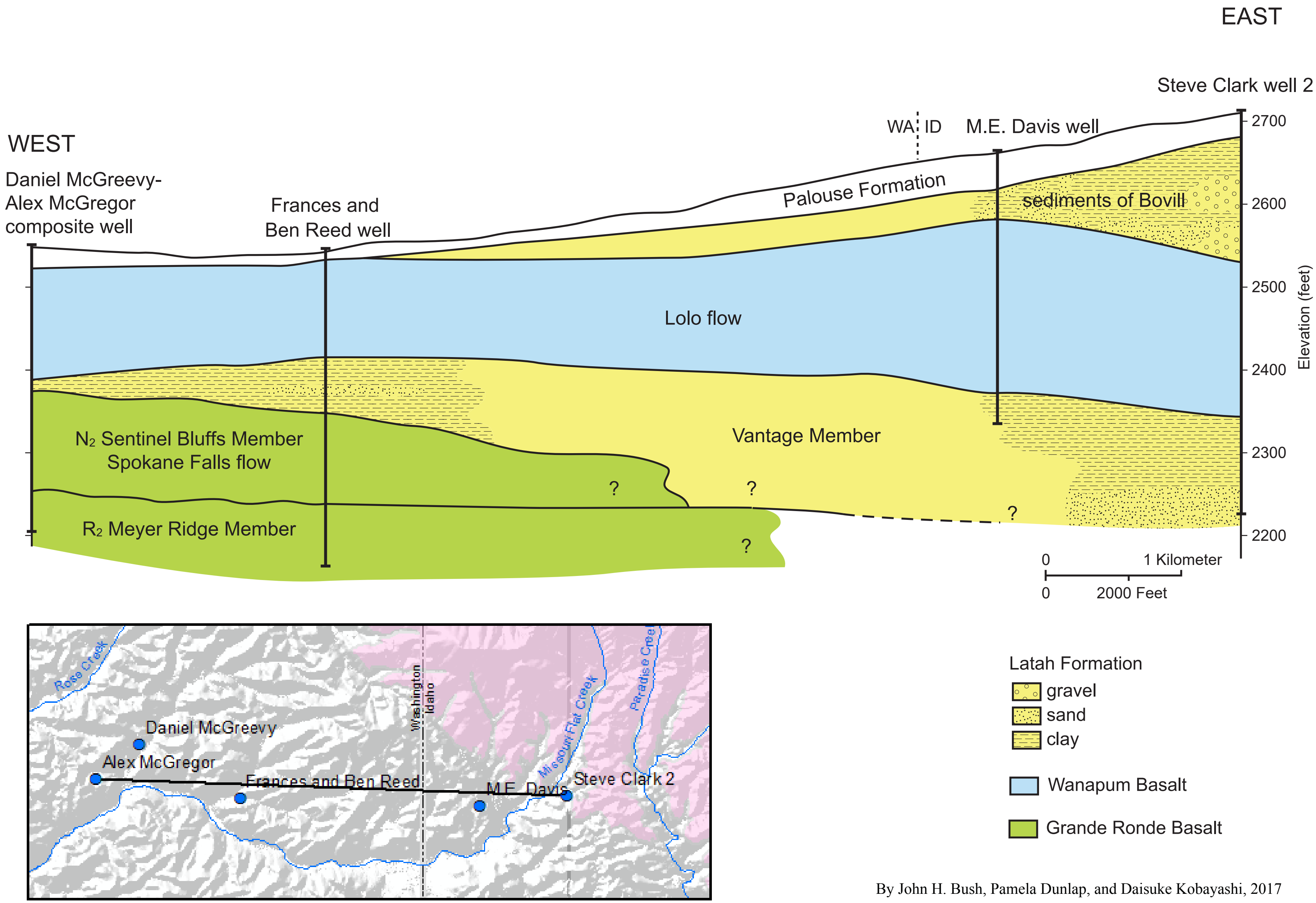


Figure 9. West-to-east geologic cross section from the Daniel McGreevy-Alex McGregor composite well sequence, Whitman County, Wash., to Steve Clark well 2, Latah County, Idaho.

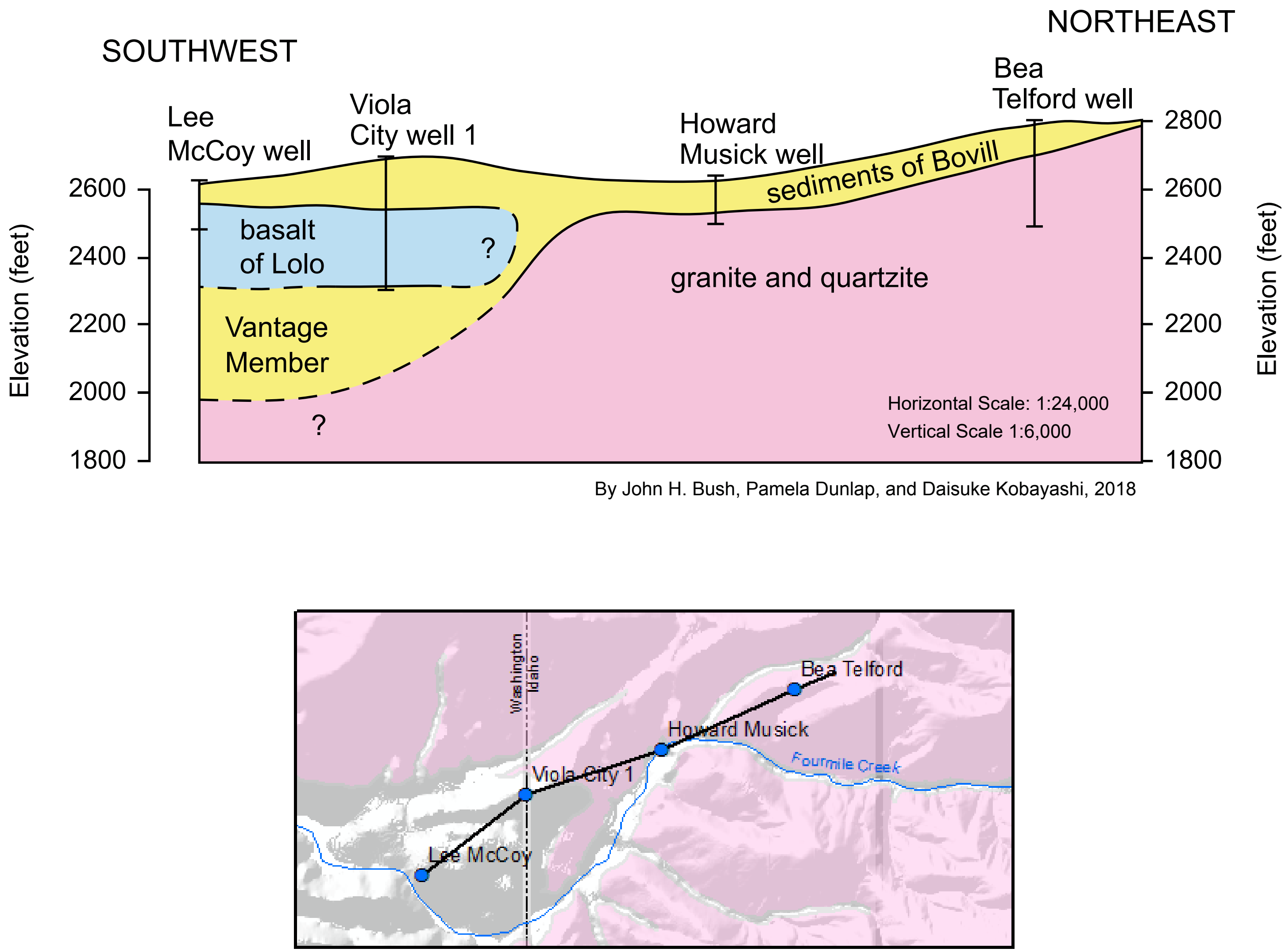


Figure 10. Southwest to northeast geologic cross section through the community of Viola, Idaho.
Note: loess is included with sediments of Bovill.

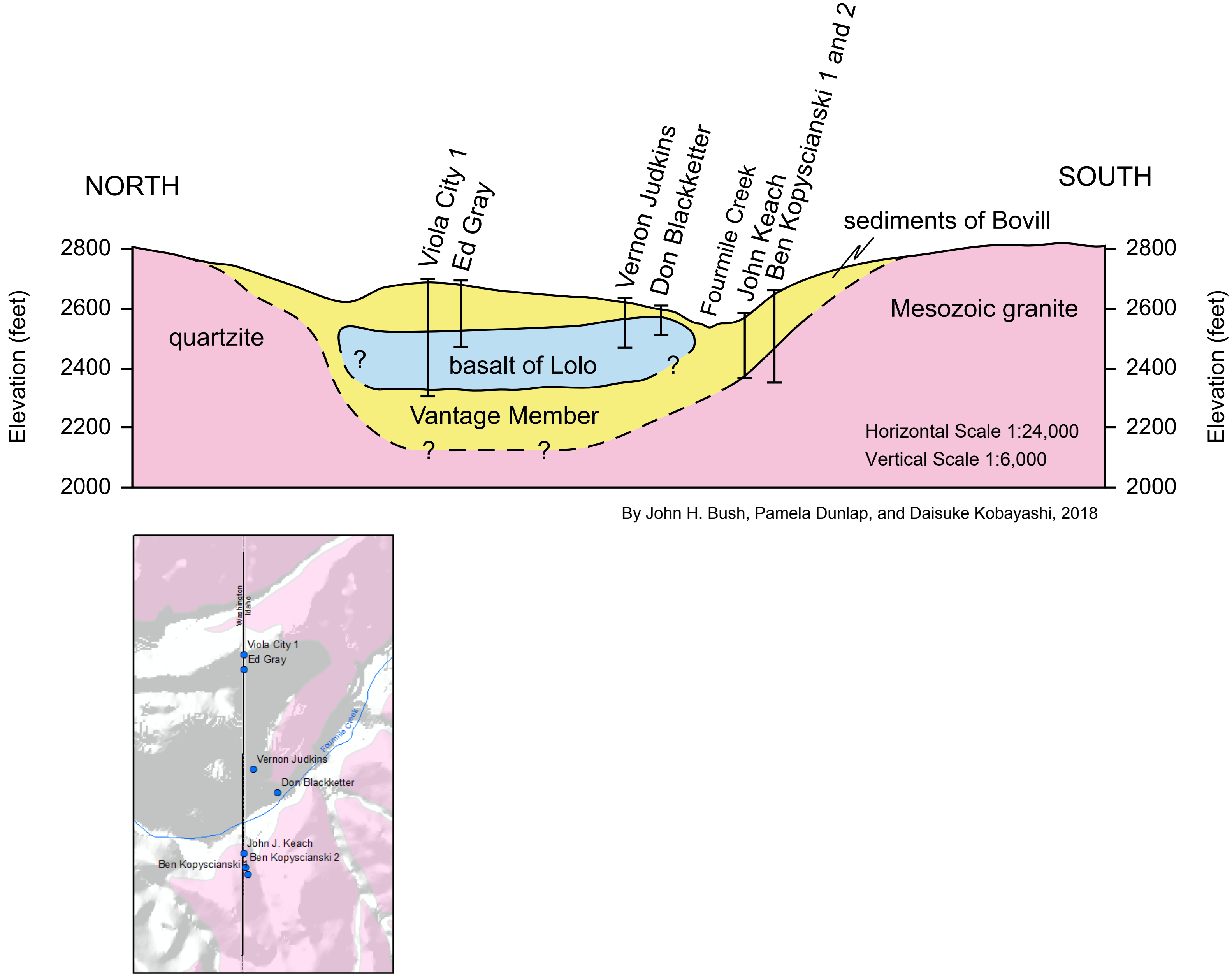


Figure 11. North-south geologic cross section along the Idaho–Washington state boundary, one mile west of Viola, Idaho. Note: loess is included with sediments of Bovill.

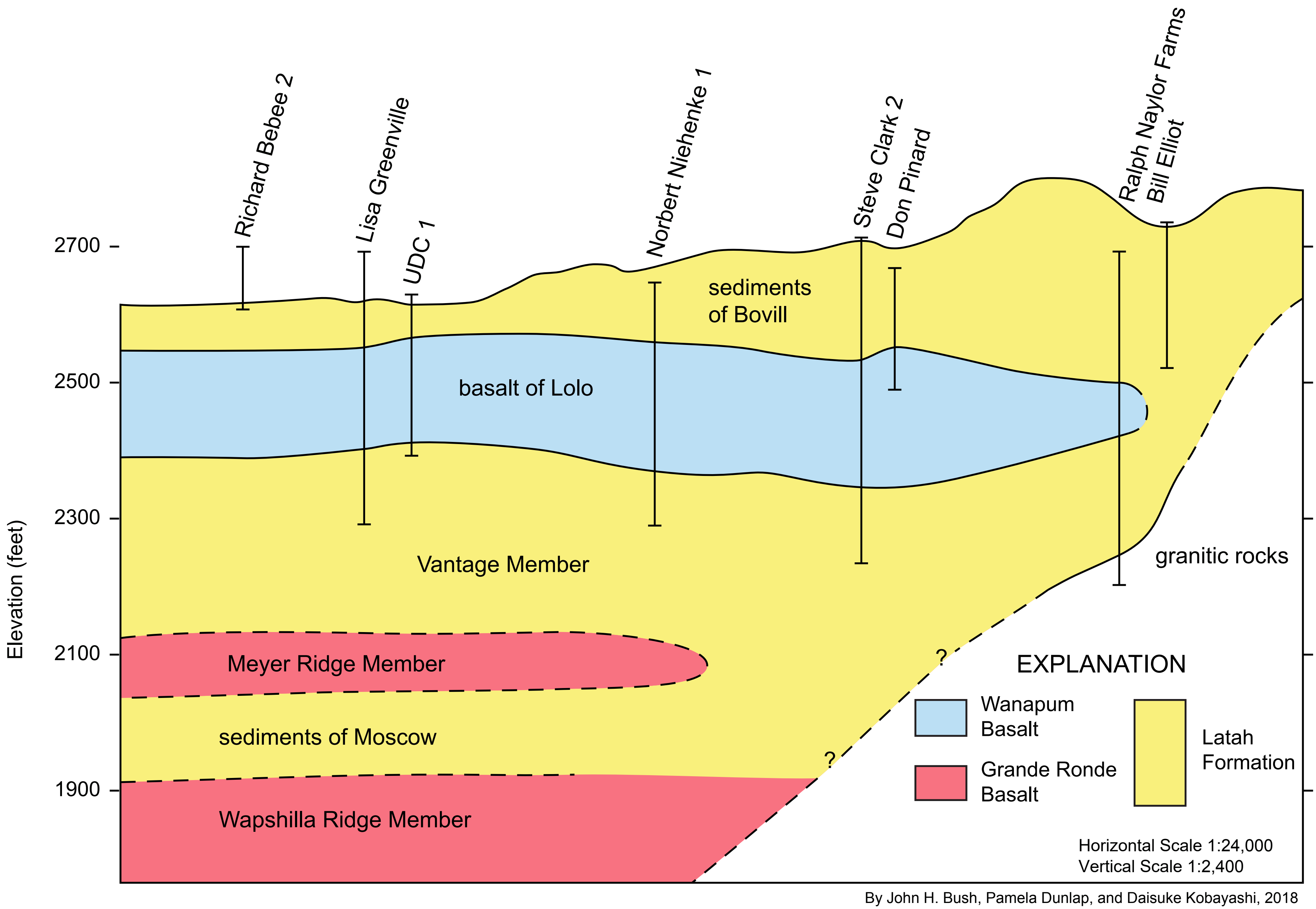
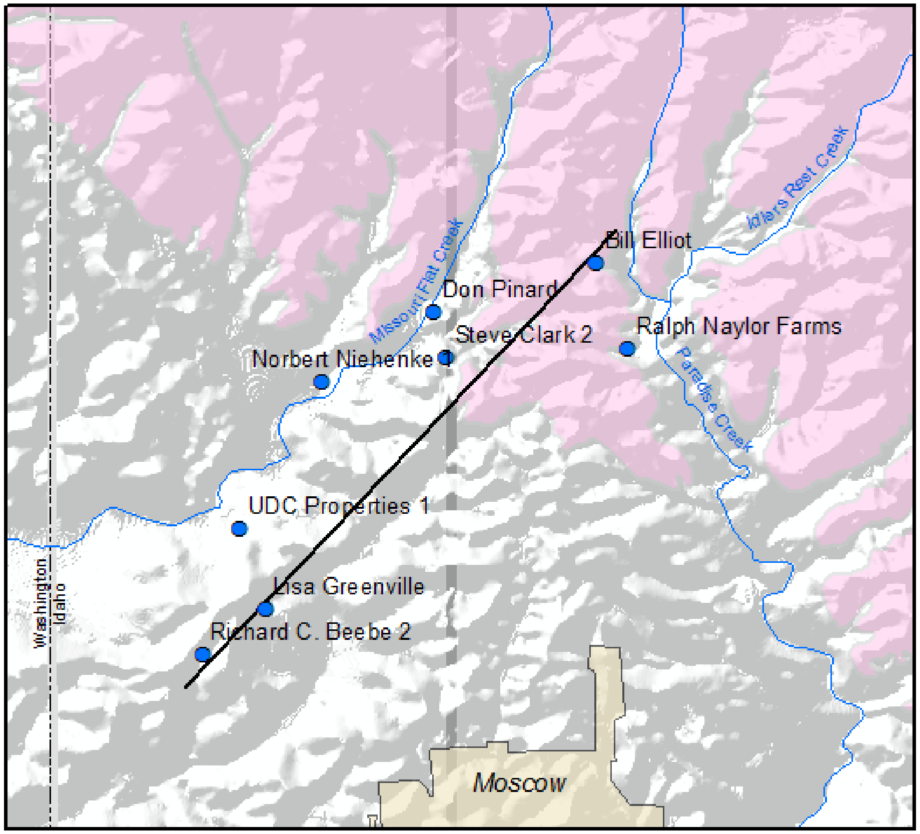


Figure 12. Geologic cross section along part of Missouri Flat Creek, Latah County, Idaho. Note: loess is included with sediments of Bovill.



Index map showing line of cross section in Figure 12.

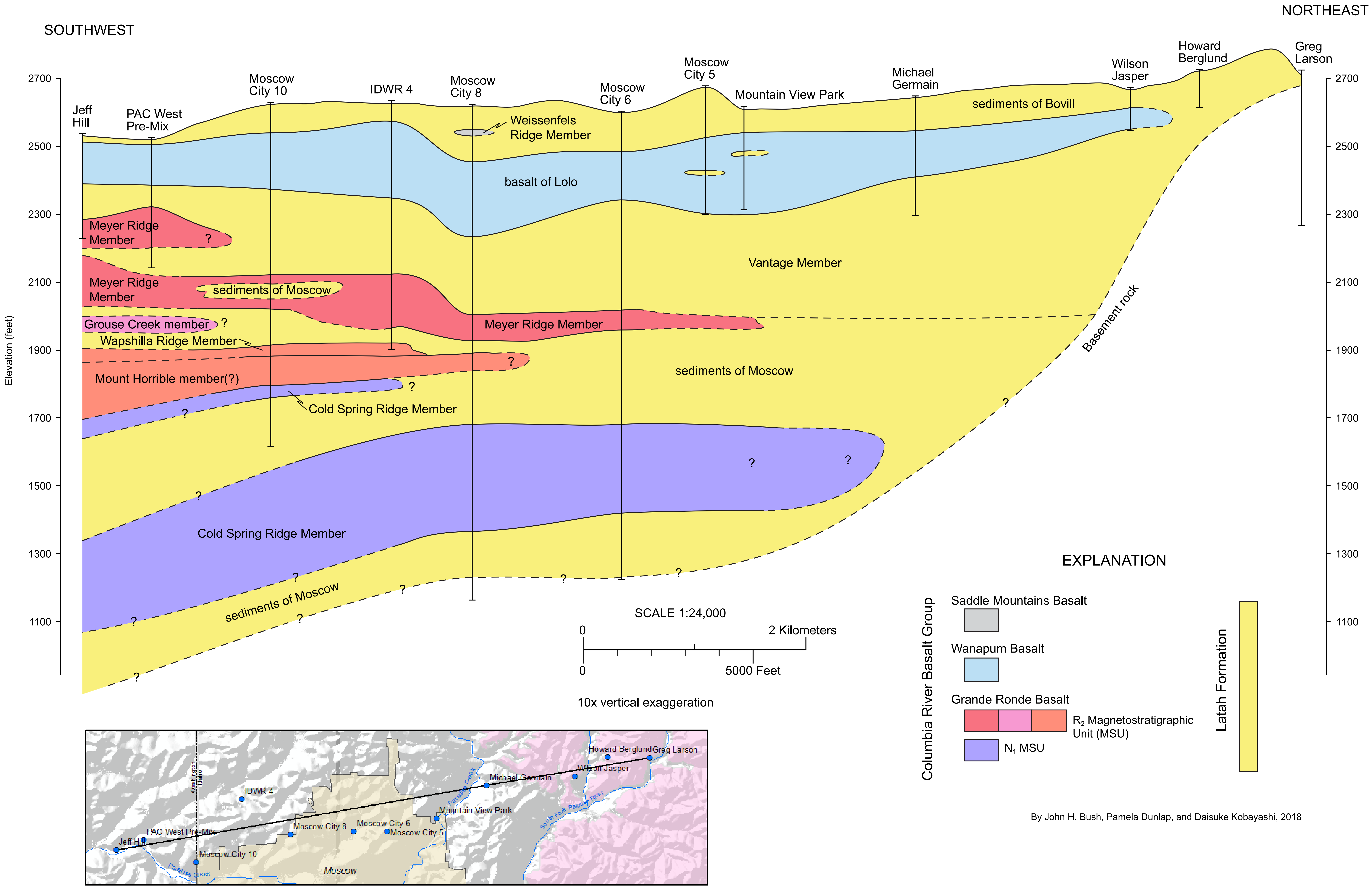


Figure 13. Southwest-to-northeast geologic cross section through Moscow, Idaho. Note: loess is included with sediments of Bovill.

DIAGRAMMATIC GEOLOGIC CROSS SECTIONS

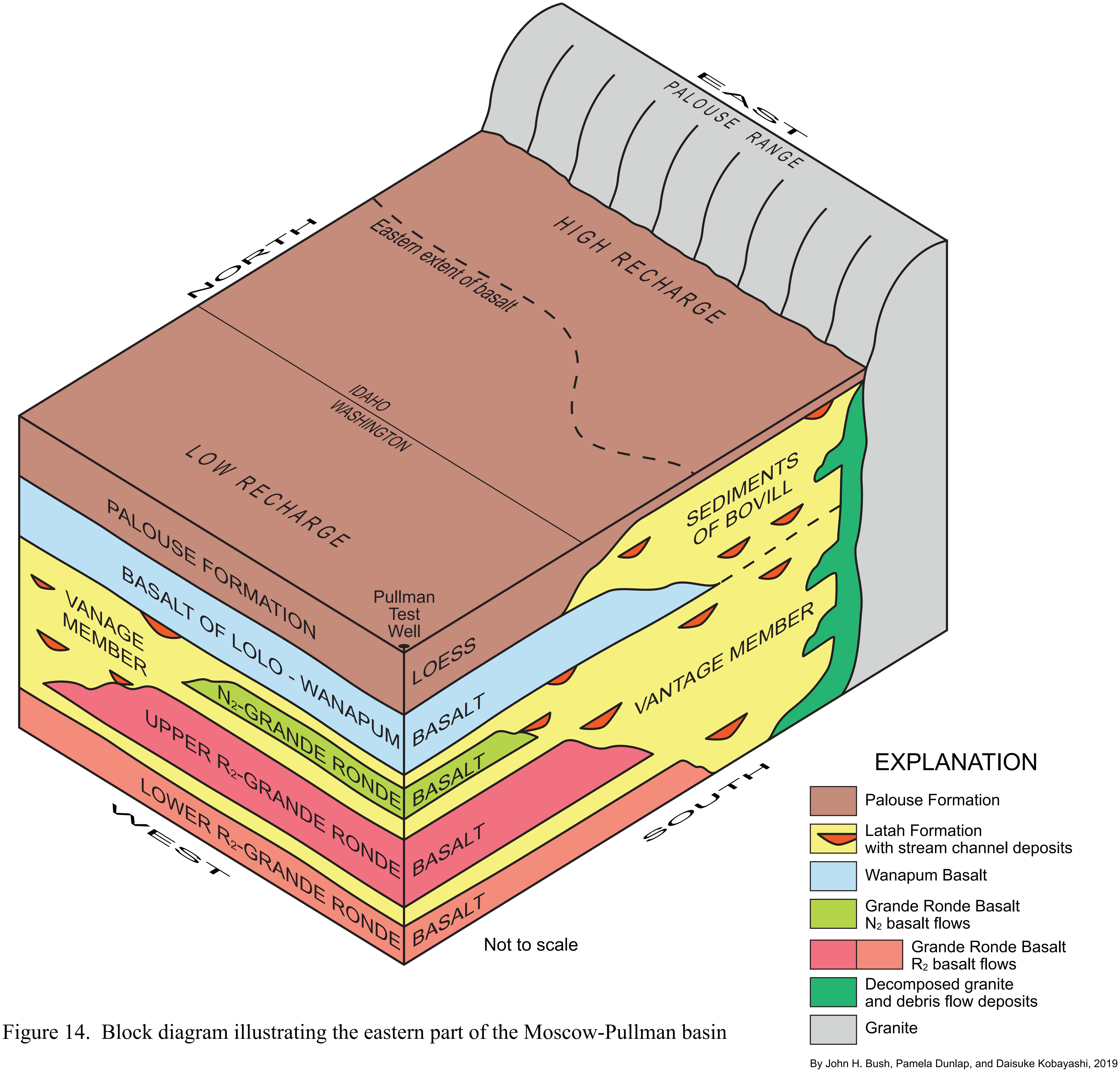


Figure 14. Block diagram illustrating the eastern part of the Moscow-Pullman basin

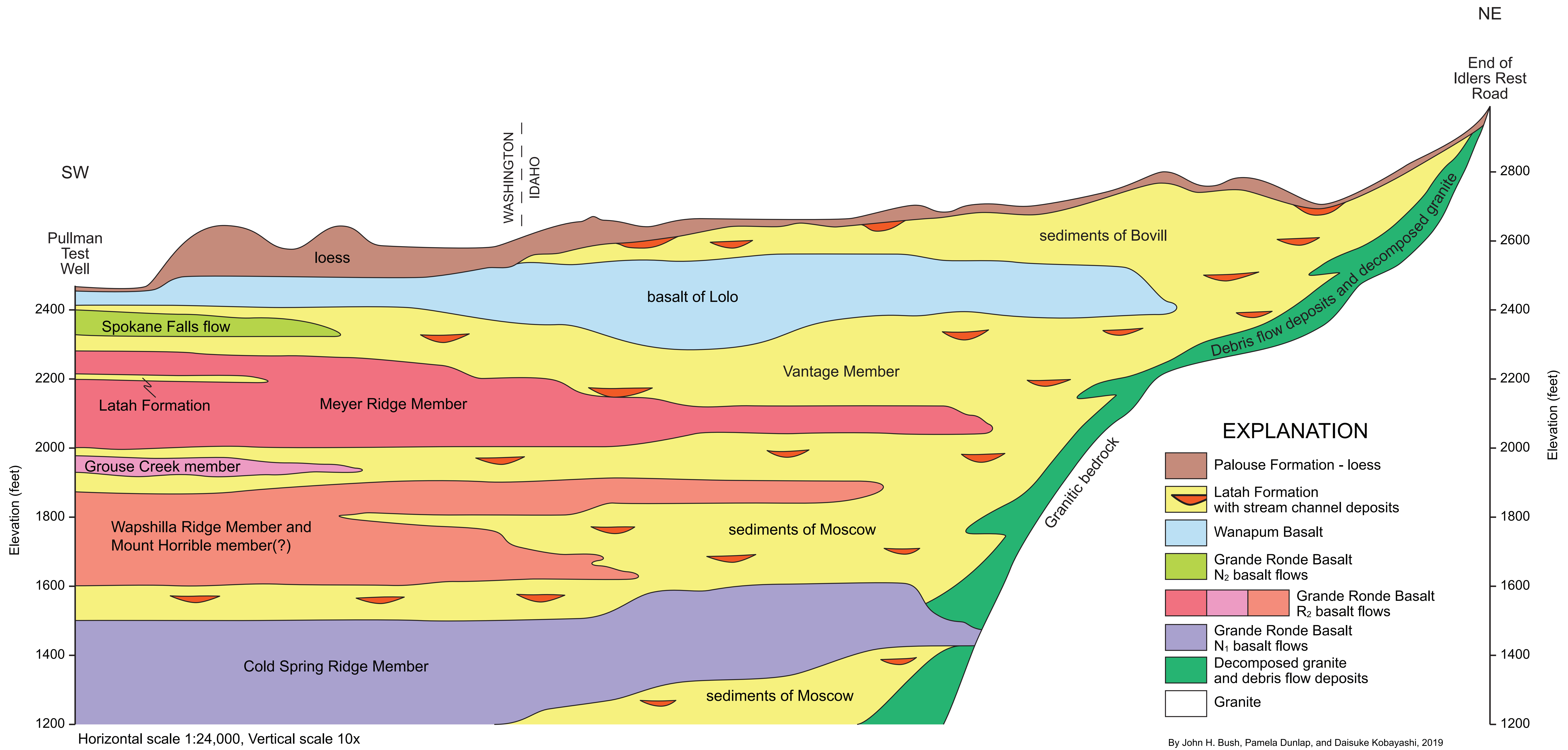


Figure 15. Diagrammatic geologic cross section from the Pullman Test and Observation well, Wash., to end of Idlers Rest Road, Idaho.

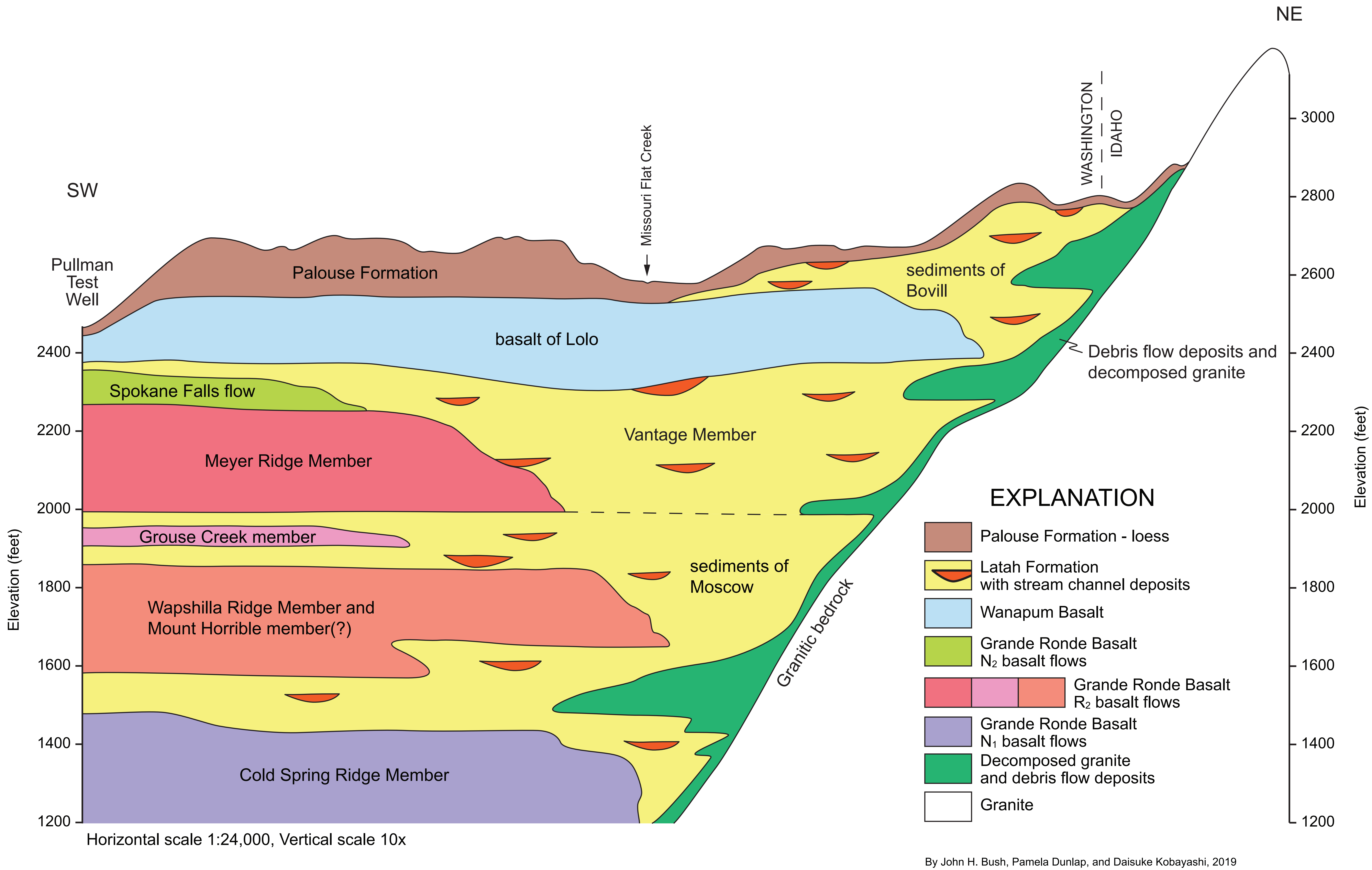


Figure 16. Diagrammatic geologic cross section from the Pullman Test and Observation well, Wash., to west end of Palouse Range, Idaho.

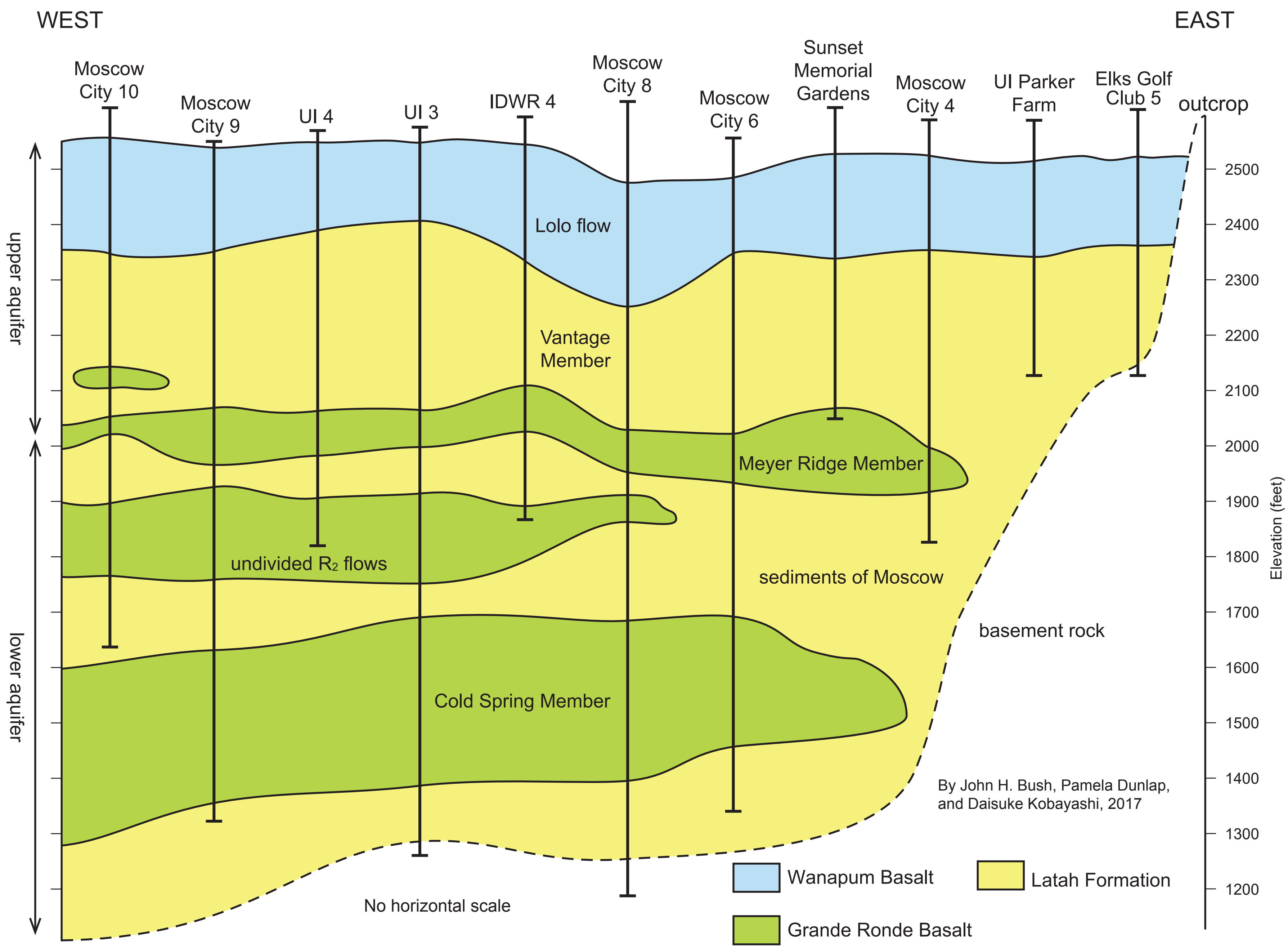


Figure 17. Diagrammatic west-to-east geologic cross section through Moscow, Idaho. (See index map on Plate 1 for location of wells.)

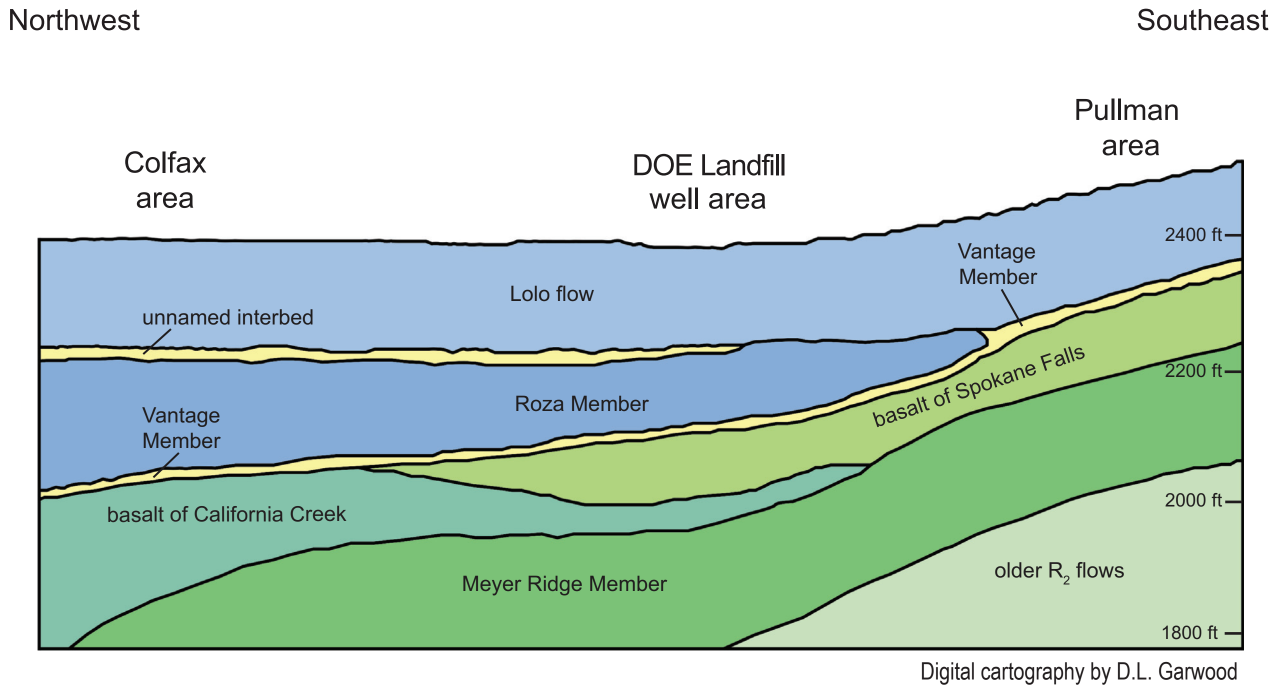


Figure 18. Diagrammatic geologic cross section showing stratigraphic relations from Colfax (northwest) to Pullman (southeast) (from Bush and others, 2016, Figure 14).

Bush, J.H., Garwood, D.L., and Dunlap, Pamela, 2016, Geology and geologic history of the Moscow-Pullman basin, Idaho and Washington, from late Grande Ronde to late Saddle Mountains time, *in* Lewis, R.S., and Schmidt, K.L., eds., Exploring the Geology of the Inland Northwest: Geological Society of America Field Guide 41, p.151–174.

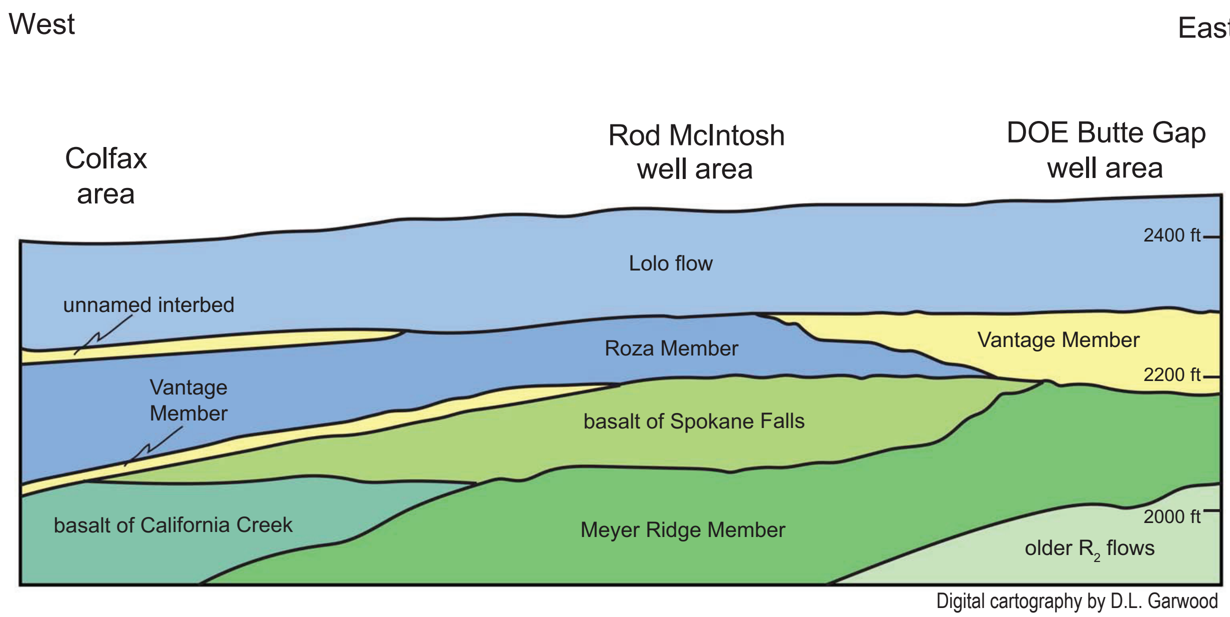
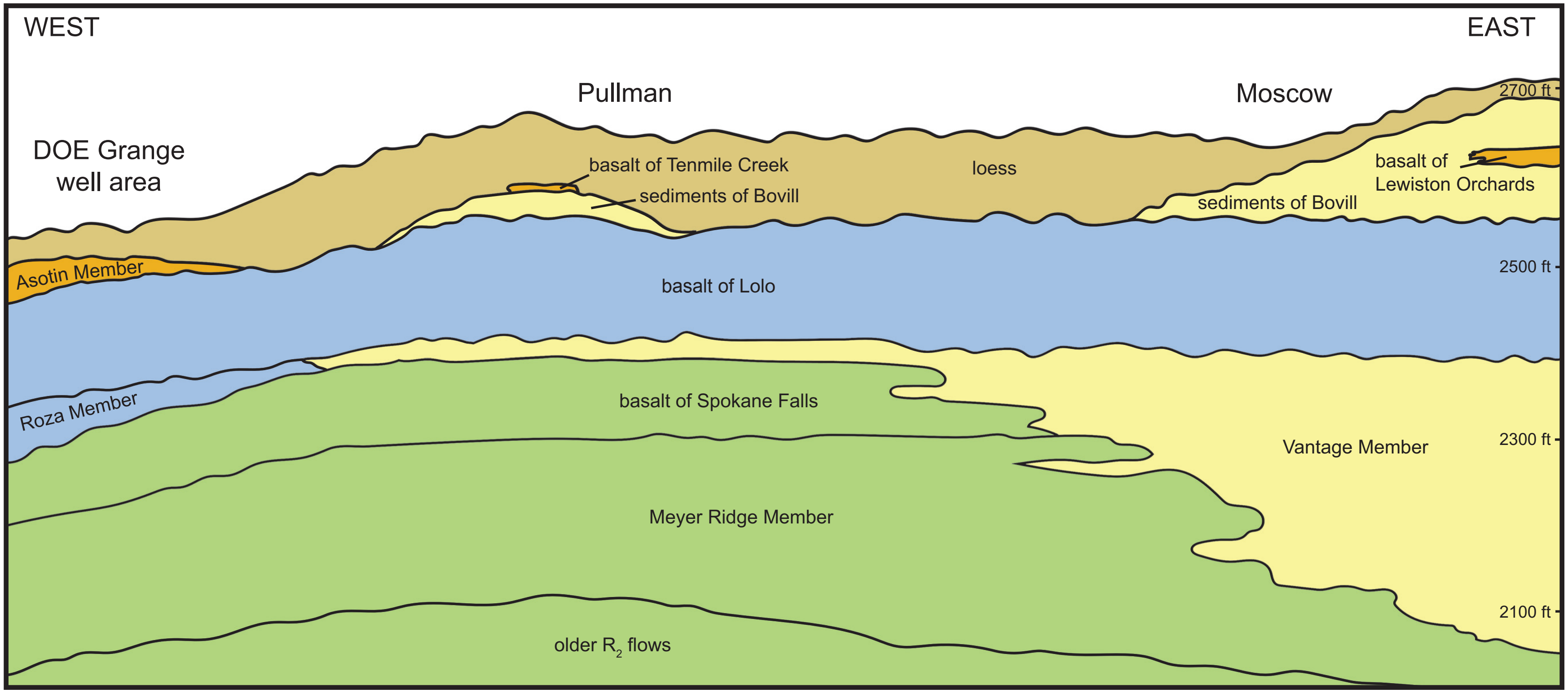


Figure 19. Diagrammatic geologic cross section from Colfax (west) to DOE Butte Gap well (east) (from Bush and others, 2016, Figure 15).

Bush, J.H., Garwood, D.L., and Dunlap, Pamela, 2016, Geology and geologic history of the Moscow-Pullman basin, Idaho and Washington, from late Grande Ronde to late Saddle Mountains time, *in* Lewis, R.S., and Schmidt, K.L., eds., Exploring the Geology of the Inland Northwest: Geological Society of America Field Guide 41, p.151–174.



Digital cartography by D.L. Garwood

Figure 20. Diagrammatic geologic cross section illustrating major stratigraphic relations east and west of Pullman (modified from Bush and others, 2016, Figure 9).

Bush, J.H., Garwood, D.L., and Dunlap, Pamela, 2016, Geology and geologic history of the Moscow-Pullman basin, Idaho and Washington, from late Grande Ronde to late Saddle Mountains time, *in* Lewis, R.S., and Schmidt, K.L., eds., Exploring the Geology of the Inland Northwest: Geological Society of America Field Guide 41, p.151–174.

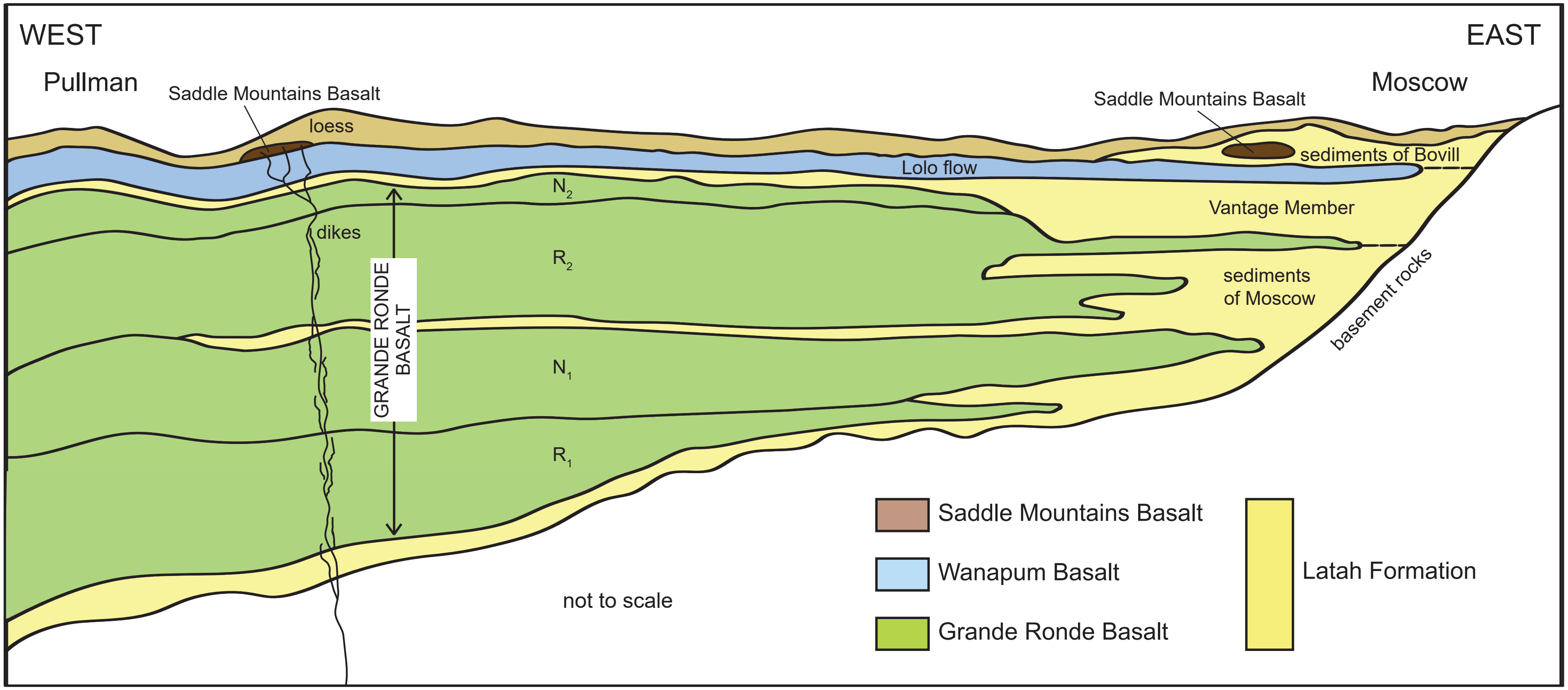


Figure 21. Generalized west-to-east geologic cross section from Pullman, Washington, to Moscow, Idaho (from Bush and others, 2018, Figure 4).

Bush, J.H., Garwood, D.L., and Dunlap, Pamela, 2016, Geology and geologic history of the Moscow-Pullman basin, Idaho and Washington, from late Grande Ronde to late Saddle Mountains time, *in* Lewis, R.S., and Schmidt, K.L., eds., Exploring the Geology of the Inland Northwest: Geological Society of America Field Guide 41, p.151–174.

STRATIGRAPHIC ILLUSTRATIONS

COLUMBIA RIVER BASALT GROUP	LATAH FORMATION
SADDLE MOUNTAINS BASALT	
Weissenfels Ridge Member (F)	Sediments of Bovill
Basalt of Tenmile Creek (I)	
Basalt of Lewiston Orchards (I)	
Asotin Member (F)	
WANAPUM BASALT	
Priest Rapids Member (F)	
Basalt of Lolo(I)	
Roza Member (F)	
GRANDE RONDE BASALT	
N2 MAGNETOSTRATIGRAPHIC UNIT	*Vantage Member (F)
Sentinel Bluffs Member (F)	
Basalt of Spokane Falls(I)	
Basalt of McCoy Canyon(I)	
Winter Water Member (F)	
R2 MAGNETOSTRATIGRAPHIC UNIT	
Meyer Ridge Member (F)	
Grouse Creek member (I)	
Wapshilla Ridge Member (F)	
Mount Horrible member (I)	
N1 MAGNETOSTRATIGRAPHIC UNIT	Sediments of Moscow
Cold Spring Ridge Member (F)	
Frye Point member (I)	
Downey Gulch member (I)	
Brady Gulch member (I)	
R1 MAGNETOSTRATIGRAPHIC UNIT	
Brady Gulch member (I)	
Kendrick Grade member (I)	
Teepee Butte Member (F)	
Basalt of Joseph Creek (I)	
Buckhorn Springs Member (F)	

Figure 22. Stratigraphic nomenclature of the Columbia River Basalt Group and Latah Formation in the Moscow-Pullman area, Idaho and Washington (from Bush and others, 2018, Figure 3).
(F), formal unit; (I), informal unit (as defined by Reidel and others, 2013, and Reidel and Tolan, 2013); N, normal polarity; R, reverse polarity; *The Vantage Member of the Latah Formation in the Moscow-Pullman area consists of sediments between the uppermost Grande Ronde and lowermost Wanapum basalts at any one locality (Bush and Provant, 1998; Bush and others, 1998a, b, 2000; Duncan and Bush, 1999).

Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).

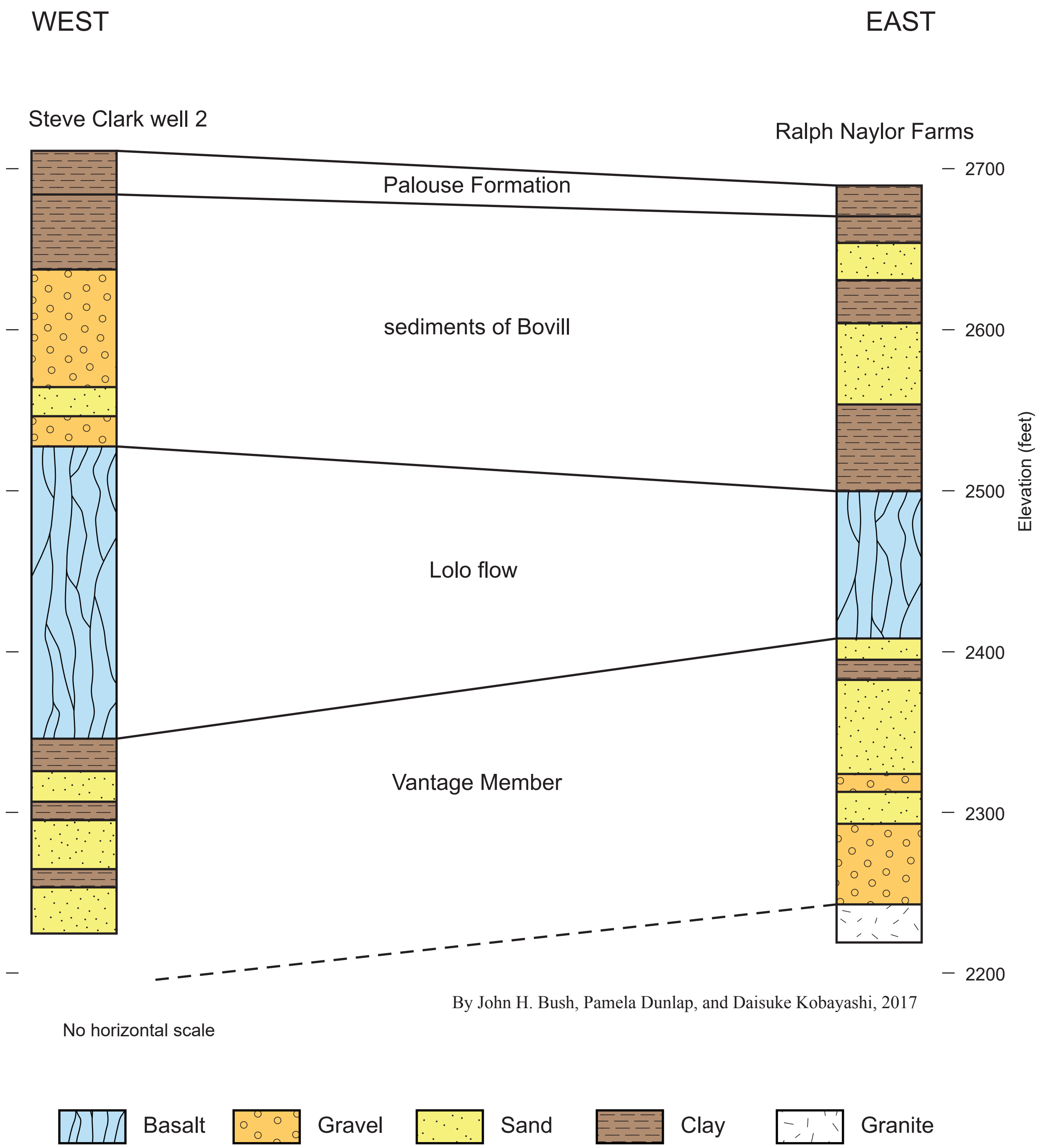


Figure 23. Comparison of Steve Clark well 2 to Ralph Naylor Farms well, Latah County, Idaho. (See index map for Figure 12 for location of wells.)

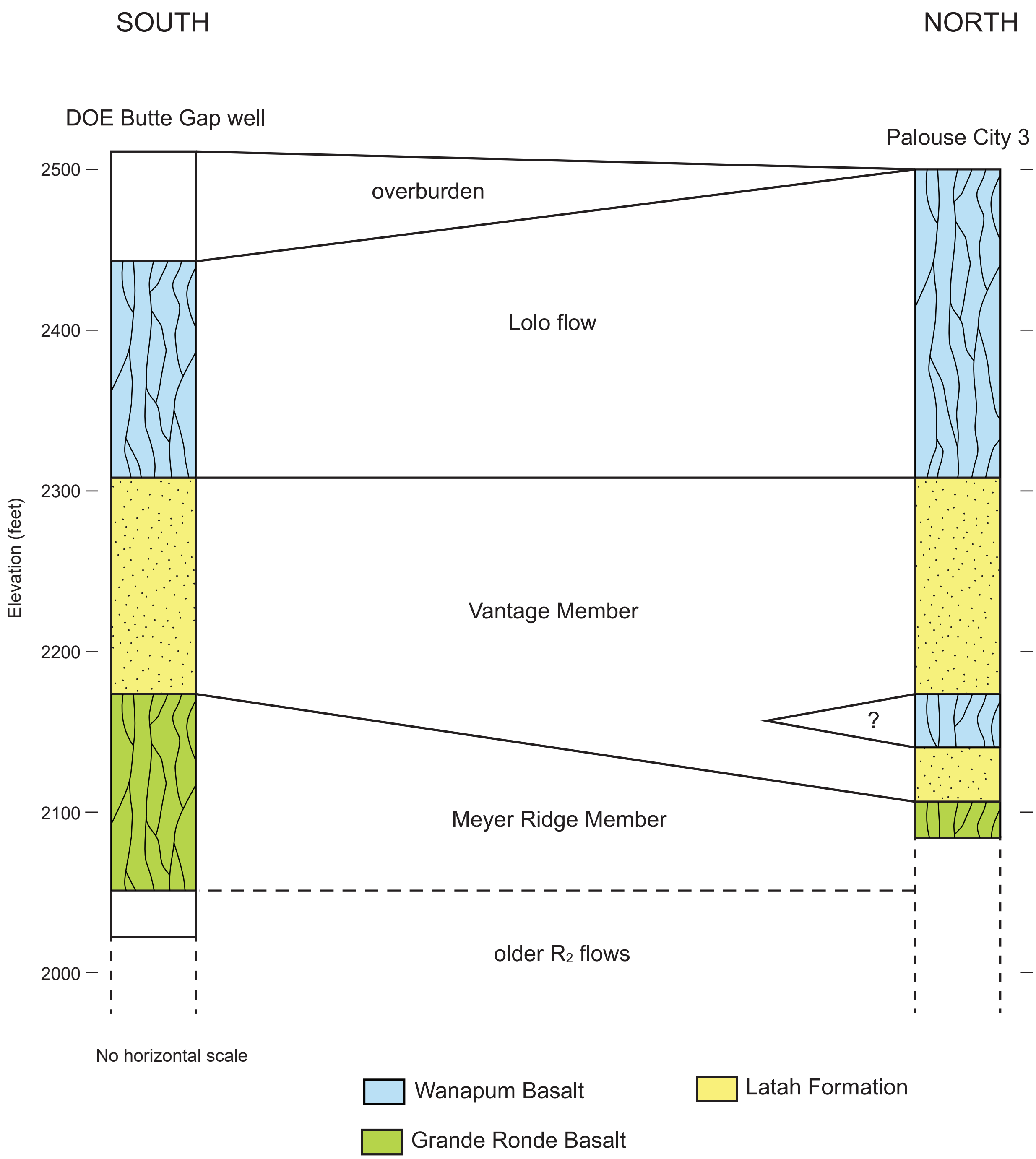


Figure 24. Comparison of DOE Butte Gap well to Palouse City well 3 (modified from Bush and others, 2016, Figure 10). (See Figure 50 for location of wells.)

Bush, J.H., Garwood, D.L., and Dunlap, Pamela, 2016, Geology and geologic history of the Moscow-Pullman basin, Idaho and Washington, from late Grande Ronde to late Saddle Mountains time, *in* Lewis, R.S., and Schmidt, K.L., eds., Exploring the Geology of the Inland Northwest: Geological Society of America Field Guide 41, p.151–174.

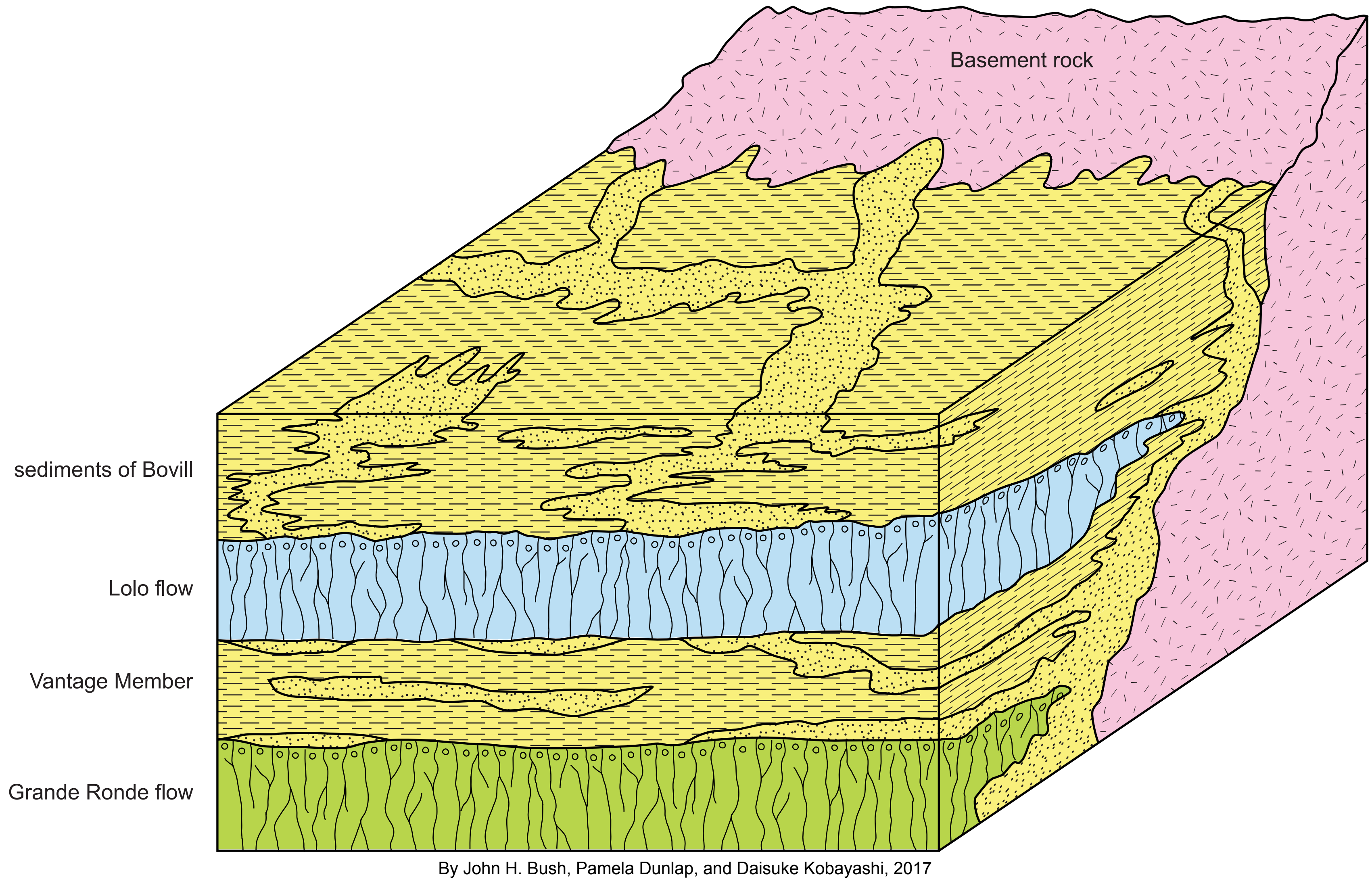


Figure 25. Model of rock unit relationships along the northeastern margin of the Moscow-Pullman basin.

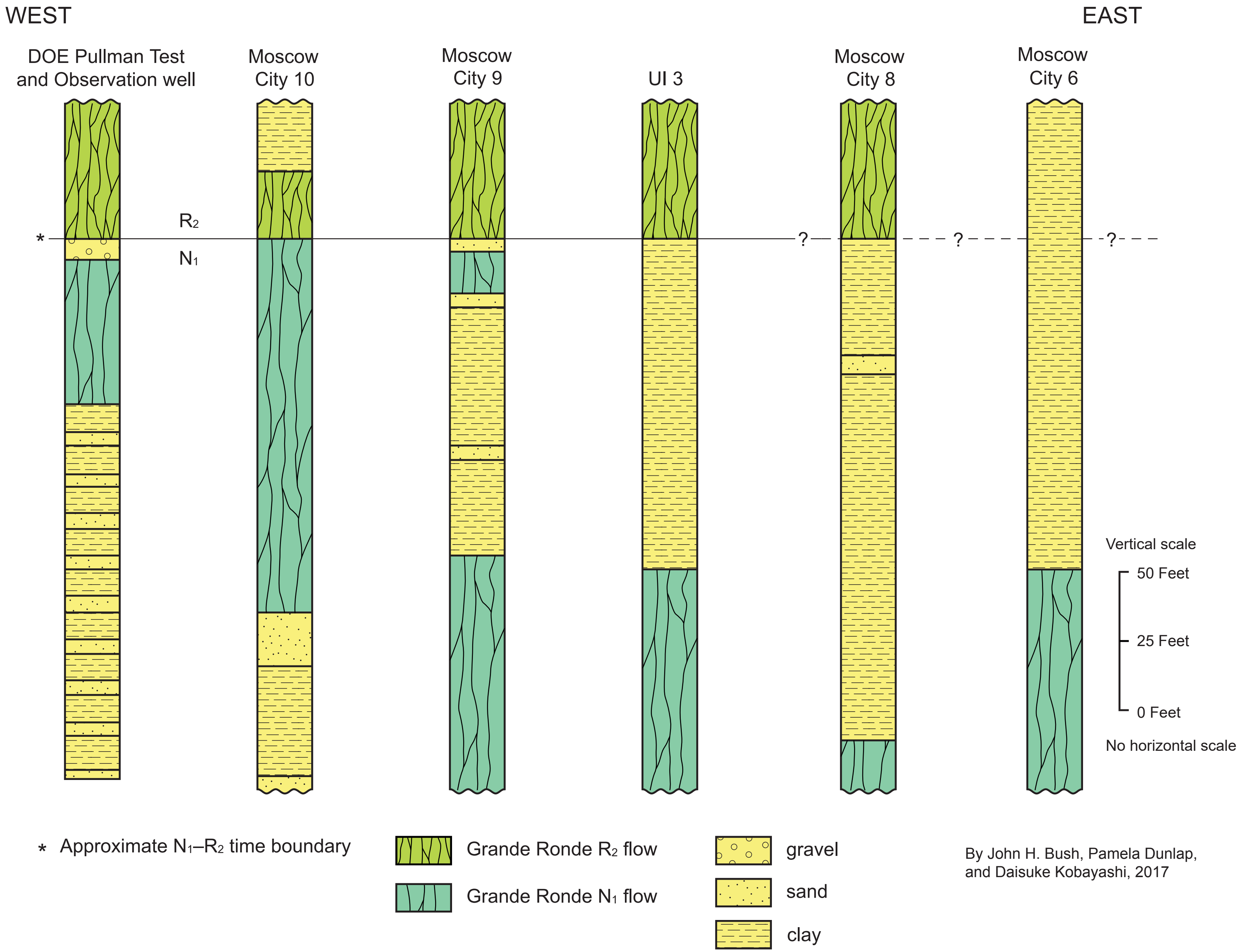


Figure 26. Diagram illustrating type of rock units above and below the N_1–R_2 boundary in the Grande Ronde Basalt in the Moscow area. (See Figure 50 for location of wells.)

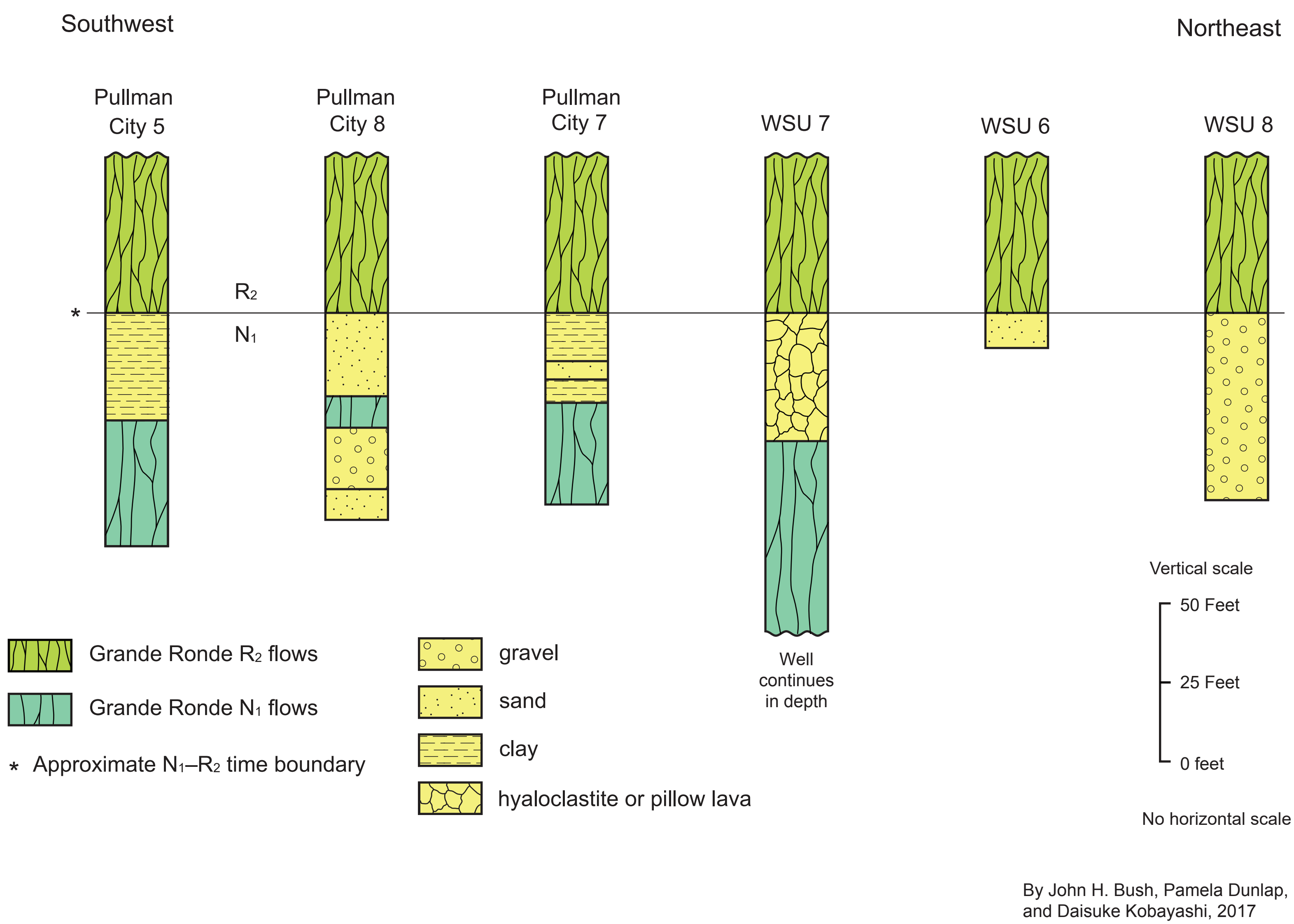
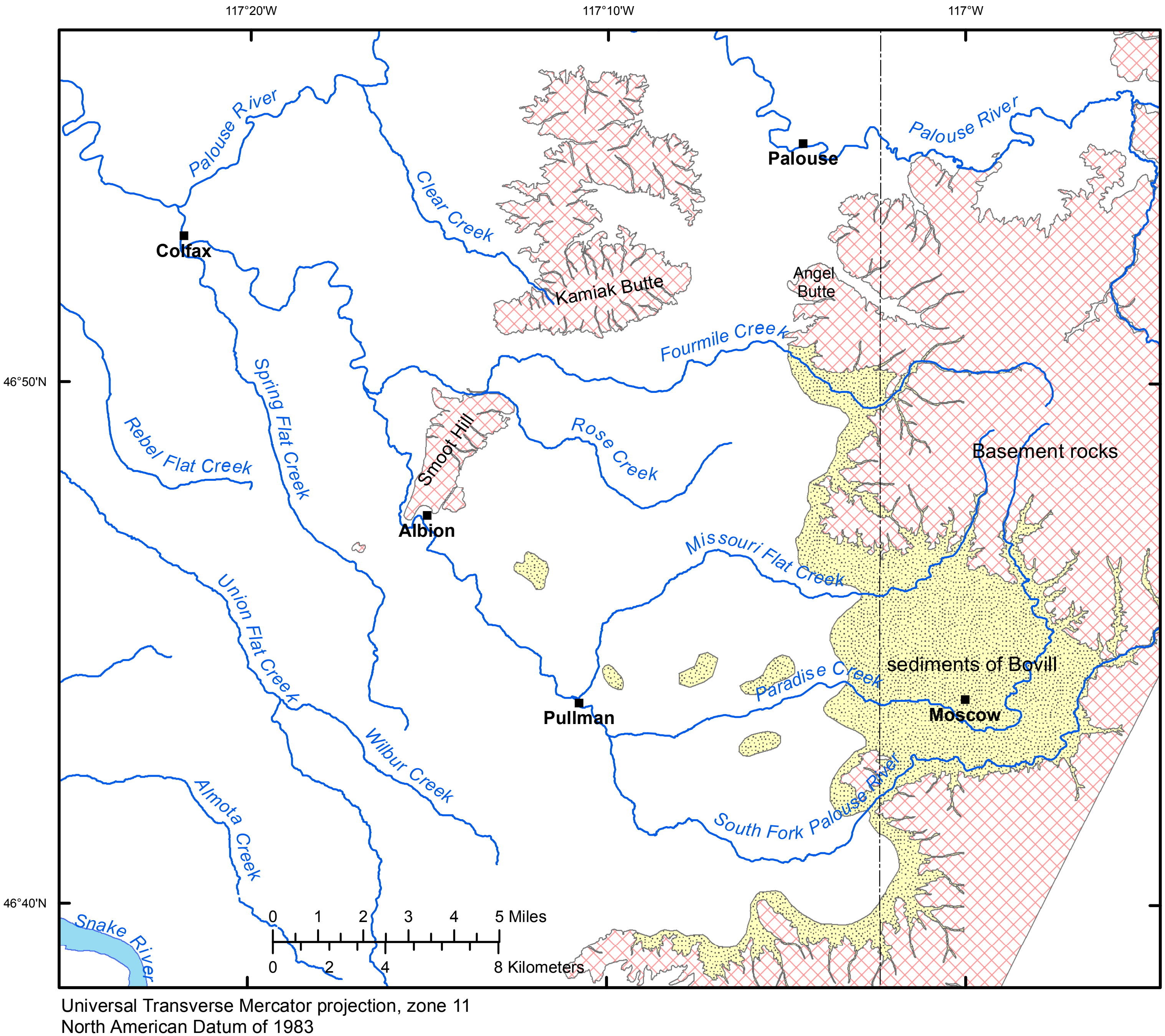


Figure 27. Diagram illustrating type of rock units above and below the N_1–R_2 boundary in the Grande Ronde Basalt in Pullman, Washington. Highest water production comes from sedimentary units (yellow) below the base of the R_2 basalt flows. (See Figure 50 for location of wells.)

DISTRIBUTION MAPS



Bush, J.H., Garwood, D.L., and Dunlap, Pamela, 2016, Geology and geologic history of the Moscow-Pullman basin, Idaho and Washington, from late Grande Ronde to late Saddle Mountains time, *in* Lewis, R.S., and Schmidt, K.L., eds., Exploring the Geology of the Inland Northwest: Geological Society of America Field Guide 41, p.151–174.

Figure 28. Generalized map showing approximate, present-day distribution of the sediments of Bovill and basement rocks (modified from Bush others, 2016, Figure 7).

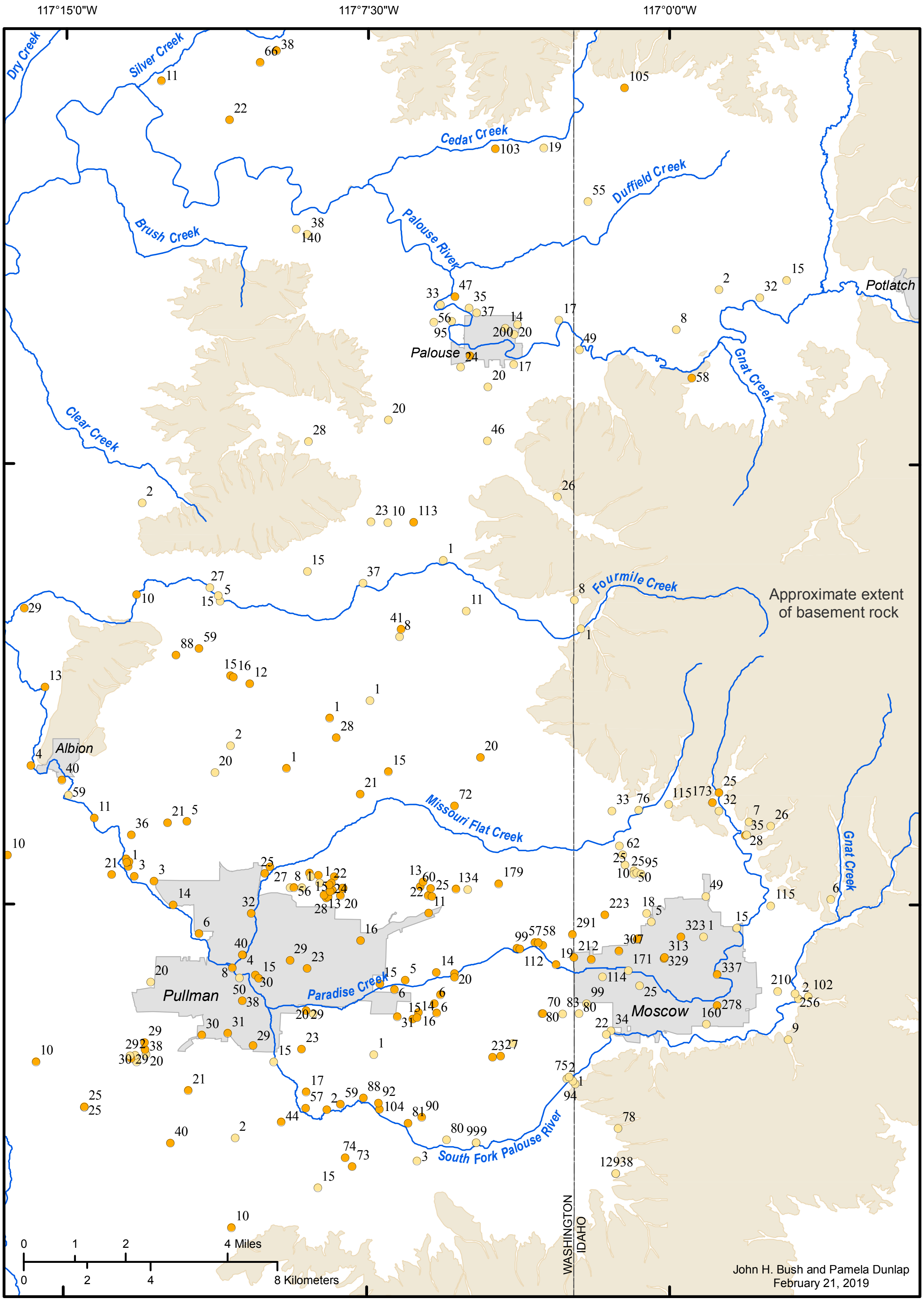


Figure 29. Thickness (ft) of the Vantage Member of the Latah Formation; dark orange dot, complete section of the Vantage Member; light orange dot, partial section; well data derived from Bush and Dunlap (2018).

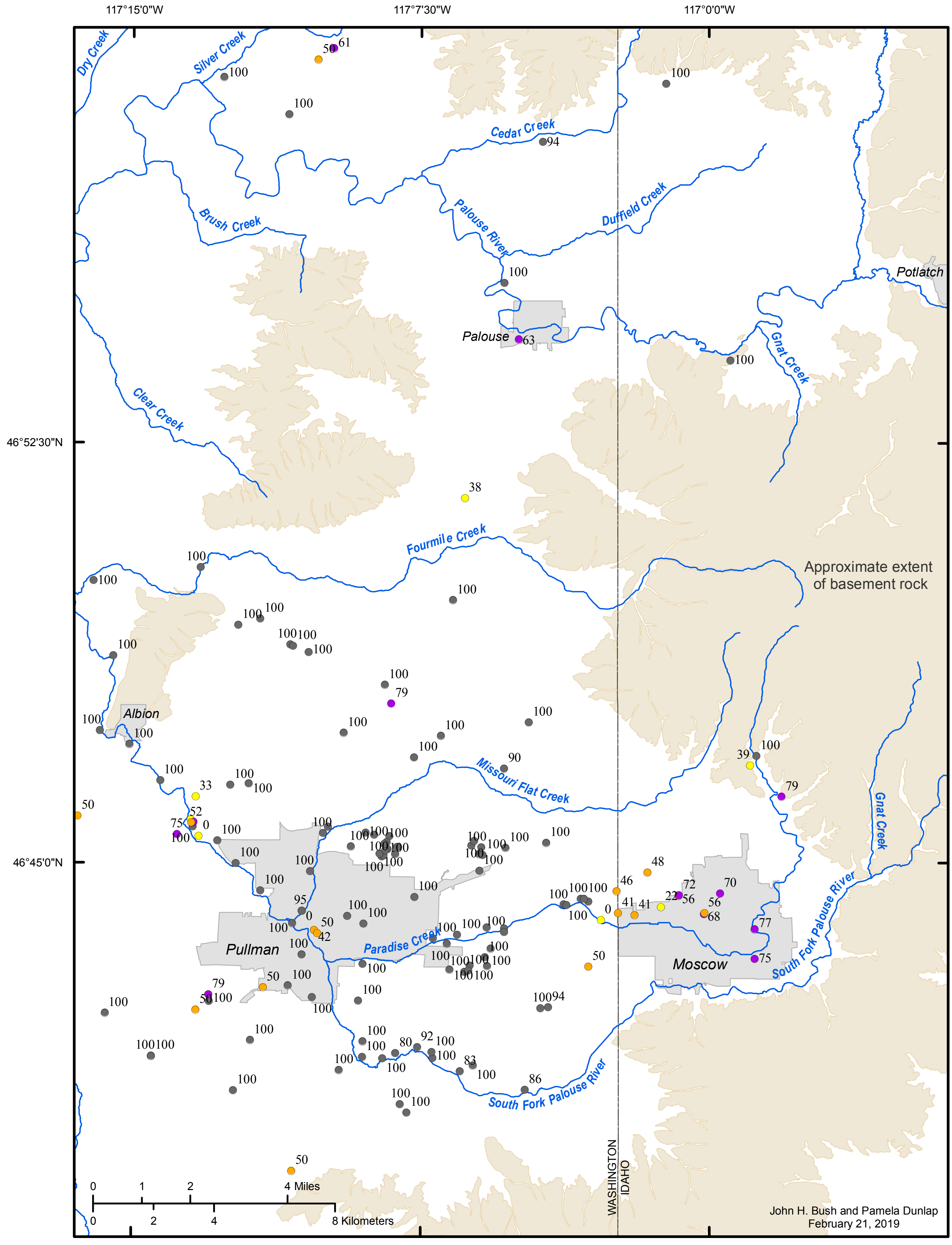


Figure 30. Ratio of clay-to-sand (in percent) in the Vantage Member of the Latah Formation through which a complete section was drilled; gray dot, 80–100% clay/sand; purple dot, 60–79% clay/sand; orange dot, 40–59% clay/sand; yellow dot, 0–39% clay/sand; well data derived from Bush and Dunlap (2018).

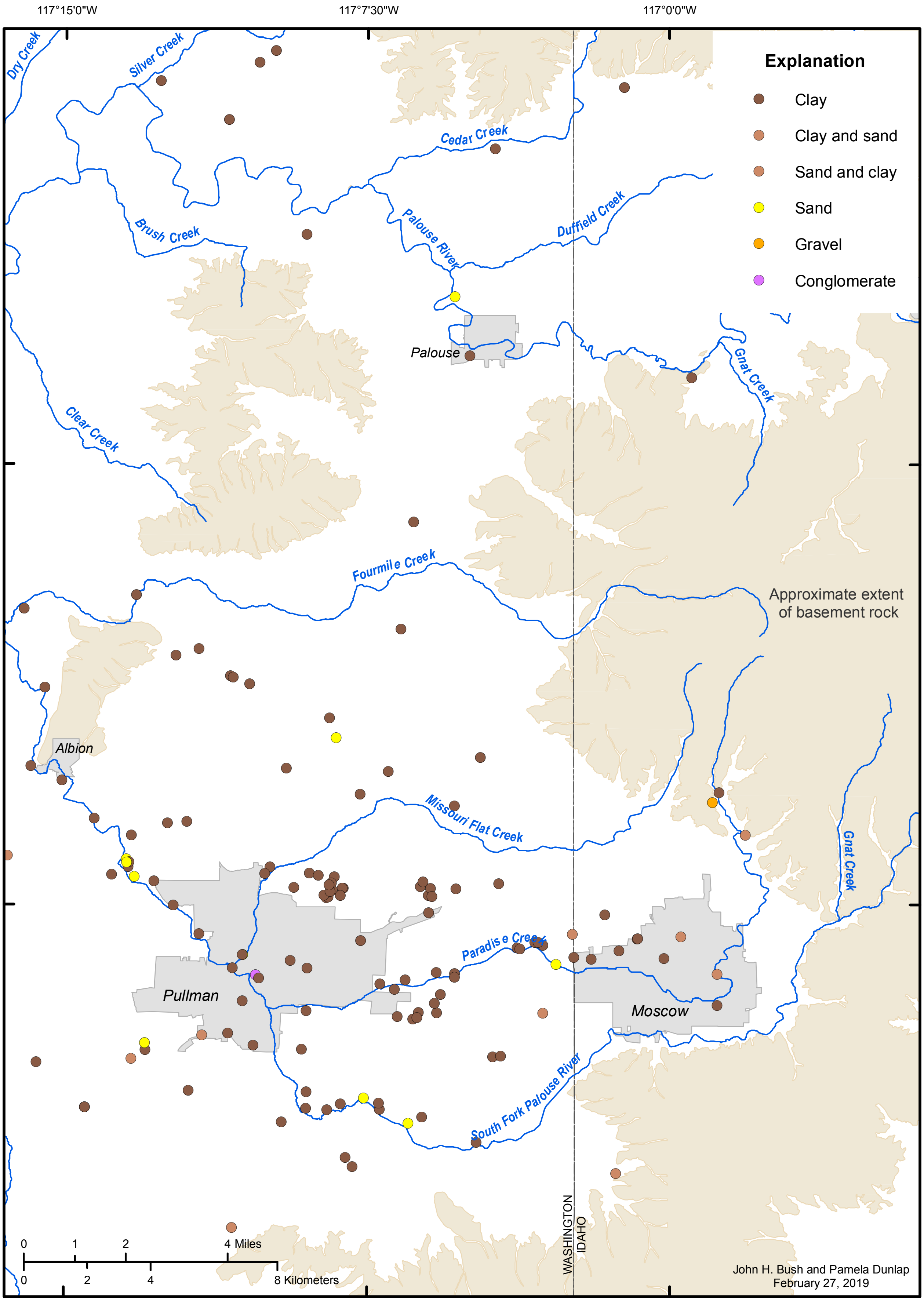
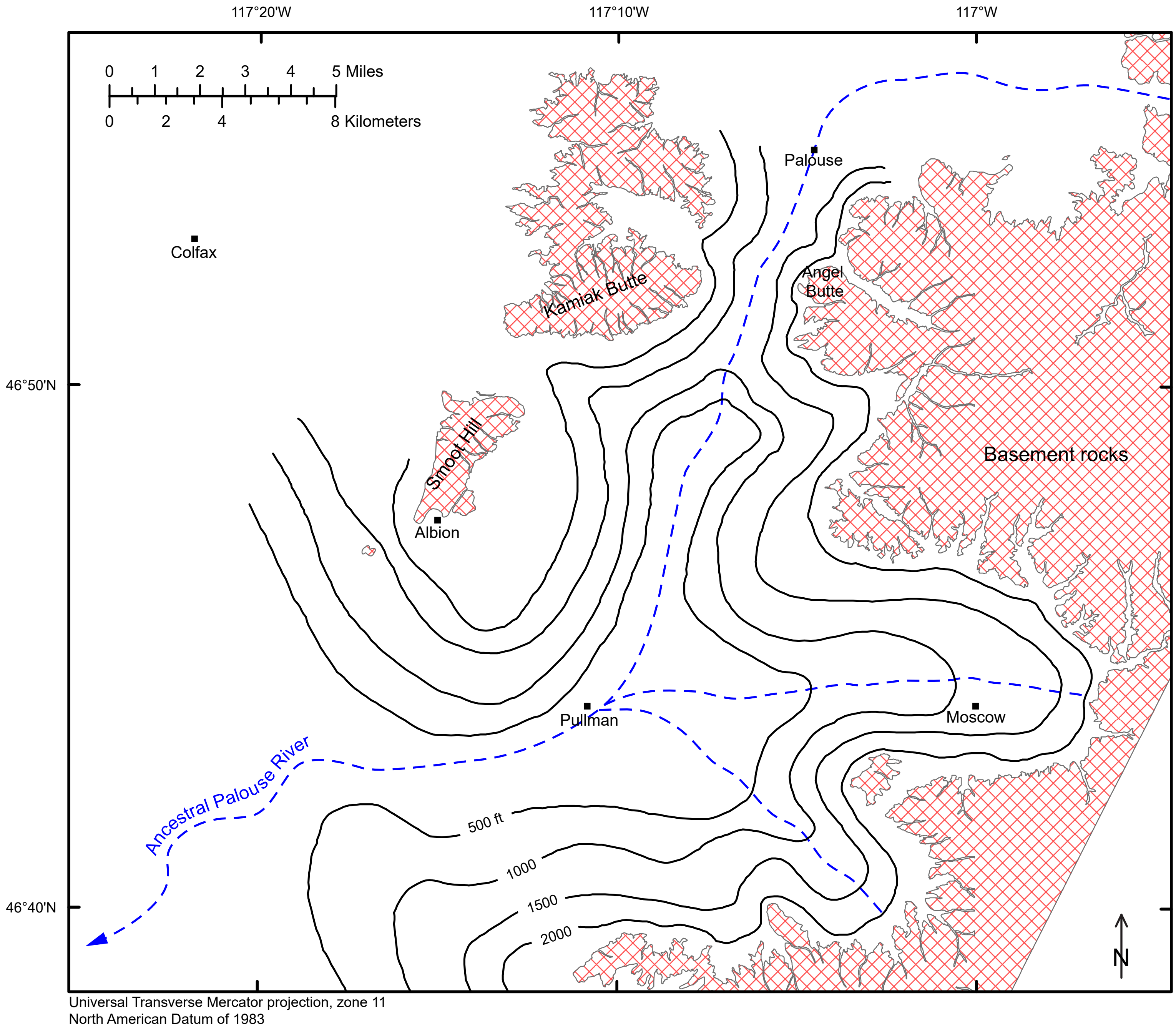


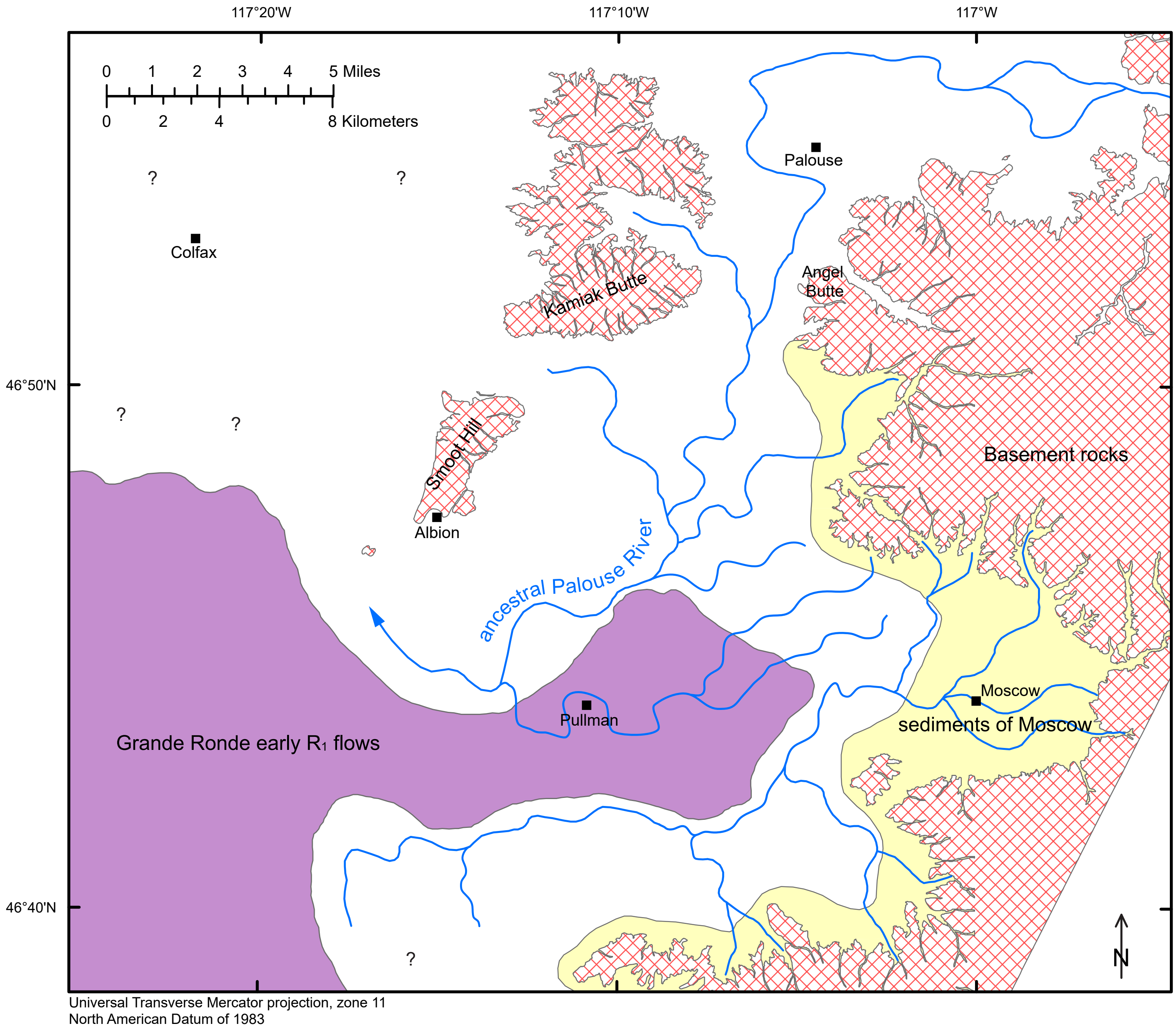
Figure 31. Map showing composition of the lowermost interval of the Vantage Member of the Latah Formation (where it overlies the Grande Ronde Basalt or basement rock at depth) in wells in the Moscow-Pullman area



Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).

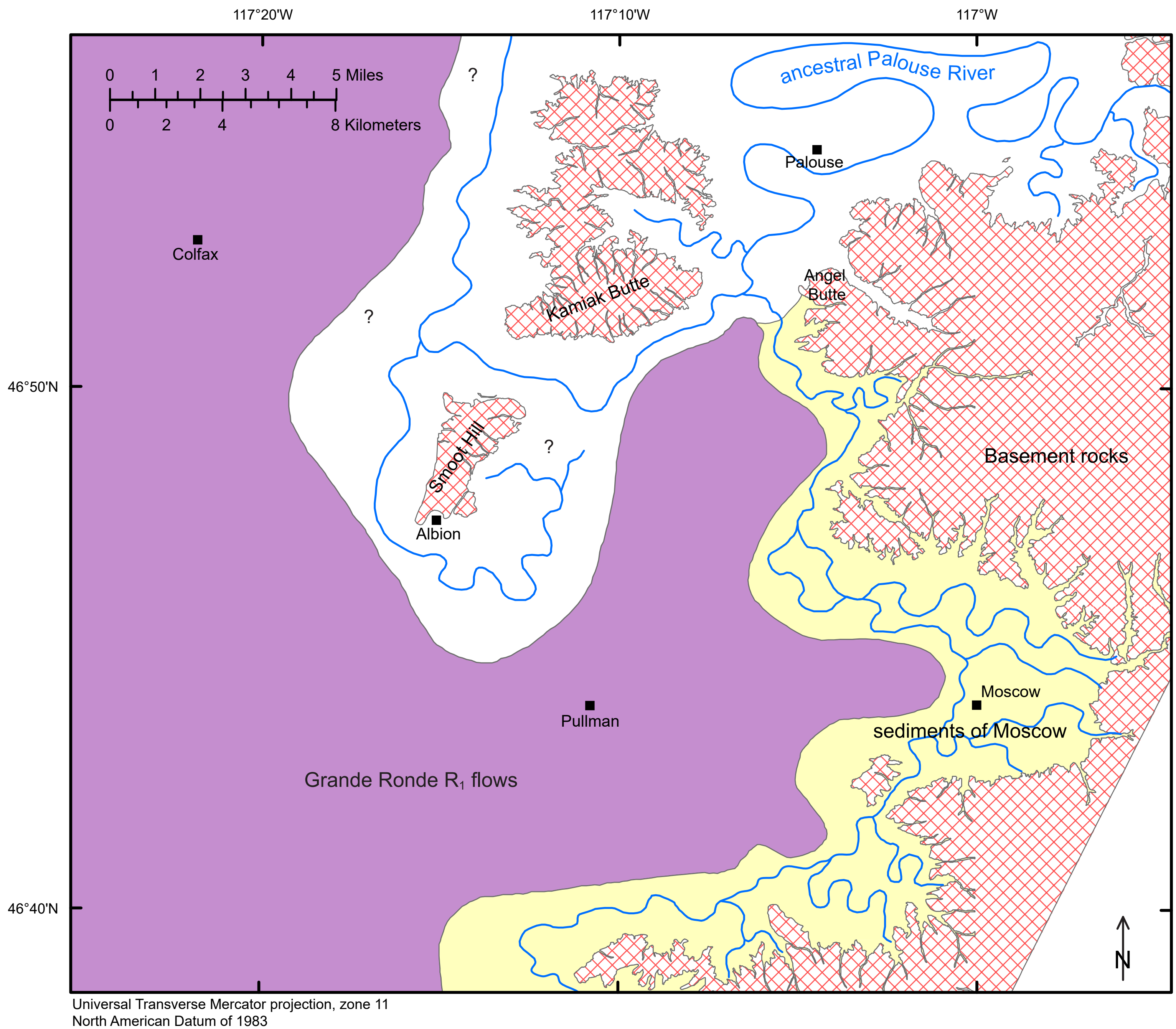
Figure 32. A topographic model of the Moscow-Pullman basin prior to emplacement of the Columbia River Basalt Group; structure contours on top of basement rock, in feet; (from Bush and others, 2018, Figure 7).

PALEOGEOGRAPHIC MAPS



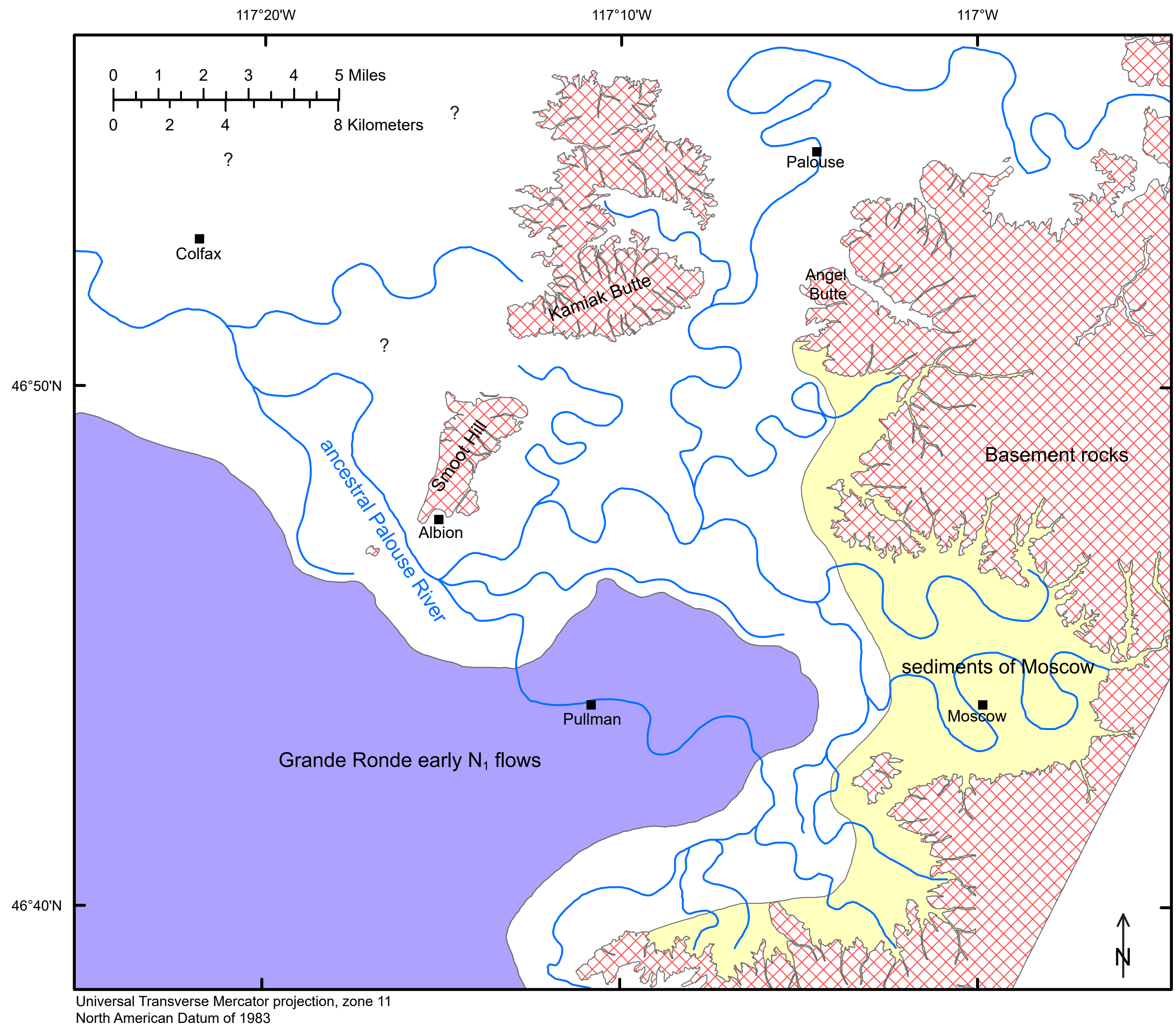
Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).

Figure 33. Possible paleogeographic setting for the Moscow-Pullman basin after emplacement of early flows of the Grande Ronde Basalt (from Bush and others, 2018, Figure 8).



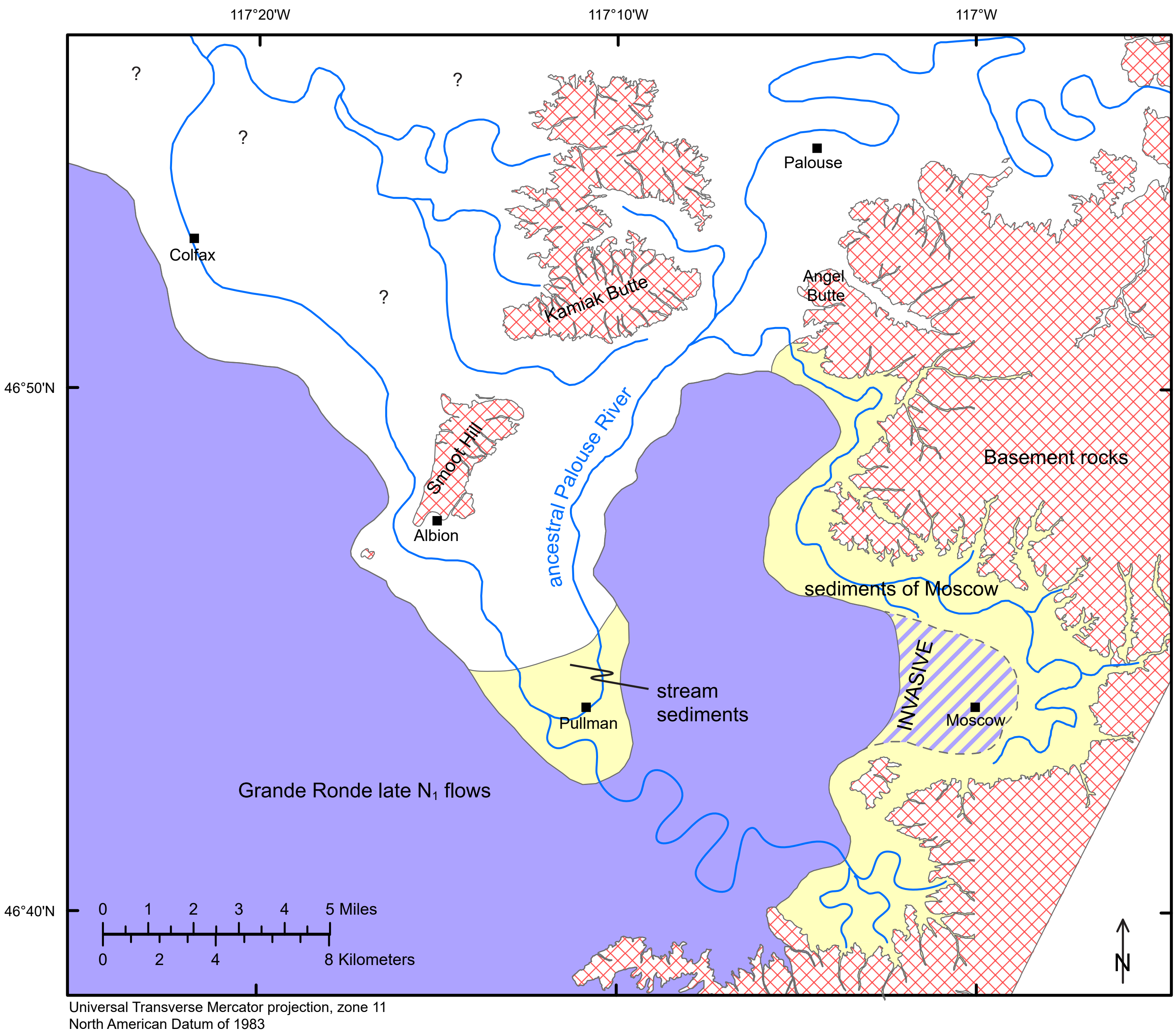
Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).

Figure 34. Possible paleogeographic setting for the Moscow-Pullman basin after emplacement of the R_1 flows of the Grande Ronde Basalt (from Bush and others, 2018, Figure 9).



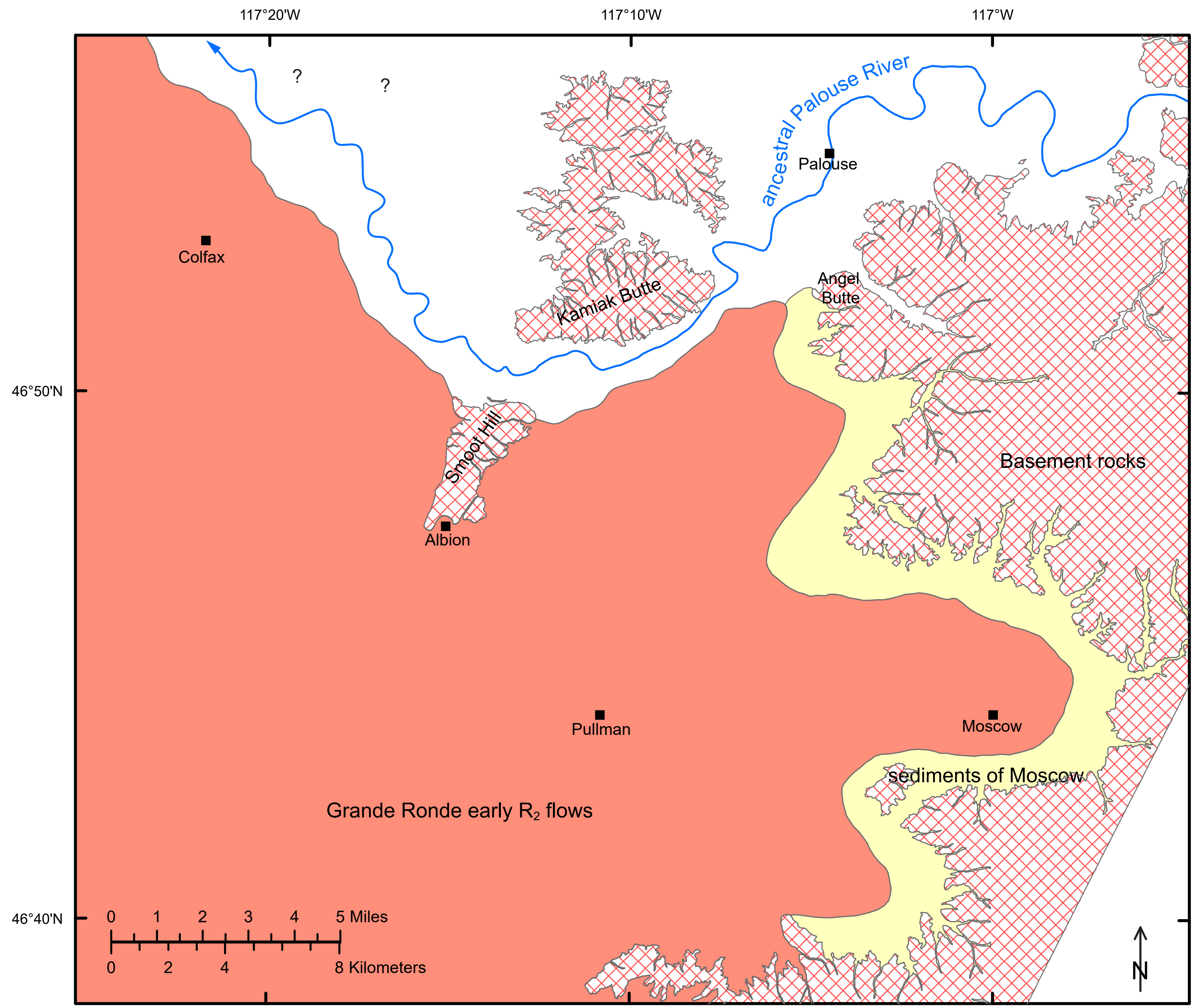
Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).

Figure 35. Possible paleogeographic setting for the Moscow-Pullman basin after emplacement of the early N_1 flows of the Grande Ronde Basalt (from Bush and others, 2018, Figure 10).



Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).

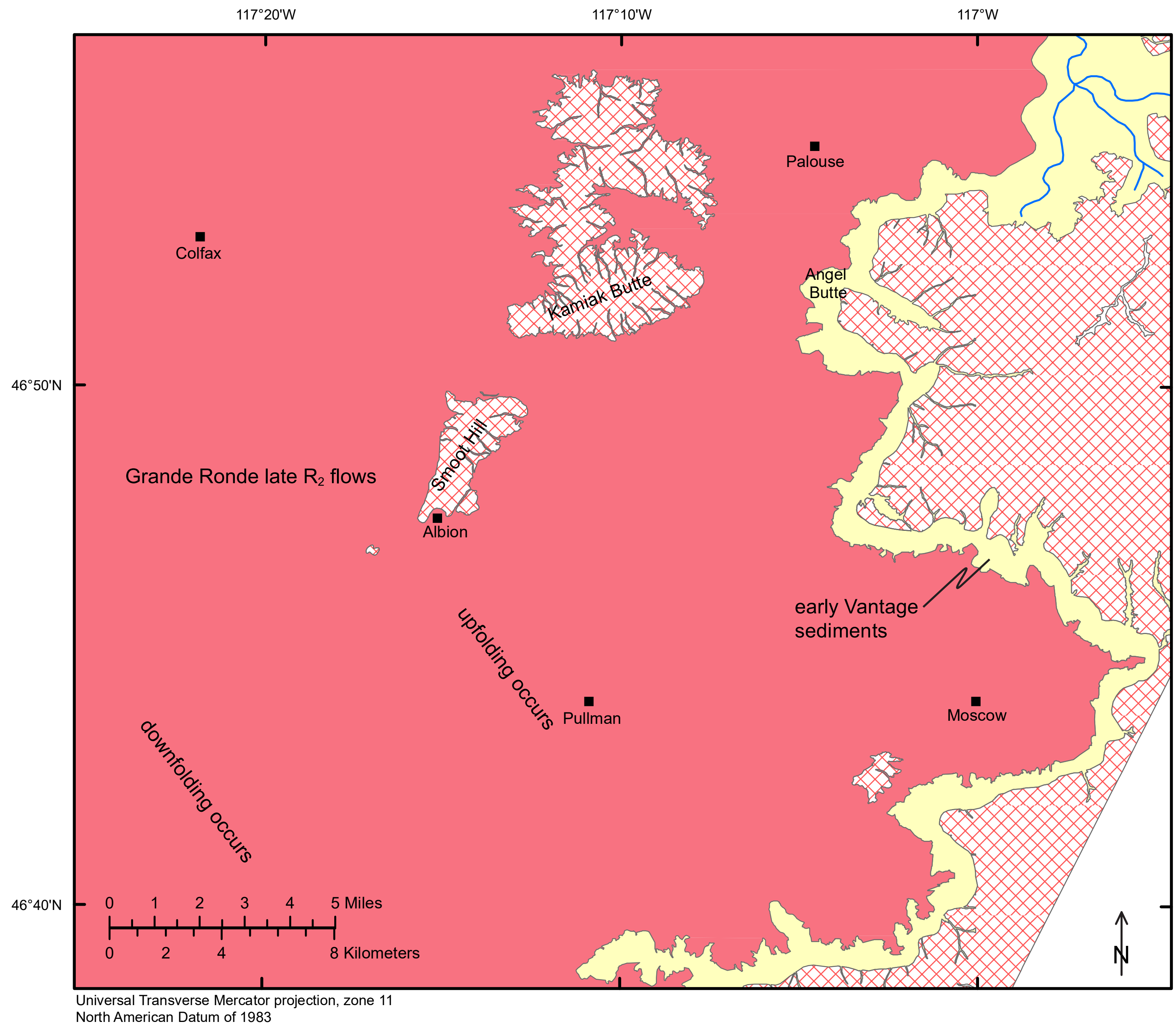
Figure 36. Possible paleogeographic setting for the Moscow-Pullman basin after emplacement of the late N_1 flows of the Grande Ronde Basalt (from Bush others, 2018, Figure 11).



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

Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).

Figure 37. Possible paleogeographic setting for the Moscow-Pullman basin after emplacement of the early R_2 flows of the Grande Ronde Basalt (from Bush and others, 2018, Figure 12).



Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).

Figure 38. Possible paleogeographic setting for the Moscow-Pullman basin after emplacement of the late R_2 flows of the Grande Ronde Basalt (from Bush and others, 2018, Figure 13).

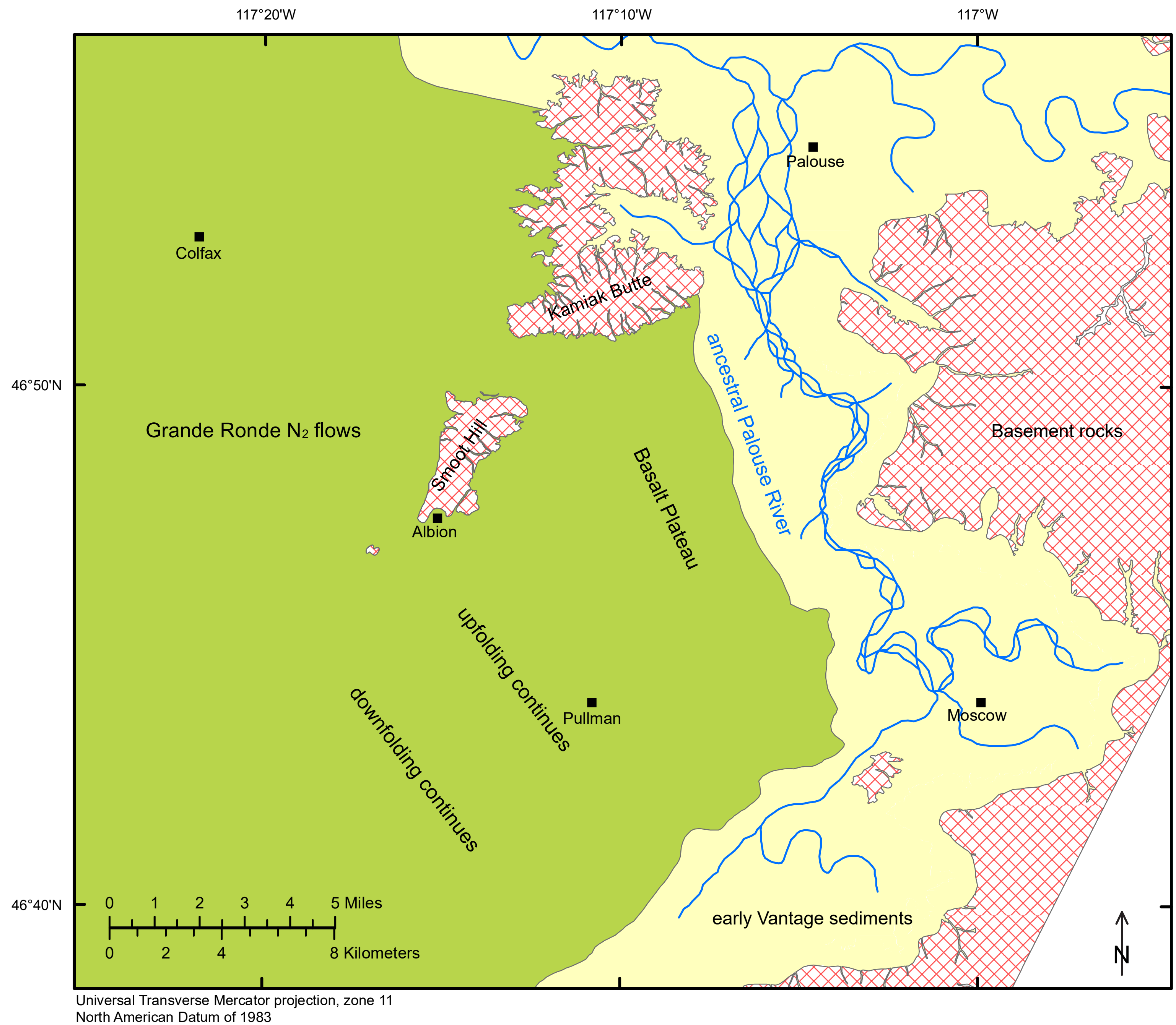
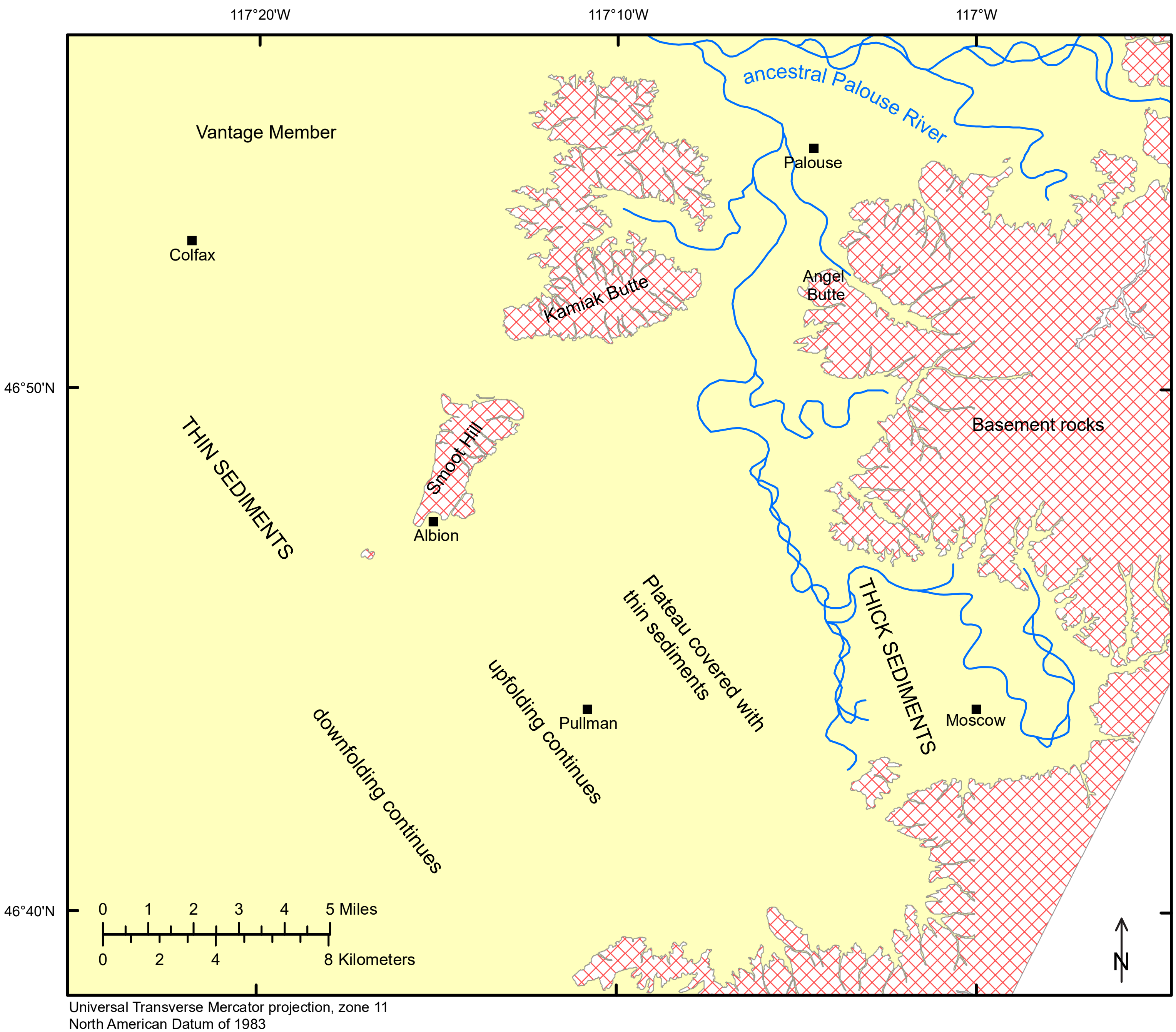


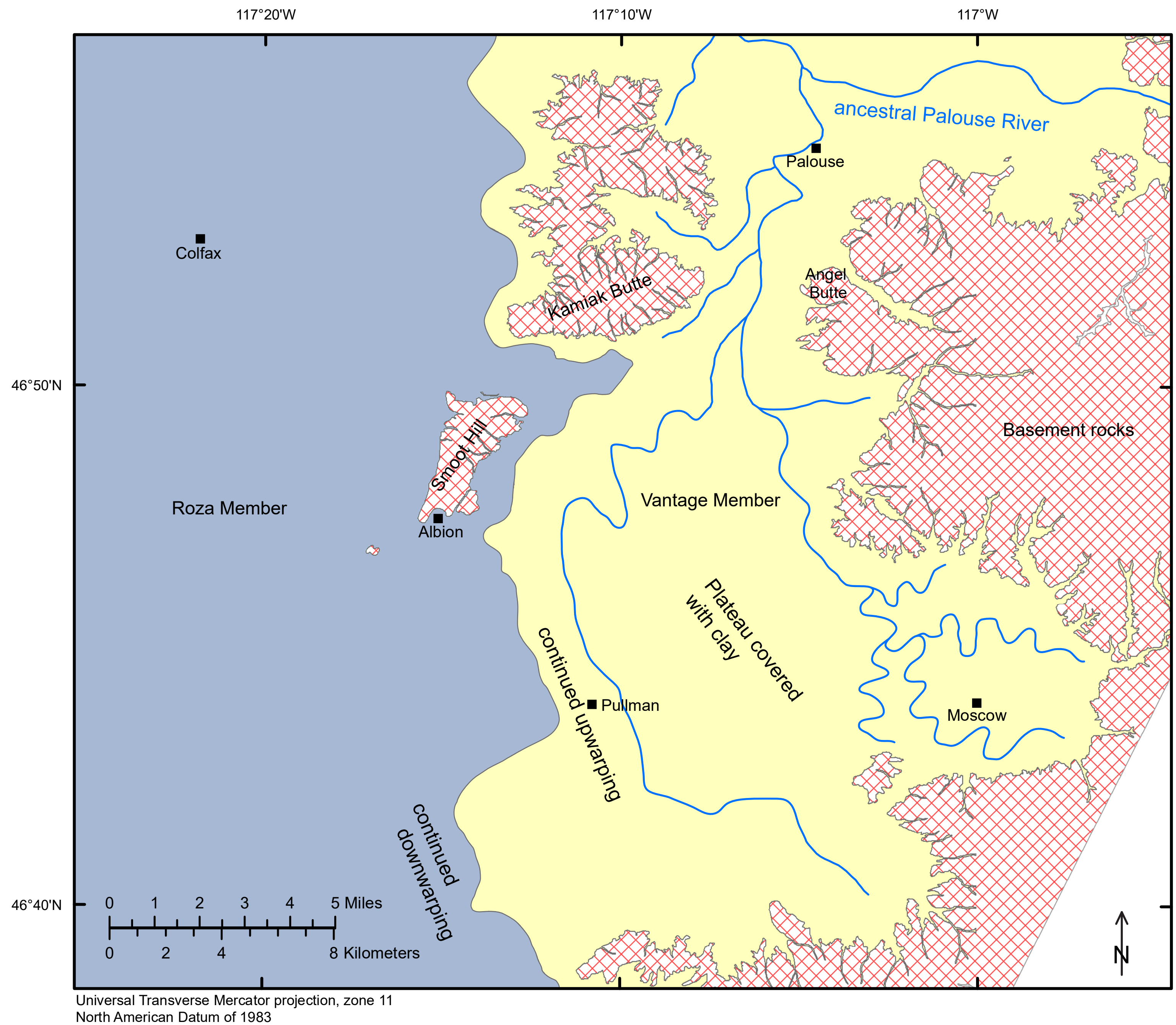
Figure 39. Possible paleogeographic setting for the Moscow-Pullman basin after emplacement of the N_2 flows of the Grande Ronde Basalt (from Bush and others, 2018, Figure 14).

Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).



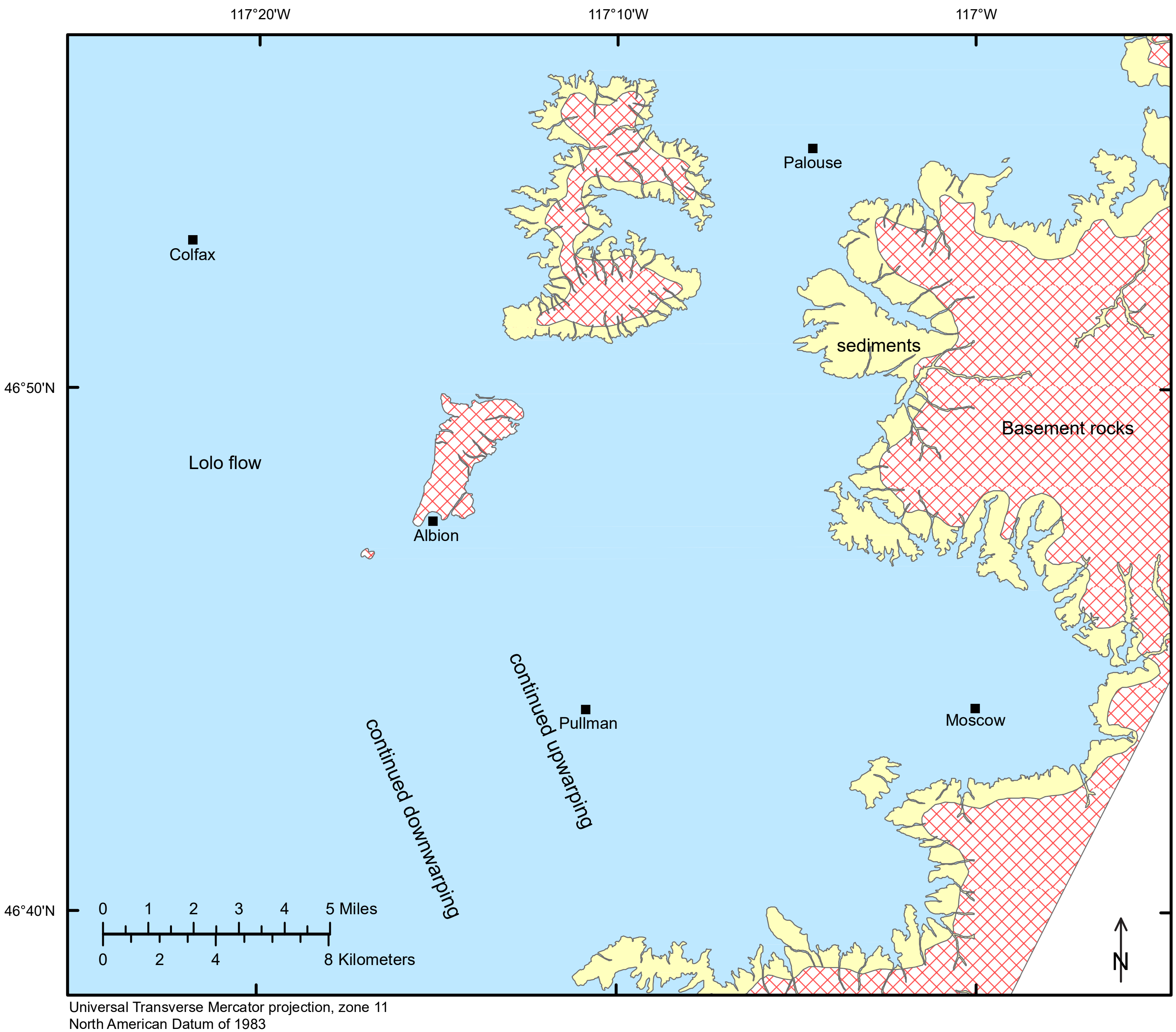
Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).

Figure 40. Possible paleogeographic setting for the Moscow-Pullman basin during deposition of the Vantage Member of the Latah Formation (from Bush and others, 2018, Figure 15).



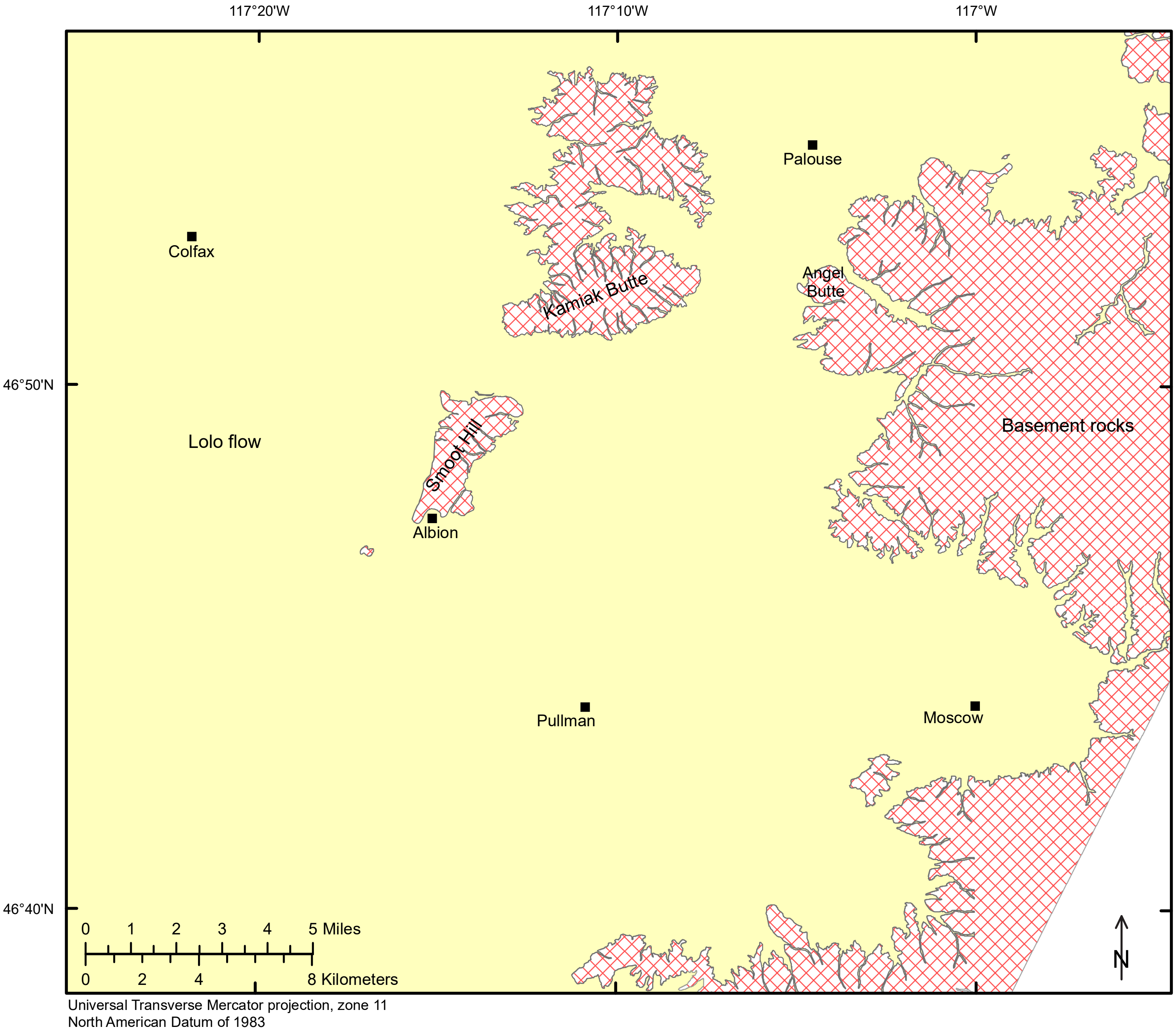
Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).

Figure 41. Possible paleogeographic setting for the Moscow-Pullman basin after the emplacement of the Roza Member of the Wanapum Basalt (from Bush and others, 2018, Figure 16).



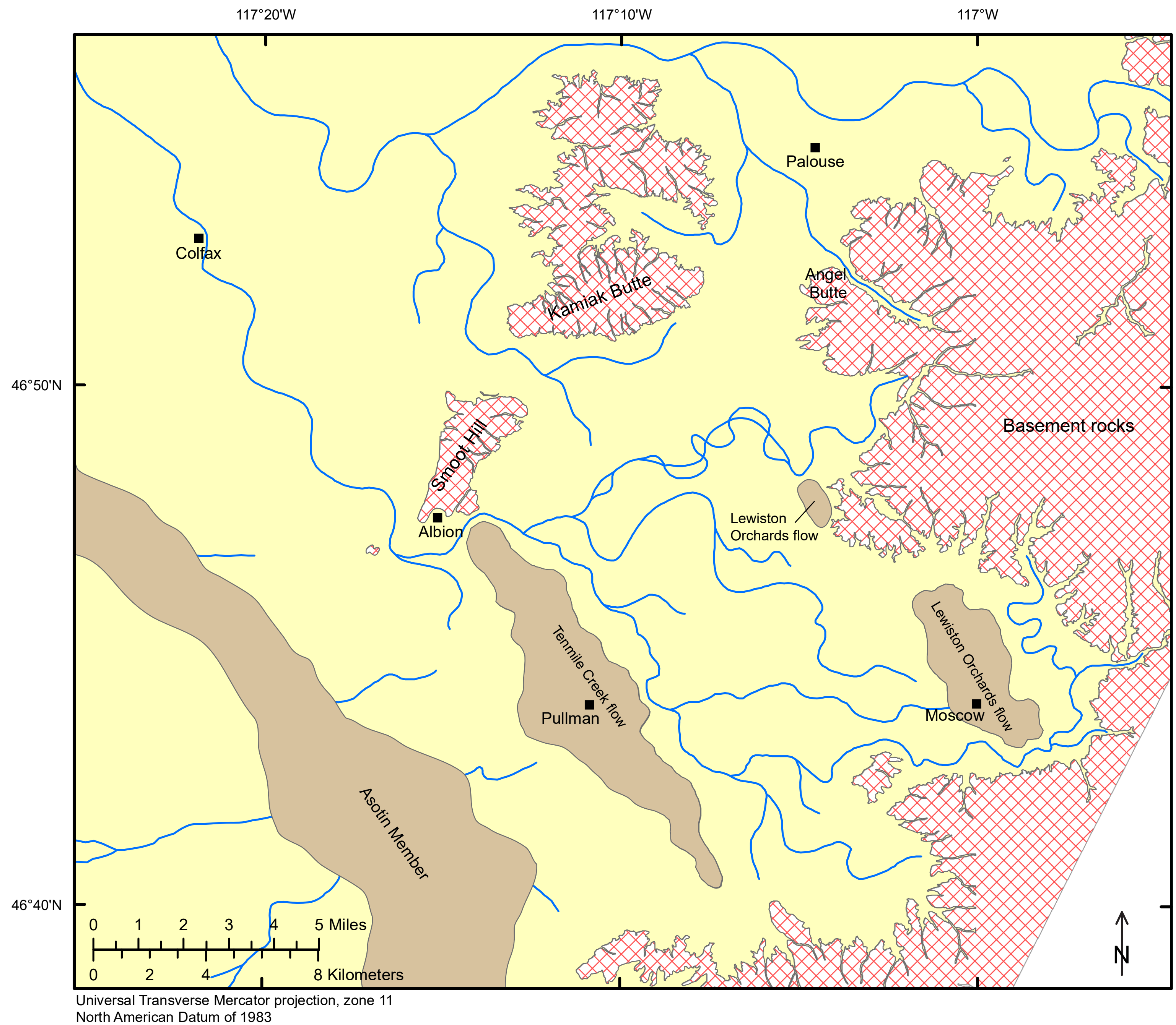
Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).

Figure 42. Possible paleogeographic setting for the Moscow-Pullman basin after the emplacement of the basalt of Lolo of Priest Rapids Member of the Wanapum Formation (from Bush and others, 2018, Figure 17).



Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).

Figure 43. Possible paleogeographic setting for the Moscow-Pullman basin during the early phases of deposition of the sediments of Bovill of the Latah Formation (from Bush and others, 2018, Figure 18).



Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).

Figure 44. Possible paleogeographic setting for the Moscow-Pullman basin after emplacement of the Saddle Mountains Basalt (brown) (from Bush and others, 2018, Figure 19).

STRUCTURAL GEOLOGY MAPS

Figure 45. Approximate locations of major structures in the Moscow-Pullman basin and vicinity

Figure 46. Structure contours on the top of the Grande Ronde Basalt (scale about 1:210,000)

Plate [47]. Structure contours on the top of the Grande Ronde Basalt in the Moscow-Pullman basin and vicinity, Idaho and Washington (scale 1:62,500)

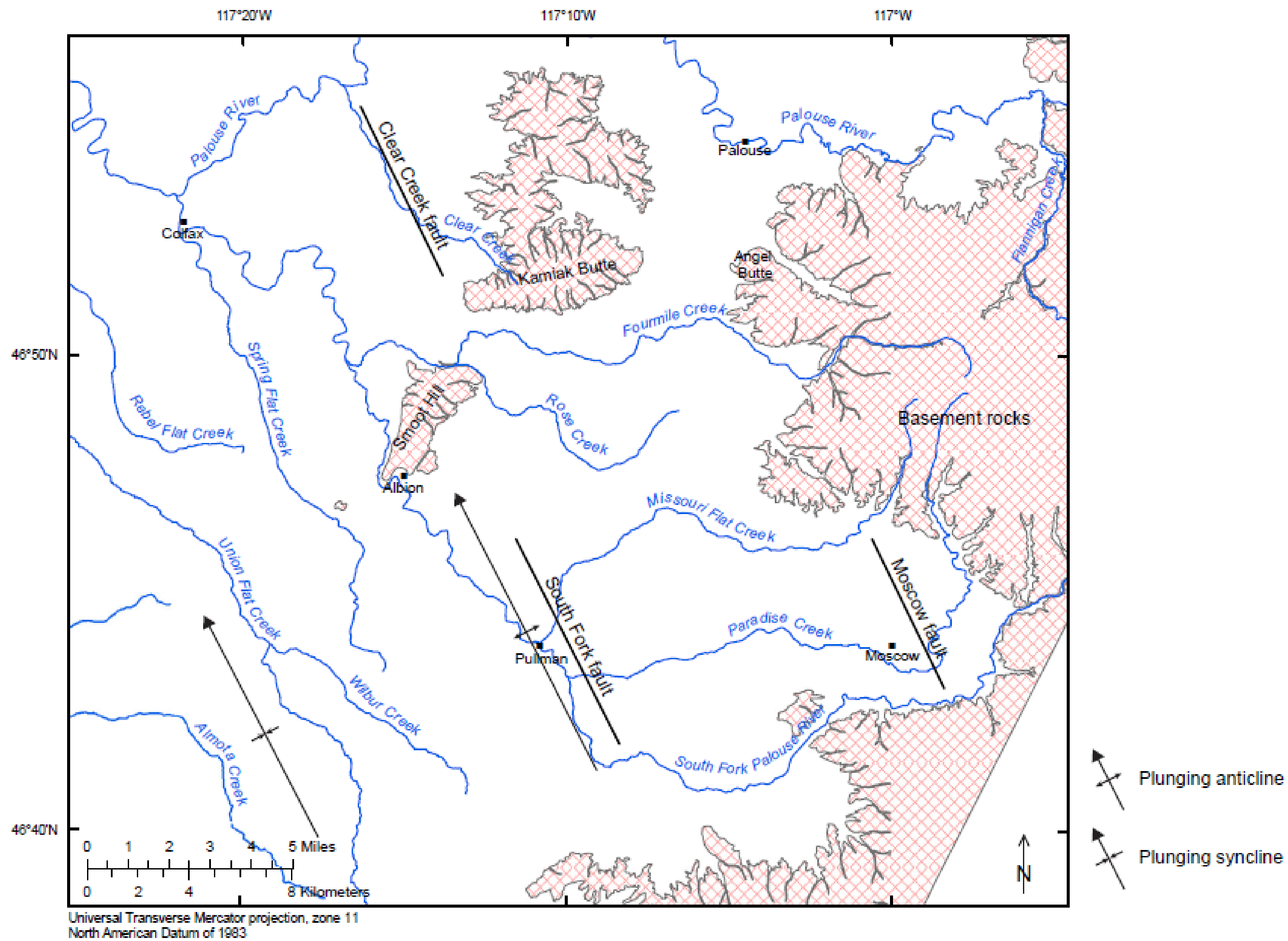


Figure 45. Approximate locations of major structures in the Moscow-Pullman basin and vicinity (from Bush and others, 2018, Figure 5).

Bush, J.H., Dunlap, Pamela, and Reidel, S.P., 2018, Miocene evolution of the Moscow-Pullman basin, Idaho and Washington: Idaho Geological Survey Technical Report 18-3, 42 p. Available at: https://www.idahogeology.org/product/t-18-3 (accessed 20 March 2019).

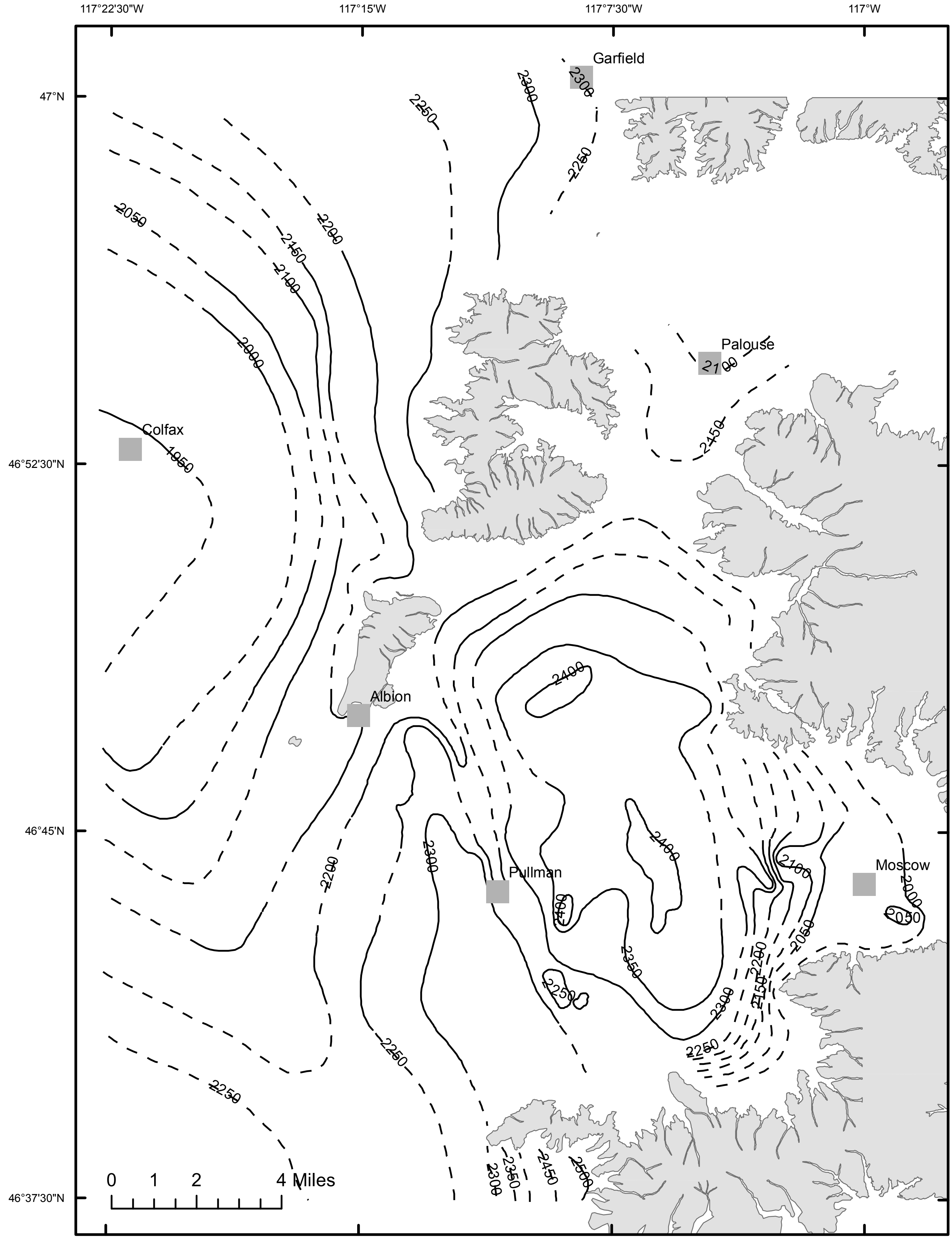
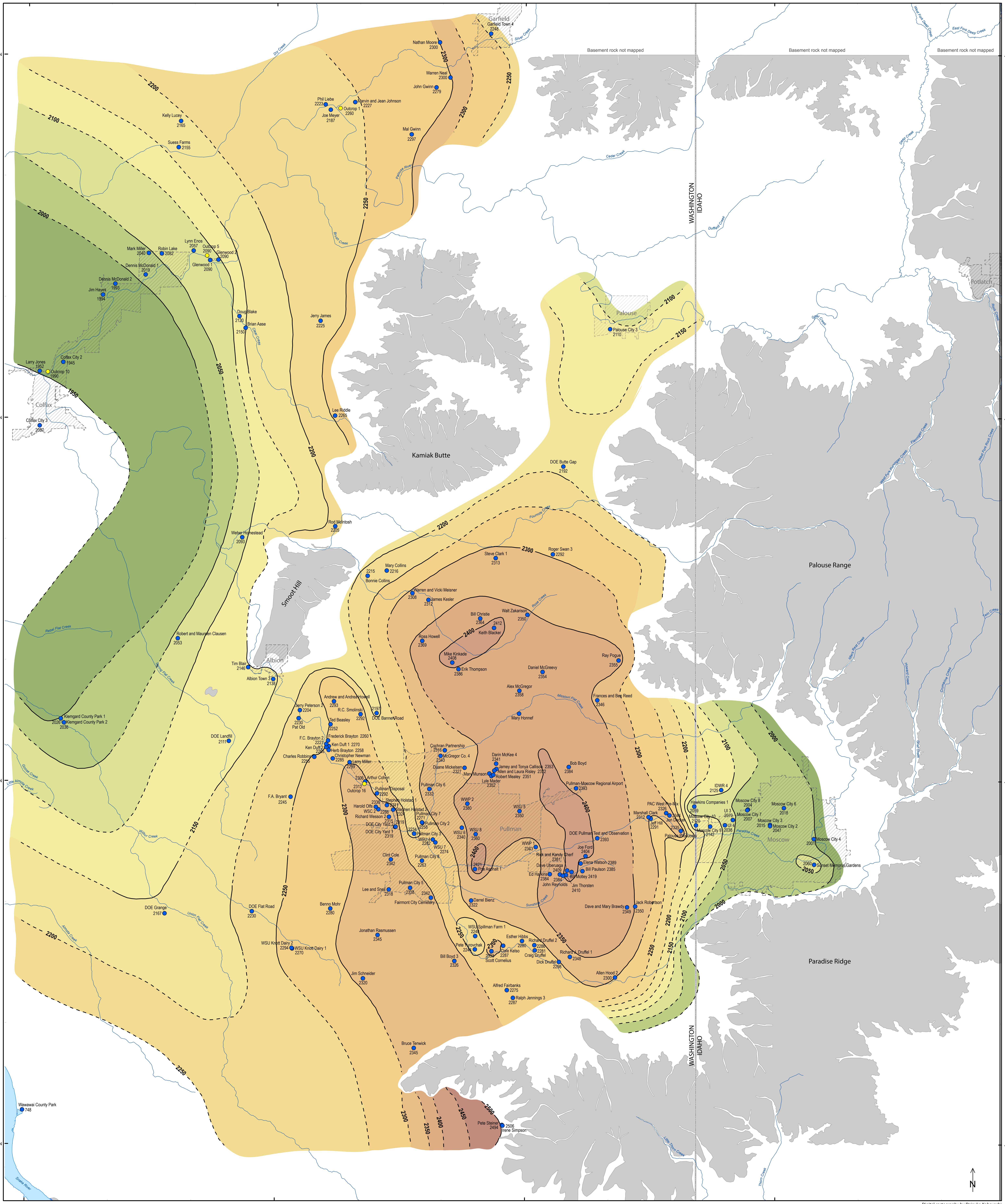


Figure 46. Structure contours on the top of the Grande Ronde Basalt; contour interval, 50 feet; dashed where approximate; gray, basement rocks (modified from Bush and Dunlap, 2018).

Bush, J.H., and Dunlap, Pamela, 2018, Structure contours on the top of the Grande Ronde Basalt in the Moscow-Pullman basin and vicinity, Idaho and Washington: Idaho Geological Survey Technical Report 18-2, scale 1:62,500. Available at: https://www.idahogeology.org/product/t-18-2 (accessed 20 March 2019).



Universal Transverse Mercator projection, zone 11
World Geodetic System of 1984 (WGS84)
Hydrography from USGS National Hydrography Dataset, 2014

INTRODUCTION

A structure contour map was constructed to illustrate the relief of the uppermost surface of the Grande Ronde Basalt (GRB) of the Columbia River Basalt Group in the Moscow-Pullman basin and vicinity. The relief illustrated is primarily a subsurface feature as the GRB is overlain by the Vantage Member of the Latah Formation which, in turn, is overlain by flows of the Wanapum Basalt. The map is read in the same way as a topographic map and uses a 50 ft (15.24 m) contour interval.

Most elevations were obtained from well reports with the exception of the area north and east of Colfax where the GRB is exposed along the Palouse River (Bush and Dunlap, 2017). Well chip chemistry was used at twenty well sites to verify the presence of the uppermost flow of the GRB (Conrey and Wolff, 2010; Conrey and others, 2013; Conrey and Crow, 2014; Bush and others, 2016; Bush and others, 2018a). An additional 141 elevations of the uppermost GRB flow were interpreted from well reports, outcrops, stratigraphic and geologic cross-sections, and geologic maps that have a vertical accuracy ranging from 10 to 25 ft (3 to 7.6 m).

The lack of data in places required the interpretation of trends based upon an overall geologic understanding of the area. For example, a small northwest-plunging anticline exists along the western edge of the city of Pullman (Conrey and Wolff, 2010; Bush and others, 2018b), but the lack of data points over the areal extent of the fold prohibited the use of statistical and computer-generated methods to properly illustrate this anticline. Therefore, the overall geologic relations, in conjunction with known points, were used to produce a realistic contour map of the fold. Similar methods were used throughout the area. Numerous geologic cross-sections were constructed to assist in these interpretations.

DISCUSSION

The area contoured is located on the northeastern edge of the Columbia River flood basalt province where the basalt flows are relatively undeformed and overall have a gentle westward dip. However, within this general setting the GRB surface is irregular due to deformation and pinchouts of individual flow units, flows, and members.

The GRB surface is essentially horizontal between the two cities of Pullman and Moscow (Conrey and Wolff, 2010). Near the Washington-Idaho state boundary the surface drops rapidly eastward to more than 300 ft (91 m) beneath Moscow as the result of the west-to-east pinching out of the GRB flows. In general, the older flows of the GRB beneath Moscow extended farther eastward than subsequent younger flows, a feature called offlap.

Westward from the central part of the basin, the GRB surface slopes down into Pullman and then rises again before dropping beneath Union Flat Creek to the southwest. These changes in elevation in the Pullman area are believed to be primarily due to the presence of northwest-trending folds. One fold is an anticline that extends from the northern end of basement rocks on the south through Pullman and northward to basement rocks at Albion (Bush and others, 2016). Another fold is the corresponding syncline southwest of Pullman (Swanson and others, 1980) that, in general, follows the northwest trend of Union Flat Creek.

GROUND WATER IMPLICATIONS

There are two major water-producing zones, referred to as the upper and lower aquifers, in the Moscow-Pullman basin. The upper aquifer occurs primarily above the upper Grande Ronde surface in the overlying Vantage sediments and the Priest Rapids Member of the Wanapum Basalt, and the lower aquifer occurs in the GRB and associated sediments of the Latah Formation. Water levels in the lower aquifer are generally more than 200 ft (61 m) below those in the upper aquifer. The relief map of the GRB surface is useful in visualizing the relations between the two aquifers and, in places, can be used to interpret the direction of lateral ground water movement.

The primary lateral movement of ground water in most Columbia River Basalt Group aquifers occurs in zones along the contact of flows and (or) flow units (Reidel and others, 2002; Tolan and others, 2009). And, the direction of lateral movement of the water is primarily down the dip of those contact zones (Reidel and others, 2002; Tolan and others, 2009). Thus, if the slope of a known subsurface feature is indicative of the dip of the contacts, then that slope would represent the primary direction of ground water movement.

Geologic cross sections (Bush and others, 2018b) show that the slopes illustrated in the Pullman area and to the southwest in the Union Flat Creek and Colfax areas are similar to the dip of underlying basalt contacts. In those areas, the slopes of the Grande Ronde surface are likely to be the primary direction of lateral ground water movement. Beneath Pullman, the primary direction of groundwater flow is likely to the northwest toward Albion. West of Pullman, the movement is also likely to the northwest, away from the Snake River. Water levels between wells are relatively consistent in the lower aquifer (Ralston and others, 2013; TerraGraphics Environmental Engineering, Inc.; and Ralston Hydrologic Services, 2013); thus, piezometric maps do not help to verify or discredit this interpretation.

The slope of the Grande Ronde surface into Moscow, however, is not caused by eastward-dipping basalt flows. Here, the slope results from an offlapping to the west of individual Grande Ronde flows and (or) flow units which are interbedded with sediments of the Latah Formation. Thus, the eastward-dipping slope illustrated is one for the top of successively older flows and not a continuous surface on the same basalt flow. It is concluded that, in this case, the eastward slope does not necessarily represent the direction of lateral ground water movement beneath Moscow.

FUTURE SITES FOR MUNICIPAL WELLS

Municipal water wells in Pullman and at Washington State University produce from the lower aquifer in the Grande Ronde Basalt. The primary production comes from an interbed of the Latah Formation located between the N1 and R2 magnetostratigraphic units (MSUs) of the GRB at 550 to 650 ft (168 to 198 m) below the top of the Grande Ronde (Bush and others, 2018b). If a new municipal well is to be constructed here, it is recommended that sites along Missouri Flat Creek north of Pullman city well 7 should be considered where basalt contacts plunge northwest toward the city of Albion. Also, sites west of Pullman in the Union Flat Creek area should be considered. Both areas occupy northwest-plunging synclines that capture subsurface water flowing down slope toward the center of the folds. The structure contour map, along with geologic cross sections (Bush and others, 2018b) can be used to estimate the location of the synclinal axis and depth to the R1–N2 contact in order to obtain maximum production.

In the Moscow area municipal wells produce from the lower aquifer and the upper aquifer. In both cases, coarse-grained sediments of the Latah Formation are believed to be the principal avenues for water supply. These coarse-grained sediments are most dominant where there is a rapid change from a near-horizontal GRB surface to an eastward drop in elevation. This occurs west of Moscow where north-south paleostreams formed along pinchouts of R2 MSU members of the GRB. The newest municipal well, Moscow city well 10 located near the Washington-Idaho state boundary, penetrated gravel and sand interbeds that exceeded 160 ft (49 m) in total thickness, and it is expected to have the largest yield of all the lower aquifer wells. If future municipal wells are to be constructed for production from either the upper or lower aquifer, it is recommended that areas in the northern and northeastern parts of the city of Moscow be considered where sequences of coarse sediments are expected at depth. The map of the uppermost Grande Ronde surface can be used to locate the trend of the rapid west-to-east change in slope where coarse-grained sediments tend to occur.

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Explanation of Map Symbols

Structure contours—On top of the Grande Ronde Basalt of the Columbia River Basalt Group. Contour interval 50 feet. Approximately located; dashed where contours are projected past control points or where structure is uncertain.

Outcrop—showing name and elevation of top of Grande Ronde Basalt.

Well—showing name and elevation of top of Grande Ronde Basalt

pre-Tertiary rocks

city limits

SCALE 1:62,500

0 2 4 8 Miles

0 3 6 12 Kilometers

CONTOUR INTERVAL 50 FEET

NORTH AMERICAN VERTICAL DATUM OF 1988

Structure Contours on the Top of the Grande Ronde Basalt in the Moscow-Pullman Basin and Vicinity, Idaho and Washington

By

John H. Bush[1] and Pamela Dunlap[2]

2018

1 University of Idaho, Moscow, Idaho
2 Oro Valley, Arizona

Published and sold by the Idaho Geological Survey
University of Idaho, Moscow, Idaho 83844-3014

MISCELLANEOUS ILLUSTRATIONS

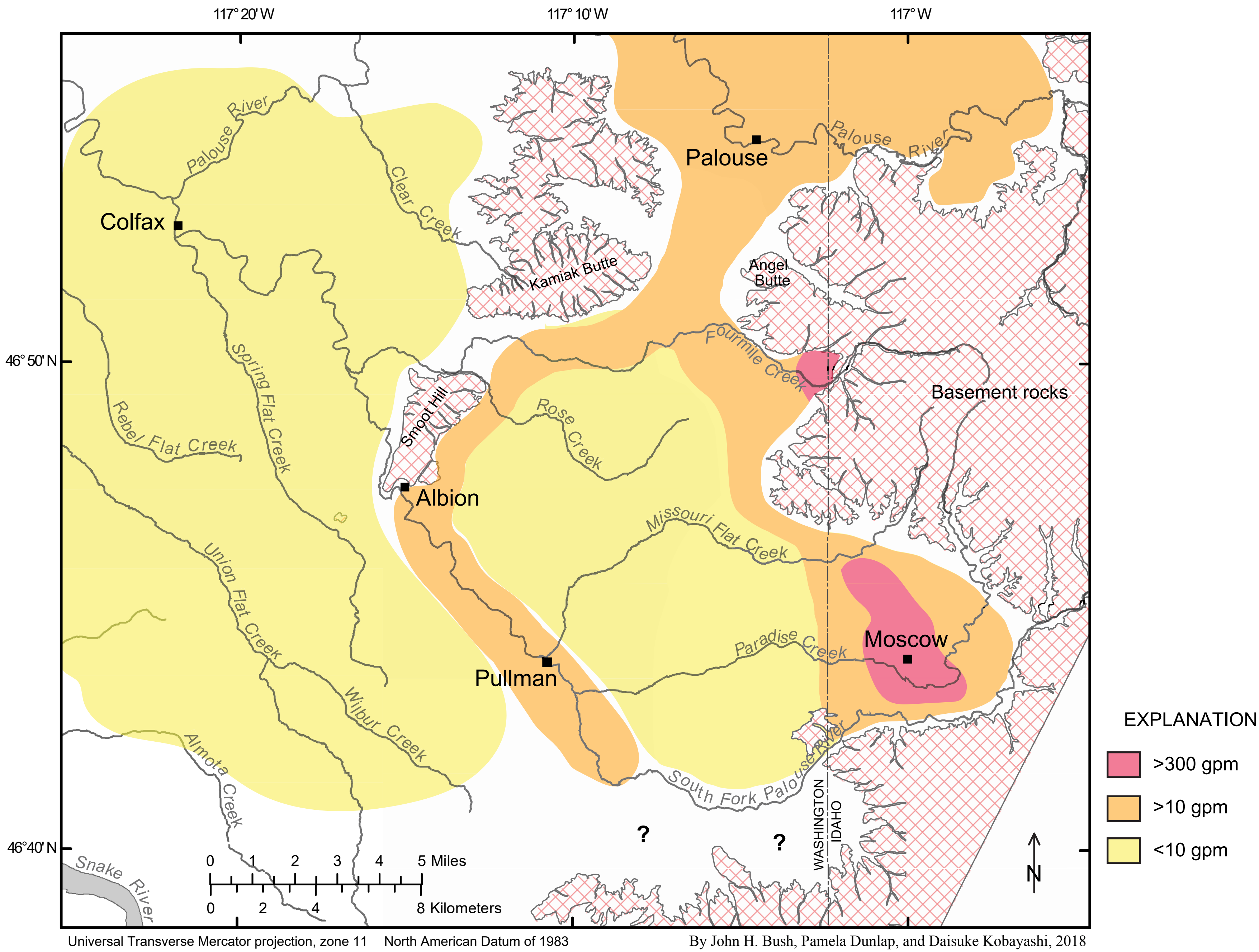

Figure 48. Generalized water supply map for the upper aquifer in the Moscow-Pullman basin and vicinity.

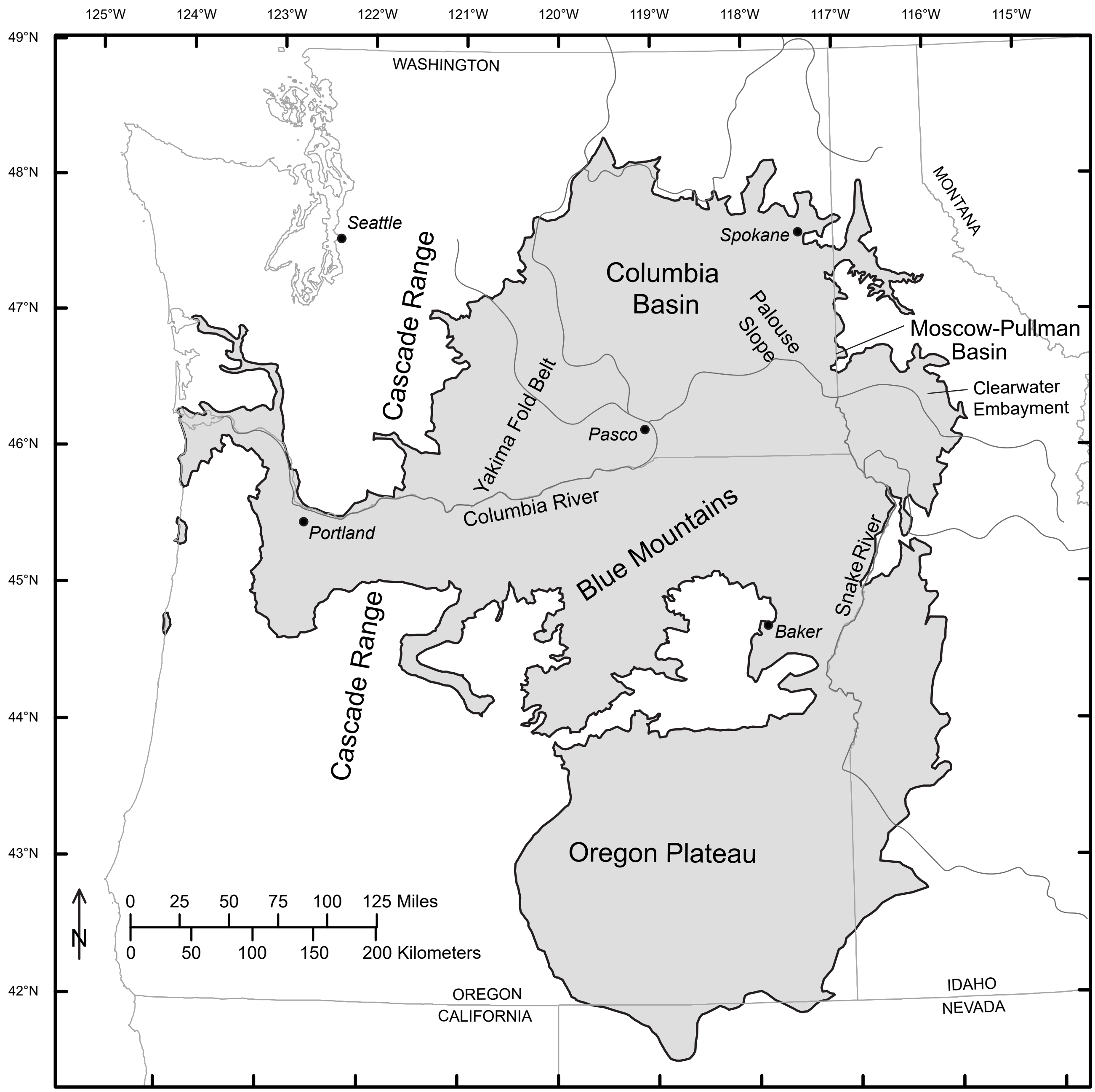

Figure 49. Map showing the Columbia River flood basalt province and areal extent of the Columbia River Basalt Group (gray, modified from Reidel and others, 2013 and Ludington and others, 2006 [2007]) and other major physiographic features (from Bush and others, 2016, Figure 1.)

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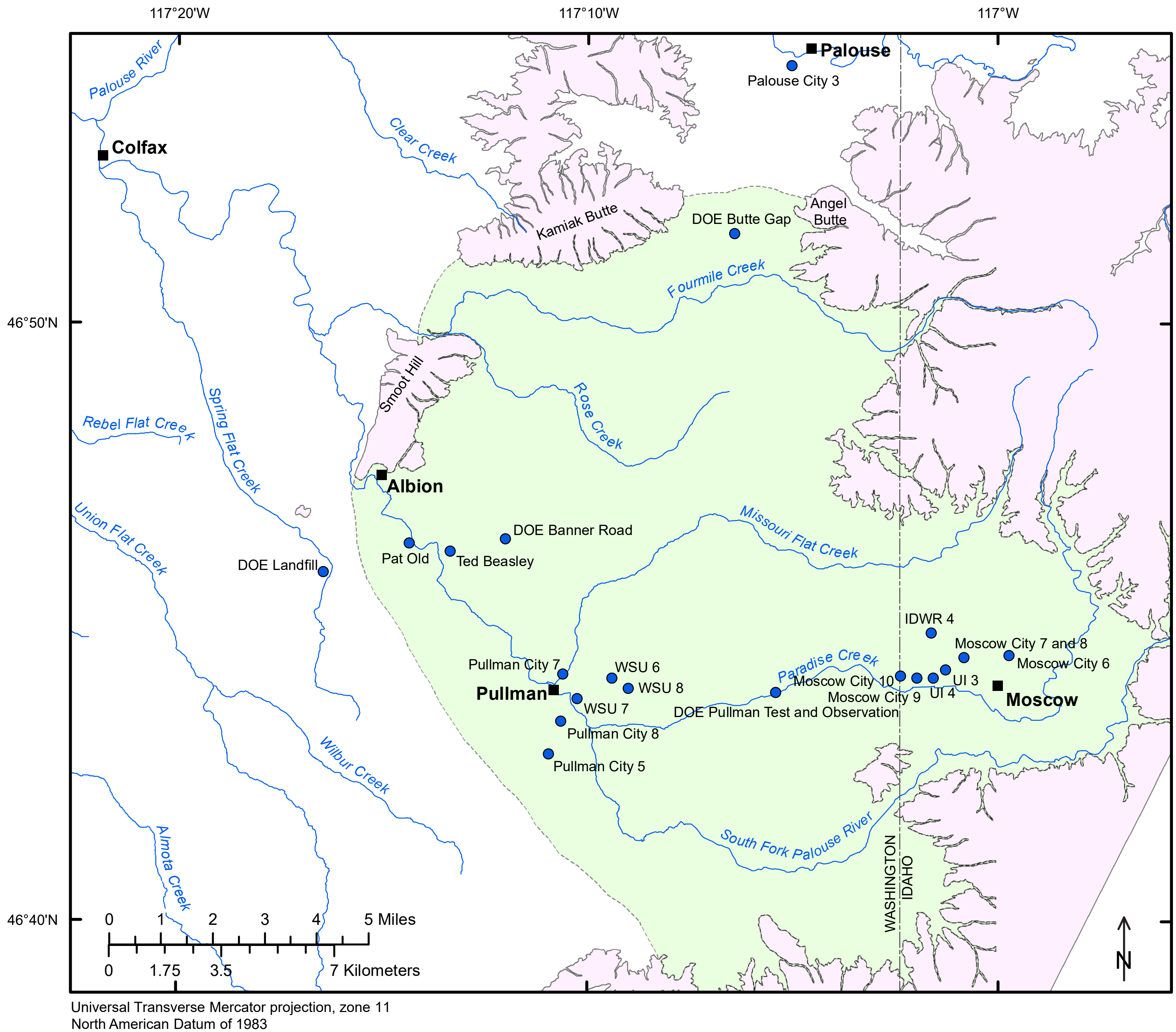

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Figure 50. Map showing Moscow-Pullman basin (green), select water wells (blue filled circles), and pre-Columbia River Group Basalt basement rocks (pink) (from Bush and others, 2018, Figure 2).

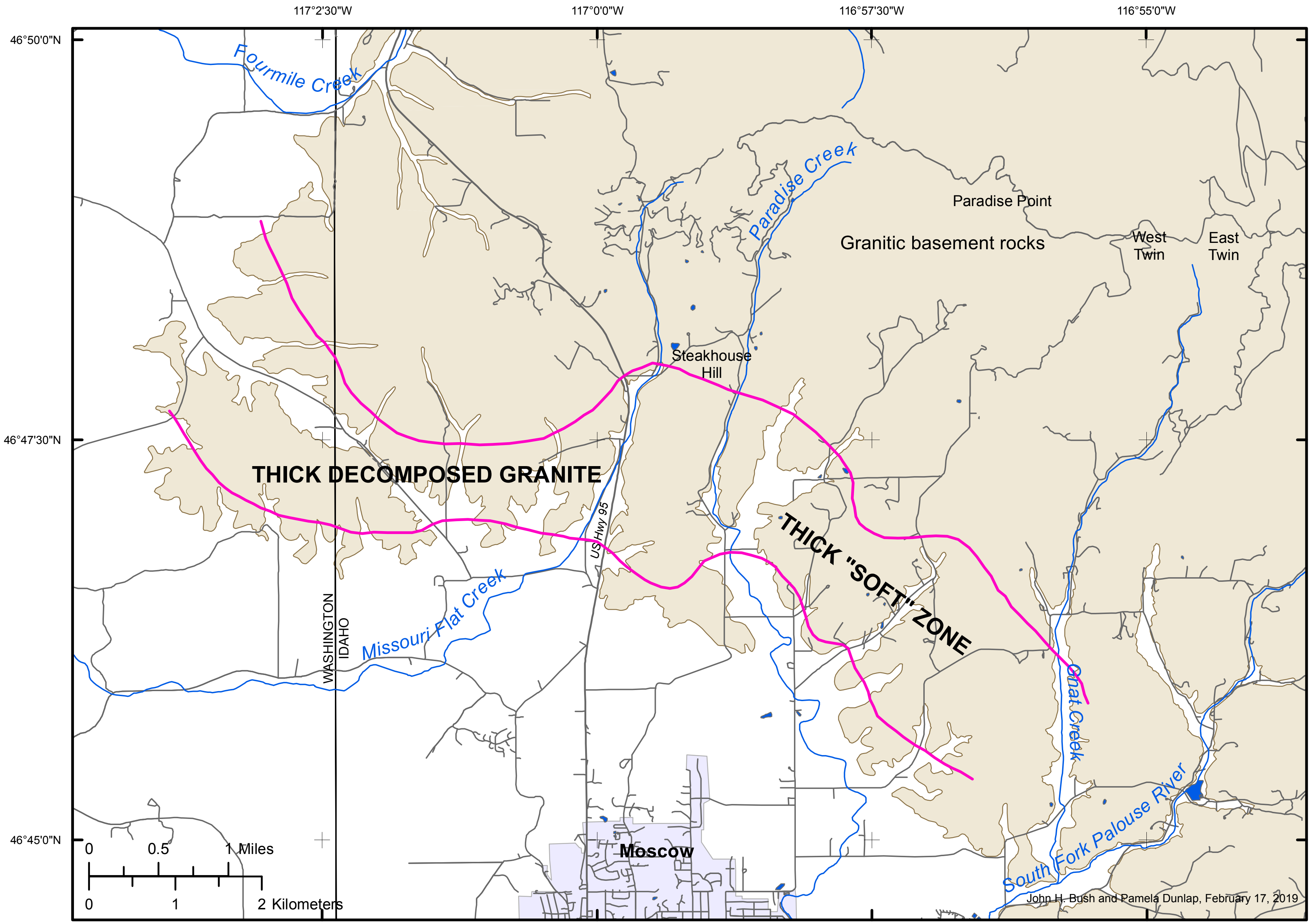

Figure 51. Distribution of zones of thick decomposed granite and thick "soft" zones on the southwest flank of the Palouse Range

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