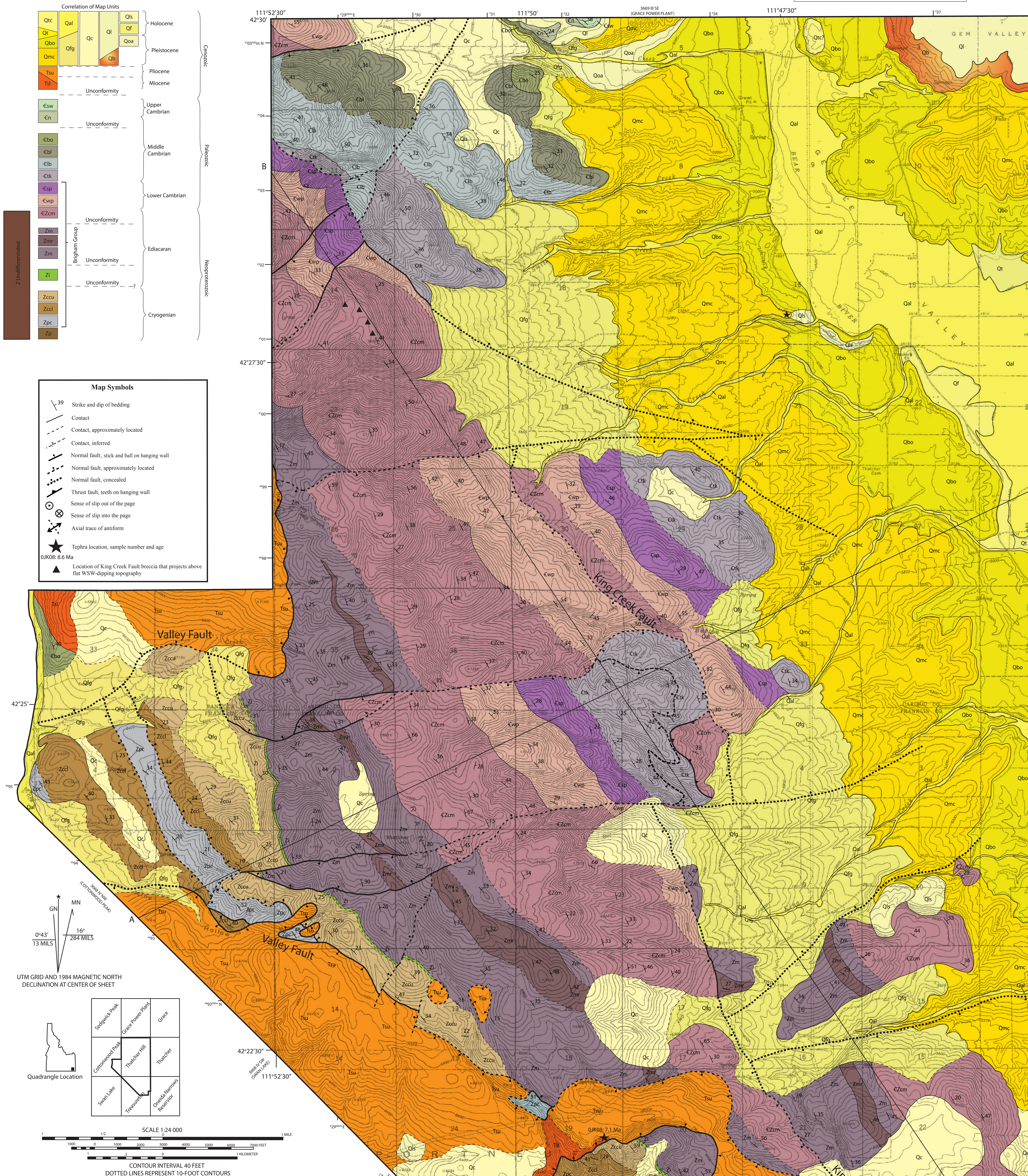
Geologic Map of the Thatcher Hill Quadrangle and portions of the Treasureton and Cottonwood Creek Quadrangles, Franklin, Bannock and Caribou Counties, Idaho

Joshua A. Keeley[1], David W. Rodgers[1], Paul K. Link[1], and Skye Cooley[2]

2011

This Technical Report is a reproduction of independent mapping by J.A. Keeley, D.W. Rodgers, P.K. Link, and Skye Cooley. Its content and format may not conform to agency standards.



REFERENCES

Armstrong, F.C., and Oriel, S.S., 1965, Tectonic development of the Idaho-Wyoming thrust belt: American Association of Petroleum Geologists Bulletin, v. 49, p. 1847-1866.

Armstrong, R.L., Leeman, W.P., and Malde, H.E., 1975, K-Ar dating of Quaternary and Neogene volcanic rocks of the Snake River Plain, Idaho: American Journal of Science, v. 275, p. 225-251.

Bouchard, D.P., Kaufman, D.S., Hochberg, A., and Quade, J., 1998, Quaternary history of Thatcher Basin, Idaho, reconstructed from the 87Sr/86Sr and amino acid composition of lacustrine fossils: implications for the diversion of the Bear River into the Bonneville Basin: Paleogeography, Paleoclimatology, Paleoecology, v. 141, p. 95-114.

Bright, R.C., 1967, Late Pleistocene stratigraphy in Thatcher basin, southeastern Idaho: Tebiwa: v. 10, p1-7.

Carney, S., and Janecke, S., 2005, Excision and the original low dip of the Miocene-Pliocene Bannock detachment system, SE Idaho: Northern cousin of the Sevier Desert detachment?: Bulletin of the Geological Society of America, v. 117, no. 3-4, p. 334-353.

Corsetti, F.A., Link, P.K., and Lorentz, N.J., 2007, del-13 C chemostratigraphy of the Neoproterozoic succession near Pocatello, Idaho, U.S.A.: Implications for glacial chronology and regional correlations: in Link, P.K., and Lewis, R.S., eds., SEPM Special Publication 86, Proterozoic geology of western North America and Siberia, p. 193-205.

Crittenden, M.D., Jr., Schaeffer, F.E., Trimble, D.E., and Woodward, L.A., 1971, Nomenclature and correlation of some upper Precambrian and basal Cambrian sequences inwestern Utah and southeastern Idaho: Geological Society of America Bulletin, v. 82, p. 581-602.

DeVecchio, D. E., 2002, Geologic map of the Downey East Quadrangle and regions of the Swan Lake, Oxford, and Cottonwood Peak Quadrangles, Bannock County, Idaho: Multiple phases of Miocene to Quaternary extensional tectonics [M.S. Thesis]: Idaho State University, Pocatello, Idaho,103 p.

Eversaul, M.L., 2004, Basin structure of proposed late Miocene to Pliocene supradetachment basins in southeastern Idaho based on detailed gravity and geologic data [M.S. Thesis]: Idaho State University, Pocatello, Idaho, 132p.

Fanning, C.M., and Link, P.K., 2004, U-Pb SHRIMP ages of Neoproterozoic (Sturtian) glaciogenic Pocatello Formation, southeastern Idaho: Geology, v. 32, no. 10, p. 881-884.

Gilbert, G.K., 1890, Lake Bonneville: U.S. Geological Survey Monograph 1, 438 p.

Harper, G.D., and Link, P.K., 1986. Geochemistry of Upper Proterozoic rift-related volcanics, northern Utah and southeastern Idaho. Geology, v.14, p. 864-867.

Izett, G. A., 1981, Stratigraphic succession, isotopic ages, partial chemical analyses, and sources of certain silicic volcanic ash beds (4.0-0.1 m.y.) of the western United States. U.S. Geological Survey Open-File Report, 81-763, 2 sheets.

Janecke, S. U., and Evans, J. C., 1999, Folded and faulted Salt Lake Formation above the Miocene to Pliocene New Canyon and Clifton detachment faults, Malad and Bannock Ranges, Idaho: Field trip guide to the Deep Creek half graben and environs, in Hughes, S.S., and Thackray, G.D., eds., Guidebook to the Geology of Eastern Idaho: Pocatello, Idaho Museum of Natural History, p. 71-96.

Janecke, S. U., S. M. Carney, M. E. Perkins, J. C. Evans, P. K. Link, R. Q. Oaks, Jr., and B. P. Nash, 2003, Late Miocene-Pliocene detachment faulting and Pliocene-Pleistocene Basin and Range extension inferred from dismem bered rift basins of the Salt Lake Formation, southeast Idaho, In R. G. Raynolds and R. M. Flores, eds., Cenozoic Systems of the Rocky Mountain Region: Rocky Mountain section of the SEPM, p. 369-406.

Keller, A.S., 1963, Structure and statigraphy behind the Bannock thrust in parts of the Preston and Montpelier quadrangles, Idaho (Ph. D. Thesis): Colombia University, New York, New York, 205 p.

Levy, M, Christie-Blick, N., and Link, P.K., 1994, Neoproterozoic incised valleys of the eastern Great Basin, Utah and Idaho: Fluvial response to changes in depositional base level: in Dalrymple, R.W., Boyd, R., and Zaitlin, B.A., editors, Incised Valley Systems: Origin and Sedimentary Sequences, Tulsa, OK., SEPM Special Publication 51, p. 369-382.

Link, P.K., 1983, Glacial and tectonically influenced sedimentation in the Upper Proterozoic Pocatello Formation, southeastern Idaho: in Tectonic and Stratigraphic Studies in the Eastern Great Basin, D.M. Miller, V.R. Todd, and K.A. Howard, eds., Geological Society of America Memoir 157, p. 165-181.

Link, P.K., 1987, The Late Proterozoic Pocatello Formation; A record of continental rifting and glacial marine sedimentation, Portneuf Narrows, southeastern Idaho: in Beus, S.S. ed., Centennial Field Guide Volume 2, Rocky Mountain Section of the Geological Society of America, p. 139-142.

Link, P.K., LeFebre, G.B., Pogue, K.R., and Burgel, W.D., 1985. Structural geology between the Putnam Thrust and the Snake River Plain: in Kerns, G., and Kerns, R., eds., Orogenic Patterns and Stratigraphy of North-Central Utah and Southeastern Idaho, Utah Geological Association Publication 14, p. 67-74.

Link, P.K., Jansen, S.T., Halimdihardja, P., Lande, A.C., and Zahn, P.D., 1987, Stratigraphy of the Brigham Group (Late Proterozoic-Cambrian), Bannock, Portneuf, and Bear River Ranges, southeastern Idaho: in Miller, W.R., ed., The Thrust Belt Revisited, 38th Annual Wyoming Geological Association Guidebook. p. 133-148.

Link, P.K., Kaufman, D., and Thackray, G.D., 1999, Field Guide to Pleistocene Lakes Thatcher and Bonneville and the Bonneville Flood, Southeastern Idaho, in Hughes, S.S. and Thackray, G.D., eds., Guidebook to the Geology of Eastern Idaho: Idaho Museum of Natural History, Pocatello, p. 251-266.

Long, S.P., Link, P.K., Janecke, S.U., and Rodgers, D.W., 2004, Geologic Map of the Henderson Creek Quadrangle, Oneida County, Idaho: Idaho Geological Survey Technical Report T-04-3, Scale: 1:24,000.

Long, S.P., Link, P.K., Janecke, S.U., Perkins, M.E., and Fanning, C.M., 2006, Multiple phases of Tertiary extension and synextensional deposition of the Miocene-Pliocene Salt Lake Formation in an evolving supradetachment basin, Malad Range, southeast Idaho, U.S.A.: Rocky Mountain Geology, v. 41, p. 1-27.

Ludlum, J.C., 1942, Pre-Cambrian formations at Pocatello, Idaho: Journal of Geology, v. 50, p. 85-95.

McCoy, W.D., 1987, Quaternary aminostratigraphy of the Bonneville Basin, western United States: Geological Society of America Bulletin, vol. 98, p. 99-112.

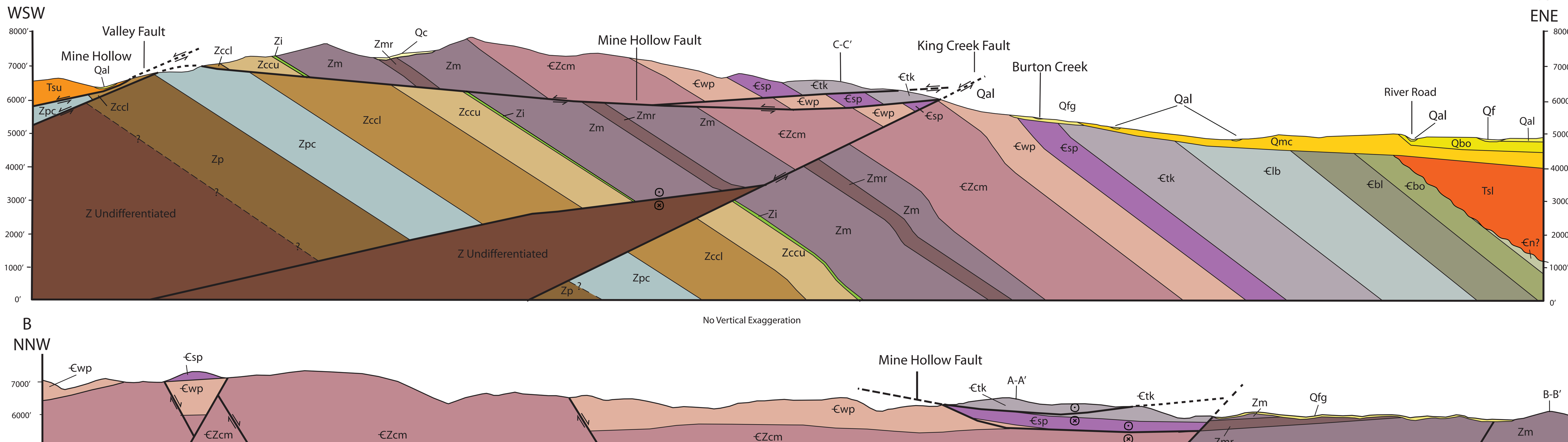
Oriel, S.S., and Armstrong, F.C., 1971, Uppermost Precambrian and lowermost Cambrian rocks in southeast Idaho: U.S. Geological Survey Professional Paper 394, p. 52.

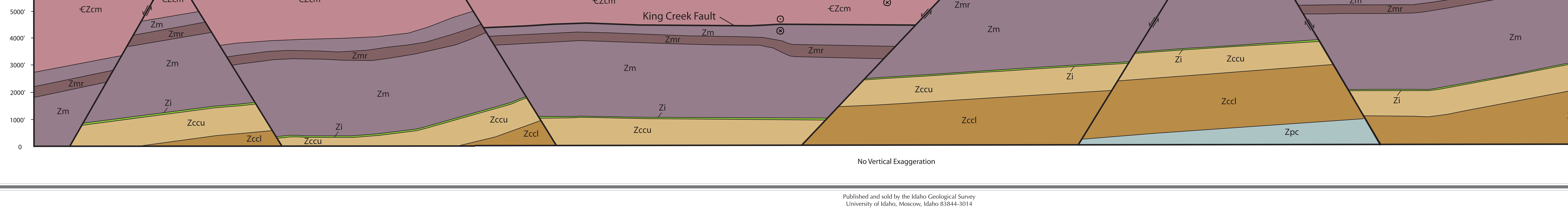
Oviatt, C.G., and Miller, D.M., 1997, New explorations along the northern shores of Lake Bonneville: Brigham Young University Geology Studies, v. 43, no. 2, p. 345-371.

Pickett, K., E., 2004, Physical volcanology, petrography, and geochemistry of basalts in the bimodal Blackfoot Volcanic Field, southeastern Idaho [Master's Thesis]: Idaho State University, Pocatello, Idaho,100 p.

Rodgers, D.W., and Janecke, S.U., 1992, Tertiary paleogeographic maps of the western Idaho-Wyoming-Montana thrust belt: in Link, P.K., Kuntz, M., and Platt, L.B. eds., Geology of southeastern Idaho: Geologic Society of America Memoir 179, p. 83-94.

Sacks, P.E., and Platt, L.B., 1985, Depth and timing of decollment extension, southern Portneuf Range, southeastern Idaho: In Kerns, G.J., and Kerns, R.L., Jr., eds., Orogenic patterns and stratigraphy of north-central Utah and southeast Idaho, Utah Geological Association Publication 14, p. 119-127.





DESCRIPTION OF MAP UNITS

Qal ALLUVIUM (HOLOCENE) - Unconsolidated, poorly to moderately well sorted, matrix- to clast-supported sand and gravel with silt sized loess matrix and moderately well-developed soil. Clasts are rounded brown, purple, pink and white fine- to coarse-grained quartzite cobbles derived from the Neoproterozoic to Cambrian Brigham Group and overlying Cambrian carbonate units. Includes stream channel and floodplain deposits. Maximum thickness is about 20 m.

Qls LANDSLIDE DEPOSITS (HOLOCENE) - Unconsolidated, poorly sorted, clast- and matrix-supported pebble to boulder conglomerate and diamict with silty loess matrix and well-developed soil. Where above 5440 ft elevation: localized headwall scarps, slump and flow toe geomorphology with clasts derived from Qfg unit. Where on terrace slopes along the Bear River and lower elevations: mass wasting products derived from Quaternary lake beds of Qmc and Qbo. Average thickness is about 5-10 m. Maximum thickness in Cottonwood Valley is 50 m.

Qf ALLUVIAL FAN DEPOSITS (HOLOCENE) - Low-relief, fan- or apron-like landforms that form the transition between valley alluvium and upland sediments. Composed of reworked material from unit that lies immediately upslope.

Qtc CALCAREOUS TRAVERTINE (HOLOCENE-UPPER PLEISTOCENE) - Tufa, calcrete and calcareous travertine. Porous, gray to white to yellowish-gray calcium carbonate hotspring and warmspring deposits that form mounds and benches along valleys. Flowing springs commonly associated with the unit. 40 m thick in Mound Valley.

Ql LOESS (HOLOCENE AND PLEISTOCENE) - Massive to stratified, unconsolidated, tan wind blown silts overlying Gem Valley Basalt or older bedrock units. Ranges from several centimeters to 8 m thick (Bright, 1967).

Qc COLLUVIUM (HOLOCENE AND PLEISTOCENE) - Angular to rounded, pebble- to cobble-sized quartzite clasts with well-developed loess and soil cover. High-elevation surfaces incised deeply by Pleistocene to Holocene streams. Includes cultivated land and hillsides with thick vegetation and soil cover. Thickness is unknown.

Qt TERRACE GRAVELS (PLEISTOCENE?) - Unconsolidated, moderately to poorly sorted cobble conglomerate that forms terraces up to 8 m above present day Cottonwood Creek. Matrix- to clast-supported, rounded and commonly imbricated quartzite cobbles with a fine- to coarse-grained sand matrix. Clast lithologies are brown, purple, pink, green and white Brigham Group quartzites. A meter of peat locally comprises the top of the terrace. In Mound and Gentile Valleys the unit forms the first terrace topographically up from active floodplain. Up to 8 m thick.

Qfg ALLUVIAL FAN GRAVELS AND SANDS (PLEISTOCENE) - Rounded, poorly sorted cobble to boulder conglomerate with loess and soil matrix. Clasts are derived from the Brigham Group and overlying Cambrian carbonate units. Shale chips are also present. Distinguished from the Tertiary Salt Lake Formation by the absence of red ilmenitic matrix and structural tilting, by the presence of loess and soil, and by the fan morphology. Crops out on the east flank of the range above 5440' elevation and on the west flank above 6120' elevation. Interfingers with fine-grained lake sediments of the Main Canyon Formation. Thickness unknown.

Qoa OLDER ALLUVIUM (PLEISTOCENE) - Poorly sorted boulder to fine-grained deposits on gently sloping valley-floor surfaces, slightly dissected by modern streams. Only present in Densmore Creek where the current drainage likely did not create the observed valley width nor boulder gravels. Deposited in an incised valley dissecting the Main Canyon Formation. Unit grades into and may incise Bonneville Lake sediments. Thickness unknown.

Qbo BONNEVILLE LAKE SEDIMENTS (PLEISTOCENE) - Poorly consolidated stratified gravel and sand deposited along the periphery of Lake Bonneville (30 to 10ka; Oviatt and Miller, 1997). Thin-bedded, generally flat lying, light red to orange to pink, silts and fine sands that form gently valley-ward sloping benches and dissected benches inset into Main Canyon Fm, Gem Valley Basalt, and older bedrock units. Grades basinward into pink silt and clay. Top is generally at 5100 ft elevation (Bright, 1967). About 30 m thick exposed (Oriel and Platt, 1980)

Qmc MAIN CANYON FORMATION (PLEISTOCENE) - Poorly consolidated, light-gray to tan silt, sand and marl deposited along the periphery of Lake Thatcher (2 Ma to 50 ka; Bouchard et al., 1998). Interfingers with hillslope colluvium (Qc), older alluvium (Qoa) and fan gravels (Qfg) that grade to shoreline level. Unit dominantly overlies but intertongues with flow toes of the Gem Valley Basalt in the map area. Top is generally around 5445 ft elevation (Bright, 1967). About 320 m thick (Bright, 1967).

Qb GEM VALLEY BASALT (PLEISTOCENE) - Dark gray fine- to medium- grained, vesicular, porphyritic basalt. Forms flat, undulating, and gently sloping flow surfaces. Includes rare pillows with palagonite/hyaloclastite rinds, pressure ridges and blisters on flow tops, cinder cones, and blocky flow front escarpments (talus). Uppermost flow surface is commonly covered by windblown silt (loess). Gem Valley lavas yield an 40Ar/39Ar of 0.09± 0.06 Ma (Pickett, 2004). 200 m thick in Gem Valley (Bright, 1967), 73 m in map area.

Tsu SALT LAKE FORMATION, UPPER MEMBER, UPPER UNIT (UPPER MIOCENE-LOWER PLIOCENE) - Unconsolidated, matrix- to clast-supported, cobble to boulder conglomerate. Matrix includes red clay and brown silt and sand. Clasts are almost exclusively rounded purple, white, pink and brown Brigham Group quartzite. Lower contact is marked at the transition from carbonate clast-bearing conglomerate of the lower unit of the Upper Salt Lake Formation to quartzite clast-dominated conglomerate with no carbonate clasts. Maximum thickness calculated from cross sections is 280 m.

Tsl SALT LAKE FORMATION, UPPER MEMBER, LOWER UNIT (UPPER MIOCENE-LOWER PLIOCENE) - Mostly unconsolidated, poorly sorted clast-supported cobble to boulder (up to 2.1m) conglomerate with light brown silt and sand matrix. Clasts include rounded, medium-gray Cambrian limestone with light brown silty partings and purple, white, pink and brown Brigham Group quartzite. Rare purple slate chips are also present. Two rhyolite tephra are present. The lower tephra (2 m thick) is a plane-laminated, light gray, silt-sized tuff with minor fine-grained sand, crystals, and lithics. Tephrochronology indicates it is correlative to the 8.6 Ma Inkom ash (B. Nash and M. Perkins, pers. comm.). The upper tephra (24 m thick) is a white, limey, vitric-lithic ashfall tuff with plane laminations, feldspar and 3 cm thick lapilli layers. Lapilli sizes range from 1-4mm. Tephrochronology indicates it is correlative to the 7.1 Ma Faust ash (Perkins and Nash, pers. comm.). The lower contact, an erosional unconformity, overlies the Cambrian Bloomington or Nounan formations. Slope-former except where well-cemented, clast-supported conglomerate and ash deposits crop out. Maximum thickness calculated from cross sections is 220 m.

€sw ST. CHARLES FORMATION LOWER WORM CREEK MEMBER (UPPER CAMBRIAN) - Light gray, tan to red-brown, fine- to medium- grained, medium-bedded arkosic sandstone and quartzite with subordinate thin beds of dolomite and limestone. Feldspar grains are weathered and iron-stained. Trough cross beds are abundant in the middle of the section. Lower contact is placed at the first feldspathic sandstone above dolomite of the Nounan Formation. Upper contact not exposed in map area. At least 160 m thick.

€n NOUNAN FORMATION (UPPER AND MIDDLE CAMBRIAN) - Medium gray to dark gray, medium-bedded oolitic packstone interbedded with maroon and light brown, undulating and discontinuous silt beds. Also contains a bed of thinly laminated pink siltstone 1.5 meters thick with carbonate cement. Bedding surfaces display trace fossils and minor trilobite fossil hash replaced by authigenic calcite while vertical cuts show silt-filled and calcite-filled lateral burrows. Forms ledges and rare slopes. Lower contact placed at the first medium- to thick- bedded dolomite ledge. 200 m thick.

€bo BLOOMINGTON FORMATION (MIDDLE CAMBRIAN) - Dark gray, thin- to thick-bedded, mottled silty limestone and green shale. Limestone has recrystallized trilobite hash, concretions, intraclastic conglomerate and chert. Thin green mudstone containing nodular siltstone beds in upper part and medium gray limestone in lower part. The lower portion is a medium-bedded trilobite-bearing wackestone. Lower contact is placed above the last oncoid-bearing limestone and quartz arenite of the Blacksmith Limestone. Ledge former that weathers red to orange. 200 m thick.

€bl BLACKSMITH LIMESTONE (MIDDLE CAMBRIAN) - Medium to dark gray thick-bedded, recrystallized, mottled limestone with oncoid and trilobite fossil hash. Lower portion contain thick beds of oncoid-bearing limestone with silt partings. Upper portion contains silty mottled limestone. The unit is noted by the absence of intraclastic conglomerate. Lower contact is placed above the last shale and/or quartz arenite of the Lead Bell Shale. May contain unit known as Bancroft Limestone towards the bottom. 325 m thick

€lb LEAD BELL SHALE (MIDDLE CAMBRIAN) - Thinly laminated black, gray, to green-yellow carbonaceous shale, gray lime mudstone and quartz arenite. Middle and upper portions are about equal proportions of medium-bedded gray recrystallized limestone and increasingly siliciclastic towards the top. Upper portion has as much as 50 m of tan quartz arenite. Lower contact placed at the first thick carbonaceous shale above the last occurrance of gray silty limestone of the Twin Knobs Limestone. Unusual thickness due to inclusion of Bancroft Limestone. 500 m thick

€tk TWIN KNOBS LIMESTONE (MIDDLE CAMBRIAN) - Thickly laminated, dark gray bioclastic packstone with interbedded purple and red-orange mudstone and yellow silty partings. Lower portion contains thin-bedded, dark gray mudstone, pink-purple mudstone laminations, green shale and intraclastic conglomerate. Silt-filled vertical borrows are abundant. Red to brown medium- grained feldspathic sandstone is rare towards the middle and commonly occurs as rubbly talus. The upper portions are composed of light and dark gray, alternating thin- to medium-bedded ooid-bearing grainstone and packstone. Ooids are about 1 mm in diameter. Trilobite- and bryozoan-bearing fossil hash, brachiopods and intraclasts of mudstone and wackestone are present higher in section. Lower contact is placed at the first gray limestone above quartzite and argillite of the Sedgwick Peak Quartzite. Ledge former that forms flat-topped steep slopes. 350-500 m thick.

€sp SEDGWICK PEAK QUARTZITE (LOWER CAMBRIAN) - Fine-grained, green quartzite interbedded with purple, plane-laminated siltite. Fresh surfaces are dark green and gray, while weathered surfaces are purple to green. Micaceous with some carbonate cement. Thick-bedded, coarse-grained, white to buff, trough cross bedded quartzite near top of formation. Interbedded siltite has more abundant burrows than siltite in the Windy Pass Argillite. Lower contact is placed at the first fine grained green quartzite above the yellow shale and argillite of the Windy Pass Argillite. Forms ledges and slopes. 200 m thick.

€wp WINDY PASS ARGILLITE (LOWER CAMBRIAN) - Shale, siltite, and quartzite. At the base is 100 m of thin beds and thick laminations of yellow, tan, and olive green shale and micaceous siltite. Above this is interbedded coarse- to medium-grained, brown, gray, and purple massive quartzite with floating granules, yellow to tan siltite, and granule conglomerate. Quartzite has rounded to subrounded hematite clasts. Siltite has abundant trace fossils including cruziana. Upper beds of quartzite are purple and green with minor purple argillite. Lower contact is placed at the first thick, >10 m, slope-forming shale above the Camelback Mountain Quartzite. Crops out predominantly as platy argillite subcrop and low relief outcrop. 300 m thick.

€Zcm CAMELBACK MOUNTAIN QUARTZITE (EDIACARAN TO LOWER CAMBRIAN) - The lower portion is thick-bedded, tabular cross-stratified, well-sorted, white and purple quartz arenite with pebble conglomerate along foreset troughs. White quartz and purple hematic chert (jaspilite) clasts are up to 4 cm. The lower to middle part of the unit contains coarse- to medium-grained, white to pink, trough cross stratified, well-sorted quartz arenite with pervasive liesegang banding and plane laminations in thick-bedded, fining upward feldpathic arenite. Fine-grained, red to black hematitic beds are interbedded. The upper portion is thin- to medium-bedded, brown, coarse- to fine-grained quartz arenite with plane beds, parting lineations, and scour marks. Gray, matrix-supported pebble conglomerate (clasts up to 5 cm) is interbedded and discontinuous. Two distinctive beds of thin-bedded, yellow to light gray shale up to 5 m thick lie at the top of the formation. The basal contact is marked by a poorly sorted pebble conglomerate in white quartz arenite with pink, purple and white vein-quartz clasts up to 20 cm in diameter. Red chert clasts and red argillite rip-up clasts as much as 4 cm in diameter are common, and 30 cm diameter chips are rarely present. Ledge-former that commonly forms large, broad, rounded hills. 750-900 m thick.

Zm MUTUAL FORMATION (EDIACARAN) - Quartzite and conglomerate. Medium- to thick- bedded, coarse-grained, purple quartzite with thin to medium interbeds of clast-supported pebble conglomerate. Trough cross beds with graded foresets, minor plane laminations and tabular cross beds are abundant. The lower portion (800 m thick) is pink and purple feldpathic quartzite with feldspars up to 1 mm, minor white quartzite and minor purple argillite. This grades upward into purple, coarse-grained quartzite with interbedded clast-supported pebble conglomerate with clasts up to 5cm in diameter. Conglomerate is comprised of rounded pink, purple, white, and vitreous vein quartz clasts with minor jaspilite, feldspar and hematite. Purple micaceous shale and green fine- to medium-grained sandstone forms the tops of 15-60 cm sets of trough and tangential cross beds with graded foresets. The Rocky Peak phyllite member (200 m) lies between the lower and upper quartzite units. Lower contact is placed at the first pink to maroon quartzite above the olive green to brown siltite of the Inkom Formation. Ledge former that commonly forms large, broad, rounded hills. Up to 1100 m thick.

Zmr ROCKY PEAK PHYLLITE MEMBER OF THE MUTUAL FORMATION - Interbedded purple shale and brown fine-grained sandstone that displays tool marks, ripples, and cross beds interpreted to be starved ripples in a lacustrine setting. The upper part is exclusively purple shale. Soft sediment deformation is exhibited by slump folds and ball and pillow structures. In one locality, a 15 m incision was filled with 2 m of pink pebble conglomerates. The unit pinches out to the northwest but thickens in the center of the map area to a maximum of 200 m. Slope former.

Zi INKOM FORMATION (EDIACARAN?) - Lower portion is brown to gray, coarse-grained quartz arenite with convolute bedding, slump folds and rare pebble conglomerate. Fines upward into thin-bedded, olive green to brown siltite and argillite. Top is gray to purple, fine- to coarse-grained quartz arenite with silty interbeds and rusty weathering. In places, coarse-grained sand fills syneresis cracks within medium-grained quartzite. Lower contact is placed below coarse-grained, green to brown quartzite with granule conglomerate or, when missing, below thin beds of shale. Slope former. 2 to 5 m thick.

Zccu CADDY CANYON QUARTZITE, UPPER MEMBER (CRYOGENIAN?) - White, light brown to blue-gray, well-sorted, fine- to medium-grained quartz arenite. Medium- to thick-bedded with trough and tabular cross stratification. Up section are increasingly more granule conglomerates at the base of thick beds of quartz arenite. Granules are white, vitreous and pink quartz with 10-15% angular coarse-grained feldspars. Unit is purple to maroon to the east. Lower contact is placed at the top of underlying carbonate rocks of the lower member. Forms ledges and slopes. 325 m thick.

Zccl CADDY CANYON QUARTZITE, LOWER MEMBER (CRYOGENIAN) - White orthoquartzite with orange to brown weathered surfaces and liesegang banding. Mostly comprised of thick-bedded, medium- to coarse-grained, well-sorted, feldspathic and quartz arenite. Lower portion has several 0.5-2 meter beds of fine-grained brown argillite with disrupted beds of siltite with sand injections and convoluted bedding. Top is marked by a 1.5 m thick carbonate unit that contains thin-bedded pink dolostone, massive white to yellow recrystallized limestone, and gray to pink dolostone with thin beds of carbonate pebble conglomerate with rare ooids. Thin-bedded yellow argillite and siltite bound this unit above and below. Lower contact placed at the first tan to white quartite bed above the siltite of the Papoose. Forms ledges and slopes. 600 m thick.

Zpc PAPOOSE CREEK FORMATION (CRYOGENIAN) - Brown to gray, fine- to medium-grained, moderately well-sorted to poorly sorted, sublitharenite interbedded with black, brown, and gray-blue, slightly phyllitic siltstone and shale. Sedimentary structures include sand injections, syneresis cracks, slump folds and ball and pillow structures.Also contains minor beds of purple argillite and several beds of very thick-bedded, well-sorted white quartz arenite. Forms platy to blocky talus. Lower contact is not exposed in the field area but should be placed above gray to black quartz arenite or black to silver shale of the upper member of the Pocatello Formation. Ledge and steep hill former. The unit thins from 480 m thick in Cottonwood Creek to 300 m in the northwest portion of the map area.

Zp POCATELLO FORMATION (CRYOGENIAN) (Only present in cross section) - Upper member is exposed immediately southeast of the map area where it is a thin-bedded, black to brown phyllitic shale interbedded with medium- to thick-bedded, black to brown, medium- to coarse-grained sandstone. Regionally present below the upper member is interbedded conglomerate, diamictite and quartz arenite of the Scout Mountain Member and mafic volcanic rocks of the Bannock Volcanic Member. Total thickness to the north and west, outside the study area is 1,920 m (Link and Stanford, 1999).

GEOLOGIC HISTORY

Introduction - The map area is located within the southern Portneuf Range of southeastern Idaho about 70 km southeast of the city of Pocatello. The map area is bounded on the west and south by Cottonwood Creek, on the east by State Highway 34 and the Bear River, and on the north by 42° 26' 45" latitude. Geologically, the map area is located in the northeastern corner of the Great Basin physiographic province, in the late Cenozoic Basin and Range Province, and in the late Mesozoic Sevier thrust belt.

Neoproterozoic to late Cambrian Sedimentation - The Neoproterozoic-Cambrian succession in southeastern Idaho includes the Pocatello Formation (Ludlum, 1942), the Brigham Group (Link et al, 1985), and overlying carbonate rocks. The Pocatello Formation includes the basal Bannock Volcanic Member consisting of greenstones and mafic volcanic rocks, the Scout Mountain Member composed of sandstone, argillite, conglomerate, carbonate and diamictite, and the upper member comprising thin-bedded black shale. This succession records the initial rifting of the supercontinent Rodinia (Link, 1987; Fanning and Link, 2004) to form a NNW-SSE trending rifted margin. The Bannock Volcanic Member represents a rift-related magmatic episode prior to or coeval with the deposition of shallow marine glaciogenic and reworked lodgment till and debris flow diamictite (Link; 1983; Crittenden et al., 1983; Harper and Link, 1986; Link, 1987). None of the Pocatello Formation is exposed in the map area, but it is inferred to exist at shallow depth and shown in cross sections.

The cyclic Blackrock Canyon Limestone (Corsetti et al., 2007) overlies the Pocatello Formation at Pocatello but has not been recognized in the Portneuf Range or southern Bannock Range.

The Brigham Group (Link et al., 1985; 1987) includes several quartzose formations with predominately clastic strata. The Papoose Formation contains intertidal and subtidal marine deposits interpreted to record the initial development of the western Laurentain miogeocline (Crittenden et al., 1971). This is overlain by shoreface to shelf deposits of the lower Caddy Canyon Quartzite. A thin carbonate interval is overlain by shoreface to coarse deltaic deposits of the upper Caddy Canyon Quartzite. A sequence boundary at the top of the Caddy Canyon Quartzite is interpreted to reflect early Ediacaran eustatic sea level fall, due to the Marinoan glaciation (Levy et al., 1993). This is overlain by slate of the Inkom Formation (Crittenden et al., 1971; Link et al., 1987). The overlying channelized Mutual Formation is interpreted to record fluvial deposition. It is capped by a sequence boundary, which is overlain by the fluvial/marine Camelback Mountain Quartzite. Evidence of the Sauk Transgression appears as tan shale in the upper Camelback and overlying siltite of the Windy Pass Argillite (Oriel and Armstrong, 1971). A brief regressive pulse produced the Sedgwick Peak Quartzite at the top of the Brigham Group.

Cambrian carbonate rocks and subordinate shale include the Twin Knobs, Blacksmith, Bloomington, and Nounan formations. This sequence represents the cessation of terrigenous deposition and accumulation of subtidal fossiliferous dolostone and limestone on a carbonate platform.

Late Cambrian to Early Cretaceous history – No rocks of this age are preserved in the map area. Elsewhere in the Portneuf and adjacent ranges, a 4-6 km thick section of Cambrian to Triassic strata is present and records a prolonged period of predominantly marine sedimentation (Oriel and Armstrong, 1965). The absence of these rocks in the map area is interpreted to indicate significant post-Triassic uplift and erosion, probably associated with the late Mesozoic Sevier Orogeny.

Late Cretaceous(?) to Early Eocene Sevier Orogeny - No rocks of this age are present in the map area, but regionally there is evidence for widespread crustal shortening associated with the Sevier Orogeny. At this latitude, five primary thrust faults with top-to-the-east vergence developed in Proterozoic, Paleozoic, and Mesozoic strata. From west to east these are the Paris, Meade, Absaroka, Darby and Prospect thrust faults. The southern Portneuf Range is located within the hanging wall of the Paris thrust, which may have slipped 60 km to the east relative to underlying strata (Armstrong and Oriel, 1965).

Throughout most of the Southern Portneuf Range, Cambrian strata are disconformably overlain by Miocene rocks (Keller, 1963). These relations indicate uplift and erosion of ~5,000 m of strata as well as a horizontal orientation of remaining strata prior to Miocene time. Based on these relations, Rodgers and Janecke (1992) interpreted the subsurface Paris thrust geometry in the map area to be characterized by a hanging wall flat over a footwall flat, and Carney and Janecke (2005) named this the Cache-Pocatello culmination.

Structural evidence of regional shortening is not widespread in rocks in the map area. One map-scale thrust fault, that dips gently east and places Camelback Quartzite on Twin Knobs Limestone, is present in the northeast part of the map area, while en echelon tension gashes and bedding-parallel fault striations are present in some quartzite units.

Early Eocene to Early Miocene history - No rocks of this age are preserved in the map area. South of the Portneuf Range, thin and discontinuous fluvial deposits of the Eocene Wasatch Formation are locally present (Long et al., 2006). The absence of these rocks is interpreted to indicate uplift and erosion in the map area at this time.

Middle Miocene to Pliocene(?) Basin and Range extension - During this time, the Salt Lake Formation accumulated in numerous normal fault-bounded basins throughout southeastern Idaho. In the map area, the Salt Lake Formation is represented by cobble and boulder conglomerate whose clast content documents progressive unroofing of first Cambrian carbonate rocks (lower unit) and then Neoproterozoic quartzite (upper unit). No radiometric ages were obtained from the map area, but new tephrochronologic correlation of rhyolite tuff documents deposition of the lower unit between 8.6 - 7.1 Ma (B. Nash and M. Perkins, pers. comm.).

Regionally, conglomerate, rhyolitic tuff and minor fresh water limestone comprise the Salt Lake Formation and record primarily fluvial and lacustrine depositional environments. Sacks and Platt (1985) described the Salt Lake Formation immediately west of the map area, and outcrops of the formation are present along the northeastern margin of Cache Valley and the southeastern end of Marsh Valley (Devecchio et al., 2003). These rocks include a basal tuffaceous, pebble-to-cobble conglomerate with interbedded tephra and limestone (Skyline Mb.), a medial fine-grained lacustrine unit with interbedded tephra and tuffaceous siltstone and sandstone (Cache Valley Mb.), which is interfingered with proximal pebble-to-cobble tuffaceous conglomerate (Third Creek Mb.), and an upper quartzite-dominated pebble-to-cobble conglomerate (New Canyon Mb.)(Janecke and Evans, 1999; Long et al., 2006). Regionally, the Salt Lake Formation accumulated between ~12 Ma (Janecke and Evans, 1999; DeVecchio, 2002) and 4.4 Ma (Long et al., 2006). In the map area, the lower unit of the Salt Lake Formation is lithologically and age-correlative with the Third Creek Member (Janecke et al., 2003), whereas the upper unit may be correlative with the New Canyon Member.

New mapping associated with this project indicates the map area contains three sets of normal faults distinguished by their contrasting strikes: NNW, E, and NE. The three sets record four stages of extension as shown by their varying attitudes and cross-cutting relationships.

Stage 1 is represented by the Mine Hollow fault, which dips gently east except along the western rangefront, where it dips gently west. The fault shows top-to-the-west normal displacement with approximately 740m of slip (AA', BB'). The fault also appears in a structural window beneath the Valley fault just north of Cottonwood Creek.

Stage 2 is represented by the Valley Fault, whose orientation based on well-constrained fault locations is N30W, 10-15°SW, in stark contrast to previous work (Sacks and Platt, 1985) which interpreted the fault as steeply west-dipping. Hanging wall strata of the Salt Lake Formation strike NNW and dip 11° ENE adjacent to the fault and steepen progressively downsection to ~60° ENE just west of the map area. Footwall strata strike NNW and dip 45±15° ENE. Top-to-the-west offset across the Valley Fault, using the Tertiary unconformity as a marker, is 8600 m.

The initial dip of the Valley Fault is interpreted to have been steeper than its present 10-15° dip. If footwall strata were subhorizontal prior to extension, as indicated by reconstruction of the Tertiary unconformity (Keller, 1963; Rodgers and Janecke, 1992), then the Valley Fault had an initial dip of 60±15° WSW based on measured bedding-to-fault angles. Hanging wall bedding-to-fault angles diminish upsection from ~70° to 20°. Combined with the modern low dip of the Valley Fault, these data are interpreted to indicate the Salt Lake Formation accumulated adjacent to the active Valley Fault while the fault as well as footwall and hanging wall strata tilted NE through time. The Valley Fault's planar to mildly listric shape, the progressive domino-style tilting, and the moderate amount of total slip suggest the Valley Fault is a typical large Basin-Range normal fault.

If the Stage 2 Valley Fault slipped during accumulation of the lower and upper units of the Salt Lake Formation, it initiated prior to 8.6 Ma and remained active through 7.1 Ma. It may have slipped more recently than 5.1-4.4 Ma, the age of strata underlying the potentially correlative New Canyon formation in the Deep Creek half graben (Janecke et al., 2003).

Stage 3 faults strike NE, dip moderately to steeply(?) and bound a horst. Though concealed by Quaternary colluvium, fan gravels, and the Main Canyon Formation, these faults are required in order to explain 740m of horizontal separation between low-lying ridges on the east side of the range.

Stage 3 faults are truncated by one stage 4 fault, hereby named the King Creek Fault, that strikes NNW, parallel to the Valley Fault, and dips moderately(?). Offset along the fault is 900 m.

The final stage of faulting before the initiation of a possible NNW-striking range-bounding fault to the east is represented by east- and west-striking cross faults that offset older faults of stages two and four. Offset is as much as 1km (?). One small graben downfaulting Neoproterozoic strata is formed as a result of antithetic faulting on the western end of the southernmost of the two faults, which dip 34° N. An extensional fault ramp is present in a small accommodation zone on the western end of the northern of the two faults, which dips 63° to the south.

Miocene to Pliocene normal faults are prevalent throughout the region and provide evidence of Basin and Range crustal extension. Many basin-bounding faults to the west and south of the map area are interpreted to be in the hanging wall of the laterally extensive, gently west-dipping Bannock detachment system (Janecke and Evans, 1999; Carney and Janecke, 2005), which slipped in multiple phases between 10-4 Ma (Long et al. 2006). The Valley Fault was previously interpreted as a strongly listric fault by Sacks and Platt (1985), as a tilted planar fault by Eversaul (2004), and as the breakaway fault of the Bannock detachment system by Carney and Janecke (2005). This new mapping indicates the Valley Fault is a tilted, mildly listric, domino-style normal fault rather than an originally low-angle detachment fault.

Pliocene to Holocene history - Evidence for Pliocene strata is a layer of ash that lies two meters below the lowest exposed marsh and lake deposits at the base of the Main Canyon Fm (denoted by the star on the map) as reported by Izett (1981) and Bouchard (1998). The ash is chemically and stratigraphically similar to the 2 Ma Huckleberry Ridge tephra (Izett, 1981).

Late Pleistocene climate change led to ice caps and valley glaciers in the Uinta Mountains, from which the Bear River was sourced. The formerly north-flowing Bear River was diverted south by a newly erupted lava flow in Gem Valley, north of the map area. The drainage pattern led to the filling of Thatcher Basin immediately east of the map area as early as 2 Ma (Izett, 1981; McCoy, 1987) and intermittently between ~140 ka (Armstrong et al., 1975) and 80 ka. The Bear River was tributary to Thatcher basin by 50 ± 10 ka (Bouchard et al., 1998). Clastic sediments accumulated on the floor and margin of the basin and now comprise the Main Canyon Formation. The lake filled to a level of 5445 ft (Bright, 1967) controlled by the lava flow to the north and ultimately spilled over a drainage divide to the south, incising Neoproterozoic to Cambrian strata and creating the Oneida Narrows Gorge by ~20 ka (^{14}C age) (Bouchard et al., 1998). The lake eventually drained, but Thatcher Basin filled a second time about ~20 ka when Lake Bonneville rose and flooded regions upstream along the Bear River. Lake Bonneville sediments and associated alluvial fan deposits accumulated at this time in the map area until water level exceeded about ~5100'. The drainage divide at Red Rock Pass (Gilbert, 1890), northern Cache Valley to the west, controlled periodic overflow until about 14.5 ka (^{14}C age) when the earthen dam there was breached, causing the Bonneville basin to catastrophically drain north through Marsh Valley as the Bonneville Flood (Link et al, 1999).

Although Quaternary fault scarps are present along several nearby range fronts (Long et al., 2006), no active faults were observed in the map area.

ACKNOWLEDGEMENTS

We thank the landowners and residents of Swan Lake, Thatcher and the Cottonwood Valley area for their gracious permission to access their land. This project was funded by EDMAP grant #08HQAG0077 to D.W. Rodgers from the U.S. Geological Survey. Many thanks go to Diana Boyack, Joe Sheffield and Esther Kingsbury for assistance in the digitization process, to Paul Link and the ISU Sedimentology/Stratigraphy class of Fall 2008 for fruitful interpretations in the field and to Stan Rowland, Dean Fox, and Tim Morris for access to the field. Special thanks to Elizabeth Balgard, Tim Diedesch and Sean Polun for help in mapping the northern Thatcher Hill Quadrangle in the summer of 2009.

1 - Department of Geosciences, Idaho State University, Pocatello, Idaho 83209, USA
2 - Department of Geology, Utah State University, Logan, Utah 84322, USA

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