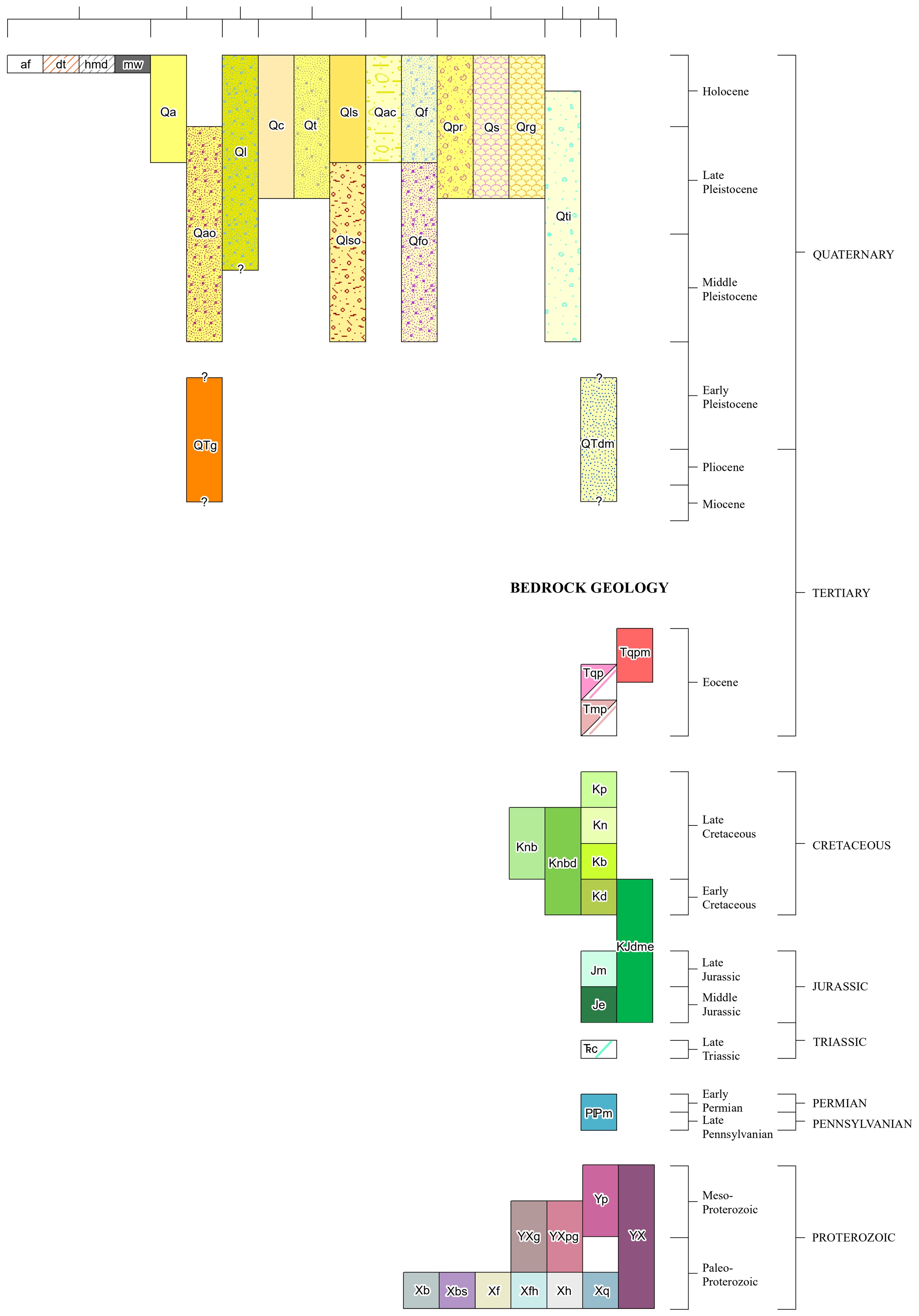
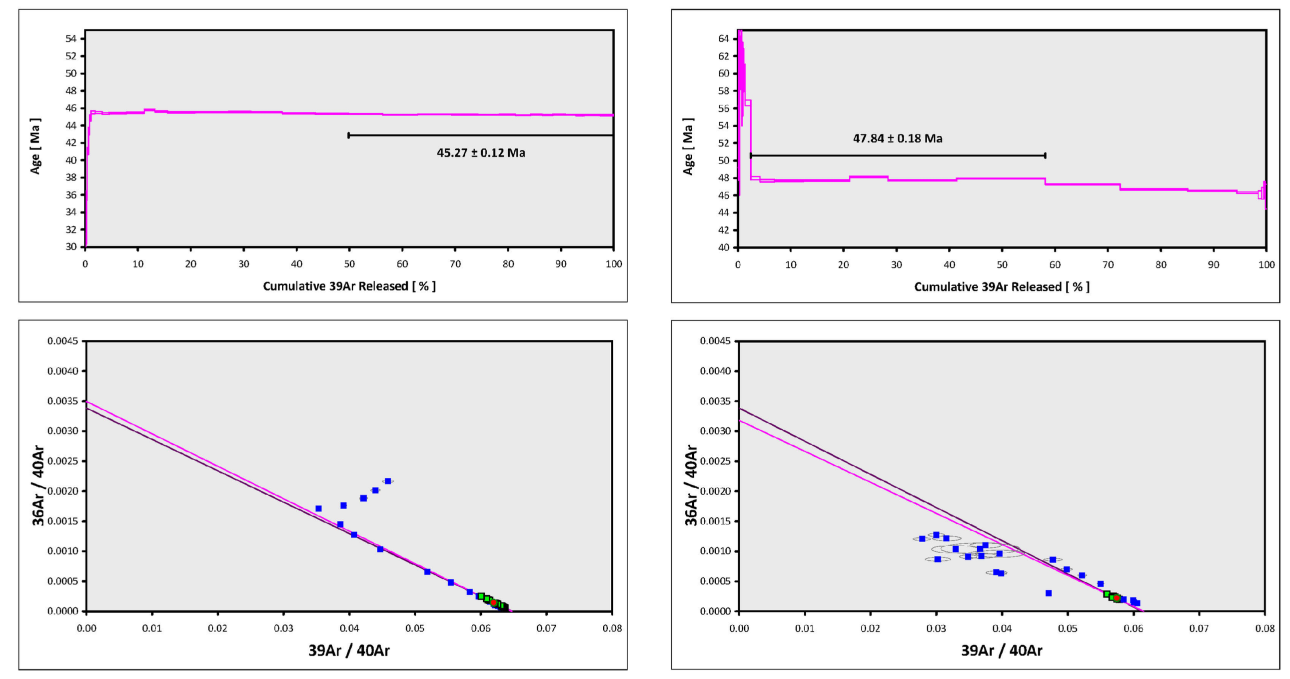
CORRELATION OF MAP UNITS



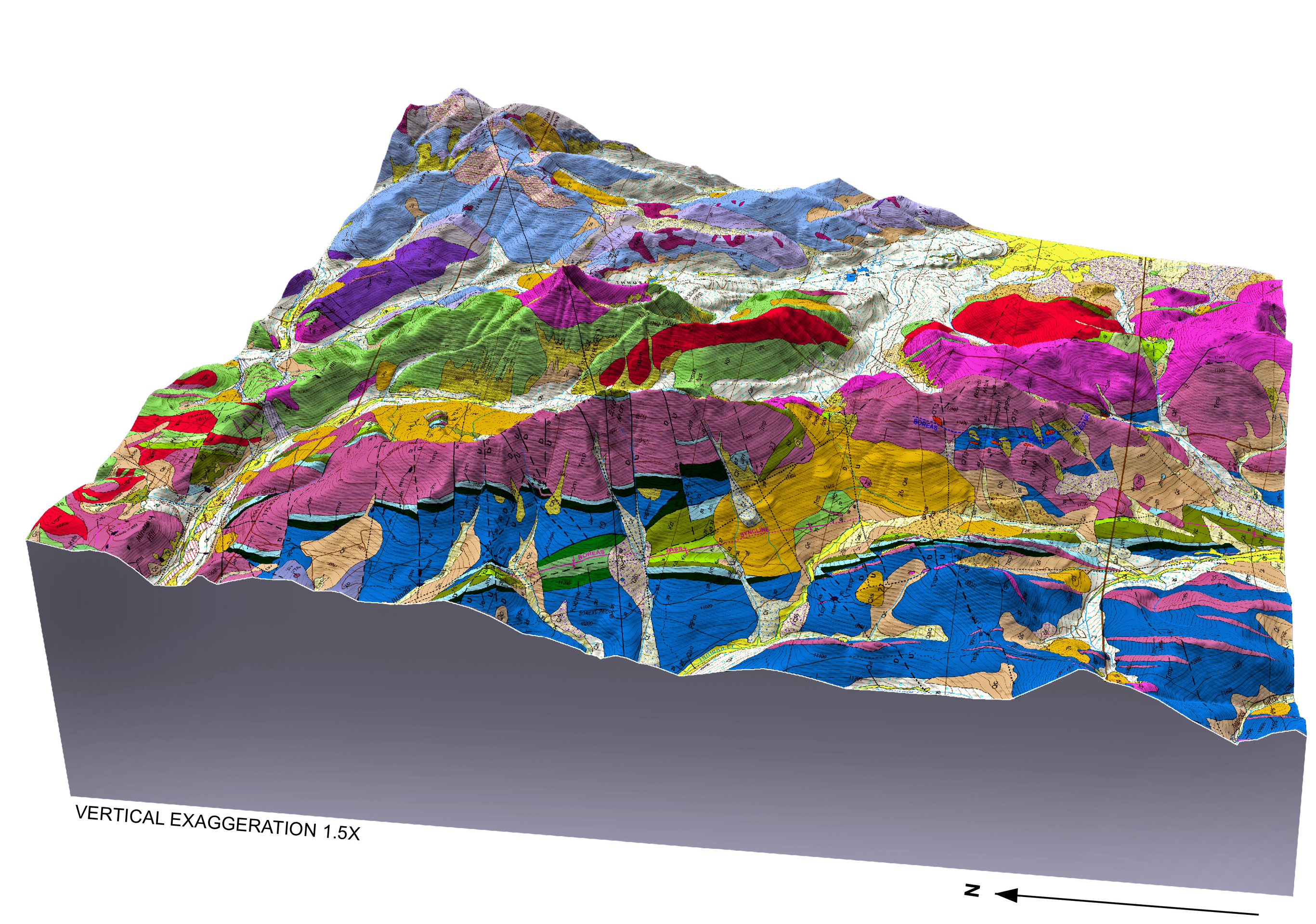
$^{40}Ar/^{39}Ar$ AGE DATE INFORMATION

Results	40(a)/36(a) ± 2σ	40(r)/39(k) ± 2σ	Age ± 2σ (Ma)	MSWD	39Ar(k) (%,n)	K/Ca ± 2σ
Age Plateau		15.44210 ± 0.00690 ± 0.04%	**45.27 ± 0.12 ± 0.26%**	1.41 13%	50.18 16	6.4 ± 0.5
			Full External Error ± 1.02	1.73	2σ Confidence Limit	
			Analytical Error ± 0.02	1.1886	Error Magnification	
Total Fusion Age		15.46098 ± 0.00438 ± 0.03%	**45.32 ± 0.12 ± 0.25%**		40	8.7 ± 0.0
			Full External Error ± 1.02			
			Analytical Error ± 0.01			
Normal Isochron	**284.33 ± 6.21 ± 2.19%**	15.46229 ± 0.01226 ± 0.08%	**45.32 ± 0.12 ± 0.26%**	0.88 58%	50.18 16	
			Full External Error ± 1.02	1.76	2σ Confidence Limit	
			Analytical Error ± 0.04	1.0000	Error Magnification	
Inverse Isochron	**286.02 ± 6.21 ± 2.17%**	15.45859 ± 0.01226 ± 0.08%	**45.31 ± 0.12 ± 0.26%**	0.85 61%	50.18 16	
			Full External Error ± 1.02	1.76	2σ Confidence Limit	
			Analytical Error ± 0.04	1.0000	Error Magnification	
				6%	Spreading Factor	

Results	40(a)/36(a) ± 2σ	40(r)/39(k) ± 2σ	Age ± 2σ (Ma)	MSWD	39Ar(k) (%,n)	K/Ca ± 2σ
Age Plateau Error Mean		16.31106 ± 0.04718 ± 0.29%	**47.84 ± 0.18 ± 0.38%**	17.14 0%	55.70 7	0.103 ± 0.001
			Full External Error ± 1.09	2.15	2σ Confidence Limit	
			Analytical Error ± 0.14	4.1400	Error Magnification	
Total Fusion Age		16.25751 ± 0.00940 ± 0.06%	**47.68 ± 0.12 ± 0.26%**		28	0.104 ± 0.000
			Full External Error ± 1.08			
			Analytical Error ± 0.03			
Normal Isochron Error Chron	**314.23 ± 129.62 ± 41.25%**	16.23721 ± 0.50512 ± 3.11%	**47.62 ± 1.47 ± 3.08%**	20.05 0%	55.70 7	
			Full External Error ± 1.81	2.26	2σ Confidence Limit	
			Analytical Error ± 1.46	4.4779	Error Magnification	
Inverse Isochron Error Chron	**314.24 ± 122.07 ± 38.85%**	16.23881 ± 0.50742 ± 3.12%	**47.63 ± 1.47 ± 3.09%**	20.31 0%	55.70 7	
			Full External Error ± 1.82	2.26	2σ Confidence Limit	
			Analytical Error ± 1.47	4.5071	Error Magnification	
				3%	Spreading Factor	



3-D OBLIQUE VIEW OF GEOLOGIC MAP



GEOLOGIC OVERVIEW

The Boreas Pass quadrangle, located entirely above elevation 9,800 ft (2987 m), is in the far southwestern part of the Front Range, a major constituent of the southern Rocky Mountains. A small area in the southeastern map area is in the northwestern part of South Park, a large, structurally complex intermontane basin. Geologically, the quadrangle is very complex, having experienced several periods of structural deformation and uplift, igneous intrusive activity, hydrothermal alteration and mineralization, and intense alpine glaciation.

Paleoproterozoic amphibolite-facies layered metamorphic rocks and Paleoproterozoic to Mesoproterozoic granitic intrusive rocks are exposed in the northeastern part of the quadrangle and in a small area along the western edge. The layered metamorphic gneisses and rare schists were derived from dominantly clastic sedimentary protoliths, possibly with some interlayered volcanic rocks. The layered rocks are foliated and commonly folded. Regional metamorphism and deformation occurred concurrently with the emplacement of syntectonic plutons during the Paleoproterozoic (Reed and others, 1987).

During the early to middle Paleozoic, the Proterozoic rocks were likely buried by marine clastic and carbonate sedimentary rocks. Early Paleozoic rocks of this type are well exposed a few miles to the west and southwest in the Breckenridge and Alma quadrangles (Wallace and others, 2002; Widmann and others, 2004). All of these early and middle Paleozoic marine sedimentary rocks were eroded away, at least in the northern and eastern map area, when the Ancestral Rocky Mountains were uplifted during Pennsylvanian time (Kluth, 1986). Clastic sediments derived from the erosion of the Ancestral Rocky Mountains formed the red bed sequences of the Pennsylvanian and Permian Maroon Formation found in the quadrangle. The Maroon Formation thickens rapidly from north to south across the quadrangle. It is less than 600 ft thick (183 m) in the northwestern part of the quadrangle, but nearly 4,000 ft thick (1219 m) in the southwestern part of the map area and the adjacent Breckenridge quadrangle. The Maroon Formation may never have been deposited in the northeastern map area. This indicates that the quadrangle may have straddled the boundary between a highland area of the Ancestral Rocky Mountains and the deep Central Colorado Trough (De Voto, 1972) sedimentary basin.

The Triassic Chinle Formation and the eolian Middle Jurassic Entrada Sandstone were deposited unconformably over an irregular erosion surface that developed on the Maroon Formation. Further deposition of sedimentary rocks, separated at times by periods of non-deposition and/or erosion, characterized the Late Jurassic to Late Cretaceous periods here as elsewhere in Colorado. The Western Interior Seaway covered the area during Cretaceous time and deposited the clastic and carbonate rocks of the Dakota Sandstone, Niobrara Formation, Benton Shale, and Pierre Shale found in the quadrangle. Combined, the Cretaceous sedimentary rocks are estimated to be over 2,500 ft thick (762 m) in the map area.

All of the Proterozoic through Upper Cretaceous rocks in the region were complexly deformed and uplifted during the Laramide orogeny, which began near the end of the Cretaceous Period. A major regional thrust fault, the Williams Range thrust, transects the quadrangle from northwest to southeast and is interpreted to connect with the Elkhorn thrust fault in South Park. The thrust fault system is fairly well exposed in the northern part of the map area; however, farther south it is completely covered by Quaternary surficial deposits for over four miles in the Michigan Creek drainage. The Williams Range thrust tectonically placed Proterozoic metamorphic and igneous rocks over the Cretaceous Pierre Shale. Many other faults in the quadrangle, as well as the two mapped synclines, also formed during the Laramide orogeny.

In middle Eocene time, which may correspond to the latter stages of the Laramide orogeny in central Colorado, porphyritic intrusions of intermediate to silicic composition were emplaced along and west of the Williams Range thrust fault zone. These intrusions formed as somewhat irregular but largely concordant sills that vary in thickness from less than 5 ft (1.5 m) to over 2000 ft (610 m). New $^{40}Ar/^{39}Ar$ age dating yielded an age of 47.84 ± 0.18 Ma for monzonite porphyry (Tmp) and 45.27 ± 0.12 Ma for quartz monzonite porphyry (Tqp). Uplift caused by the emplacement of intrusions may have bent the usually shallow-dipping Williams Range thrust fault upward, especially near the Mt Guyot pluton. The fault zone in that area may dip as steeply as 70° northeast. Only a few unambiguously discordant middle Eocene dikes were observed, and these were in Proterozoic rocks close to the Williams Range thrust. However, porphyry dikes (typically less than 20 ft (6 m) thick) were reported in mine workings in the historic Breckenridge mining district, the eastern portion of which is in the northwestern part of the map area (Ransome, 1911). Rich hydrothermal mineral deposits yielded economically significant quantities of gold, silver, lead, and zinc in the Breckenridge district. These deposits are interpreted to be genetically related to the Eocene igneous intrusive activity. Deposits were focused along faults, fractures, and contacts that formed open spaces and pathways for the mineralizing hydrothermal fluids. Later supergene enrichment of gold derived from narrow but numerous veins and veinlets produced shallow, but locally spectacularly rich deposits near the surface that were worked using hydraulic and placer methods, including those in American, Georgia, Dry, and Monitor gulches, and at the Wire Patch deposit on the northwest slope of Farncomb Hill. Although they were not economically significant (Lovering, 1934), a few small, scattered contact metamorphic mineral deposits (skarns) are present in thin calc-silicate-altered carbonate beds in sedimentary rocks adjacent to or very near intrusives.

Numerous faults, mostly vertical displacements of less than 1000 ft (305 m), cut Eocene intrusives as well as older rocks, especially in the northern half of the quadrangle. Most of these strike east-northeast to northeast. From late Tertiary (Neogene) time to the present, erosion of the high mountains was the dominant geological process in the Boreas Pass region. Evidence of a late Tertiary or early Pleistocene paleovalley was found on the high western and southern slopes of Boreas Mountain where small remnants of coarse, fluvial gravel are present. A large diamicton, possibly as old as Pliocene, composed of mostly sub-angular gravel was discovered along and south of the Continental Divide east of Georgia Pass. Further work is needed to determine the origin of this gravel, which locally forms the upper headwalls of Quaternary glacial cirques.

During Quaternary time, glaciers produced numerous cirques and the deeply glaciated valleys of French Gulch and the Middle and South Forks of the Swan River on the northwest side of the Continental Divide, and Michigan Creek, French Creek, Jefferson Creek, and North Tarryall Creek southeast of the Divide. Deposits of glacial till and outwash were produced. Rock glaciers are present and some may be active in several of the high cirque basins. A few visually spectacular protalus rampart deposits were formed from loose rocks falling and being deposited as arcuate ridges along the bases of long-lasting snow and ice fields. Rich placer gold deposits formed during the Pleistocene mainly in glaciofluvial outwash, especially along French Gulch in the northwestern part of the map area. Placers in the non-glaciated, smaller gulches north and east of Farncomb Hill were formed by mass-wasting and erosion of supergene deposits. Landslides cover a substantial portion of the Boreas Pass quadrangle and are the most extensive geological hazard. Other geologic hazards in the map area include rockfall, debris flows, floods, and swelling soils. No evidence of Quaternary faulting was found in the map area.

REFERENCES

De Voto, R.H., 1965, Facies relationships between Garo Sandstone and Maroon Formation, South Park, Colorado: American Association of Petroleum Geologists Bulletin, v. 49, no. 4, p. 460-462.

De Voto, R.H., 1971, Geologic history of South Park and geology of the Antero Reservoir quadrangle, Colorado: Quarterly of the Colorado School of Mines, v. 66, no. 3, 90 p., scale 1:62,500.

De Voto, R.H., 1972, Pennsylvanian and Permian stratigraphy and tectonism in central Colorado, *in* De Voto, R.H., ed., Paleozoic stratigraphy and structural evolution of Colorado: Quarterly of the Colorado School of Mines, v. 67, no. 4, p.139–185.

Kellogg, K.S., Bartos, P.J., and Williams, C.L., 2002, Geologic map of the Frisco quadrangle, Summit County, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-2340, scale 1:24,000.

Kirkham, R.M., Keller, J.W., Houck, K.J., and Lindsay, N.R., 2006, Geologic map of the Fairplay East quadrangle, Park County, Colorado: Colorado Geological Survey Open-File Report 06-9, scale 1:24,000.

Kluth, C.F., 1986, Plate tectonics of the Ancestral Rocky Mountains, *in* J.A. Peterson, ed., Paleotectonics and sedimentation in the Rocky Mountain region, United States: American Association of Petroleum Geologists, Memoir 41, p. 353–369.

Lovering, T.S., 1934, Geology and ore deposits of the Breckenridge Mining District, Colorado: U.S. Geological Survey Professional Paper 176, 64 p.

Lovering, T.S., 1935, Geology and ore deposits of the Montezuma quadrangle, Colorado: U.S. Geological Survey Professional Paper 178, 119 p.

Marvin, R.F., Mehnert, H.H., Naeser, C.W., and Zartman, R.E., 1989, U.S. Geological Survey radiometric ages, compilation "C"; Part five, Colorado, Montana, Utah, and Wyoming: Isochron/West, no. 53, p. 14-19.

Parker, B.H., Jr., 1974, Gold placers of Colorado (Book 1): Quarterly of the Colorado School of Mines, v. 69, no. 3, 268 p.

Poole, F.G., and Stewart, J.H., 1964, Chinle Formation and Glen Canyon Sandstone in northeastern Utah and northwestern Colorado: U.S. Geological Survey Professional Paper 501-D, p. D30-D39.

Ransome, F.L., 1911, Geology and ore deposits of the Breckenridge district, Colorado: U.S. Geological Survey Professional Paper 75, 187 p.

Reed, J.C., Bickford, M.E., Premo, W.R., Aleinkoff, J.N., and Pallister, J.S., 1987, Evolution of the Early Proterozoic Colorado province; Constraints from U-Pb geochronology: Geology, v. 15, p. 861–865.

Robinson, C.S., Warner, L.A., and Wahlstrom, E.E., 1974, General geology of the Harold D. Roberts tunnel, Colorado: U.S. Geological Survey Professional Paper 831-B, 47 p.

Ruleman, C.A., Bohannon, R.G., Bryant, Bruce, Shroba, R.R., and Premo, W.R., 2011, Geologic map of the Bailey 30' x 60' quadrangle, north-central Colorado: U.S. Geological Survey Scientific Investigations Map 3156, scale 1:100,000, pamphlet, 38 p.

Sheridan, D.M., and Marsh, S.P., 1976, Geologic map of the Squaw Pass quadrangle, Clear Creek, Jefferson, and Gilpin Counties, Colorado: U.S. Geological Survey Geologic Quadrangle Map GQ-1337, scale 1:24,000.

Wallace, C.A., Keller, J.W., Bartos, P.J., McCalpin, J., Route, E.E., Jones, N.N., Gutiérrez, F., Williams, C.L., and Morgan, M.L., 2002, Geologic Map of the Breckenridge Quadrangle, Summit County, Colorado: CGS Open-file Report 02-08, Scale 1:24,000

Widmann, B.L., Bartos, P.J., Madole, R.F., Barbá, K.E., and Moll, M.E., 2004, Geologic map of the Alma quadrangle, Park and Summit Counties, Colorado: Colorado Geological Survey Open-File Report 04-3, scale 1:24,000.

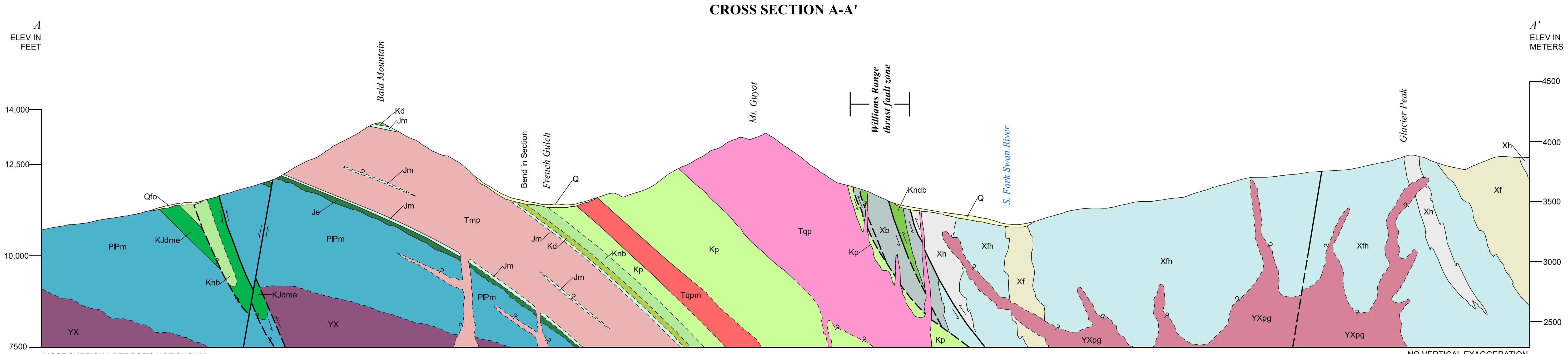
Widmann, B.L., Kirkham, R.M., Keller, J.W., Poppert, J.T., and Price, J.B., 2005, Geologic map of the Como quadrangle, Park County, Colorado: Colorado Geological Survey Open-File Report 05-4, scale 1:24,000.

Widmann, B.L., Morgan, M.L., Bartos, P.J., Shaver, K.C., Gutierrez, F., and Lockman, A., 2002, Geologic map of the Keystone quadrangle, Summit County, Colorado: Colorado Geological Survey Open-File Report 02-03,scale 1:24,000.

ACKNOWLEDGEMENTS

The authors thank the following individuals and groups for contributions to this project: the U.S. Geological Survey's (USGS) STATEMAP component of the National Cooperative Geologic Mapping Program and the State of Colorado Severance Tax on mineral extraction for funding; the Colorado Geological Survey (CGS) Geologic Mapping Advisory Committee and State Geologist Karen Berry for selecting this quadrangle for completion; Peter Barkmann, Senior Hydrogeologist and mapping geologist at CGS, for helpful field visits and many enthusiastic discussions about the geology of the region, and for his assistance with project logistics, including arranging for the age-dating of igneous rocks with Dan Miggins at Oregon State University; Robert "Bob" Kirkham, author of many geologic maps in Colorado, for donating his time to provide a thorough peer review of both plates, which substantially improved them; Caitlin Bernier of Pangaea Geospatial for diligent and professional GIS and cartographic support, and for preparing both plates for publication; the Park County Sheriff's Office, and particularly Captain Dan Muldoon, for patrolling the Georgia Pass and Boreas Pass roads, and for communicating to the senior author where the use of an ATV-type vehicle for official purposes is legal; the Summit County Open Space and Trails Department for acquiring public access rights and maintaining miles of trails and roads in privately-owned historic mining areas in the northwestern part of the quadrangle; Rick and Michelle Carroll, owners of Middle Fork RV Resort in Fairplay, for providing their "classic" Airstream trailer to the senior author for lodging, and for their camaraderie.

CROSS SECTION A-A'



GEOLOGIC MAP OF THE BOREAS PASS QUADRANGLE, PARK AND SUMMIT COUNTIES, COLORADO
CORRELATION OF MAP UNITS, 3-D OBLIQUE MAP, GEOLOGIC OVERVIEW, AND CROSS SECTION

By John W. Keller, Karen J. Houck, Erinn P. Johnson, Noah H. Keller, Matthew L. Morgan, Daniel P. Miggins, and George F. Klemmick
2017

COLORADO GEOLOGICAL SURVEY
COLORADO SCHOOL OF MINES