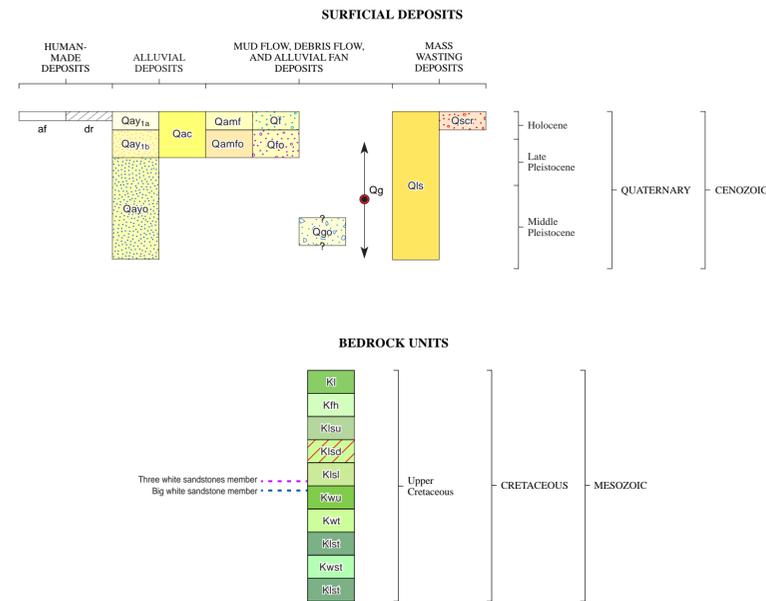
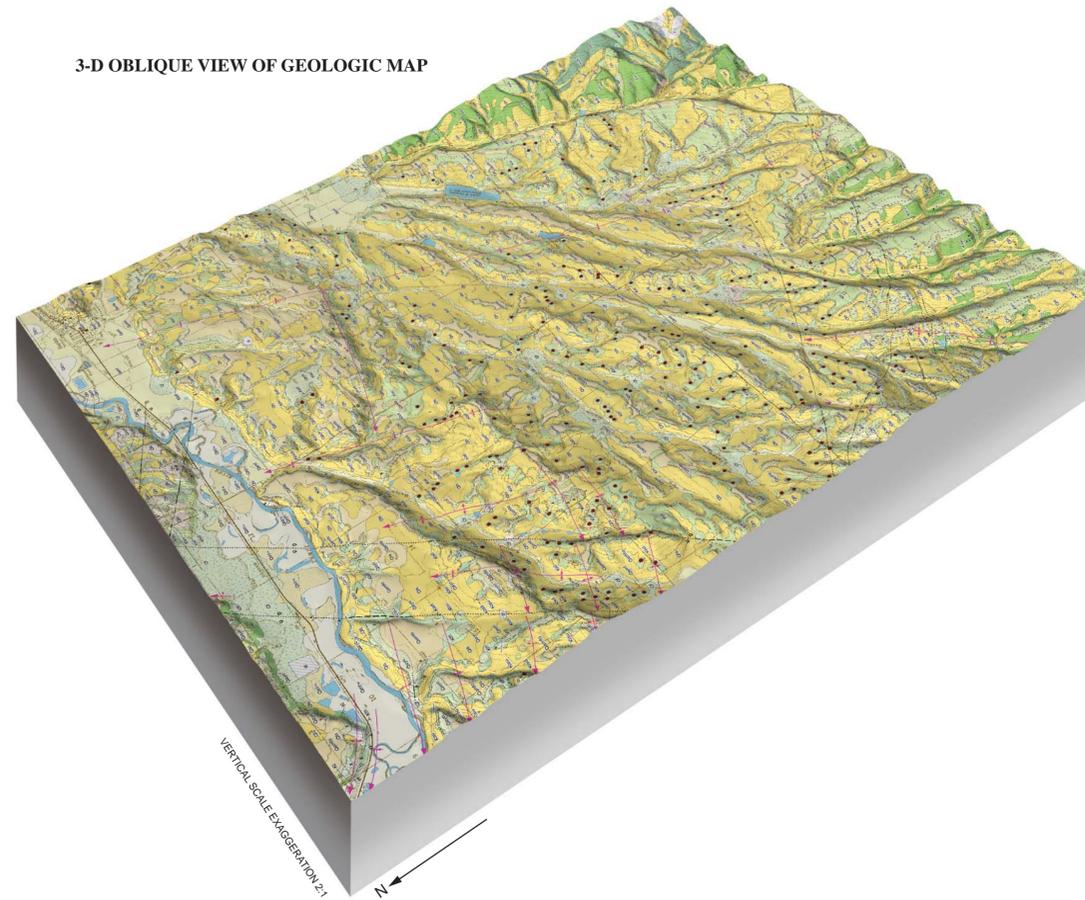


**CORRELATION OF MAP UNITS**



**3-D OBLIQUE VIEW OF GEOLOGIC MAP**



**STRUCTURAL GEOLOGY**

The Hayden quadrangle contains three structural features of note: (1) the Williams Fork Mountains in the southwestern corner; (2) the Sage Creek anticline in the southeastern corner; and (3) the Sand Wash Basin in the northern half. Sedimentary strata in the Williams Fork Mountains and Sand Wash Basin generally dip toward the north-northeast, while strata on the western flank of the Sage Creek anticline generally dip toward the west and northwest. These structural uplifts, basins, and folds are interpreted to be compressional features of Laramide age (Dickinson and others, 1988). Superimposed upon these features on the western side of the quadrangle are a series of small faults, anticlines, and synclines. They occur along two, roughly orthogonal axes, trending NNE-SSW and WNW-ESE. We interpret that the folding may be Laramide in age and caused by movements of basement sub-blocks during the formation of the main structural features. The faulting appears to be younger. The faults appear to be normal faults that cleanly cut across strata with no associated folding. We interpret that the faulting occurred during Miocene extension in Colorado, associated with a period of regional uplift and rifting (Chapin and Cather, 1994). In general, fault exposures are rare within the quadrangle. We relied upon geomorphic relationships in placing and extending the inferred fault traces. The faulting is more pronounced in the adjacent Breeze Mountain quadrangle to the west (Barkmann and others, 2015). It was nearly impossible for us to obtain strike and dip readings from outcrops of the Lewis Shale, due to grass cover and the deeply weathered nature of the formation.

**MINERAL RESOURCES**

Coal has been mined in the area for over 100 years, and numerous investigations of the coal resources have been conducted (Fenneman and Gale, 1906; Bass and others, 1955; Brownfield and others, 1999; Johnson and others, 2000; Carroll and others, 2003). The focus of historic underground mining was in the vicinity of Dry Creek, along the hogback ridges of the Mesaverde Group flanking the Sage Creek anticline (Carroll and Bauer, 2002). A large strip mine, the Seneca II West, is located in that same area, along the eastern boundary of the quadrangle, and has been reclaimed. Limited mining is reported from the Lance Formation (actually, the Dad sandstone member of the Lewis Shale) near the town of Hayden. Two small oil-and-gas fields are located in the quadrangle: the Pelt (gas; northwestern corner) and the Dry Creek (oil; southeastern corner), both of which produce from the Niobrara age-equivalent interval of the Mancos Shale (Wray and others, 2005). Oil-and-gas exploration in the region has boomed since the 2000's, with discoveries made in the Niobrara interval. The target zones are chalk benches. In addition, coal-bed methane production was attempted from the Mesaverde Group coal measures, but with limited success because of high rates of water production (Barkmann, 2011). Sand and gravel have been mined in modern and ancient deposits of the Yampa River (Guilinger and Keller, 2002; Keller and others, 2002), in units Qay1a, Qay1b, and Qay0.

**GROUND WATER RESOURCES**

There are 50 ground water wells in the Hayden quadrangle (Colorado Water Conservation Board, 2011). A majority of them are domestic wells located within the modern Yampa River valley, which produce from the alluvial sediments at depths of less than 100 feet. A few of the wells are permitted for uses such as irrigation, industrial (coal mine), commercial, and stock tanks. Deeper water wells in the quadrangle (100 to 3,643 feet in total depth) have been drilled into the Mesaverde Group. The most productive ground water aquifers are the Twentymile and Trout Creek Sandstone Members (Robson and Stewart, 1990).

**ACKNOWLEDGEMENTS**

The authors wish to thank the following individuals and entities for land access, information, and assistance in support of our geologic mapping of the Hayden quadrangle: Roy Karo, Rocky Thompson, and Scott Cowman (Peabody Coal); Lane Osborn (Colorado Board of Land Commissioners); H.J. Howard; Mary Murphy; George and Stephanie Temple; Jim and Carolyn Monteith; Dianna and Michael Murphy; Terry and Peggy Murphy; Kurt and Vonnie Fentress; Leon and Wilton Earle; Barry Castagnasso and Betsy Packer; Holly and Steven Blake; Ed and Kathy Hockin; John and Shirley Gossert; Dave and Kathy Smith; and Ralph Baird. Field mapping assistance was provided by Sonja Heuser and Robert Ressetar (Utah Geological Survey) and Nathan Rogers (CGS volunteer). Rocky Thompson provided peer review of the map materials. Larry Scott (Colorado Geological Survey) assisted with creating the 3-D map image.

**REFERENCES**

Barkmann, P.E., 2011, Coalbed methane stream depletion study, Sand Wash Basin, Colorado: Colorado Geological Survey internal report, 66 p.

Barkmann, P.E., Noe, D.C., McCall, K.J., Zawaski, M.J., and Heuser, S., 2015, Geologic map of the Breeze Mountain quadrangle, Moffat and Routt Counties, Colorado, Colorado Geological Survey Open-File Report OF 15-01, 2 plates, scale 1:24,000.

Bass, N.W., Eby, J.B., and Campbell, M.R., 1955, Geology and mineral fuels of parts of Routt and Moffat Counties, Colorado: U.S. Geological Survey Bulletin 1027-D, 260 p., 1 map plate, scale 1:62,500.

Brownfield, M.E., Johnson, E.A., Affolter, R.H., and Barker, C.E., 1999, Coal mining in the 21st Century – Yampa coal field, northwest Colorado, in Lageson, D.R., Lester, A.P., and Trudgill, B.D., eds., Colorado and adjacent areas: Boulder, Geological Society of America Field Guide 1, p. 115-133.

Carroll, C.J., and Bauer, M.A., 2002, Historic coal mines of Colorado, 2005: Colorado Geological Survey Information Series 64, CD-ROM.

Carroll, C.J., Rapp, A.R., and Kines, D.M., 2003, Available Coal Resources of the Williams Fork Formation in the Yampa Coal Field, Routt and Moffat Counties, Colorado: Colorado Geological Survey Resource Series RS-14, DVD Publication.

Chapin, C.E., and Cather, S.M., 1994, Tectonic Setting of the Axial Basins of the Northern and Central Rio Grande Rift, in Keller, G.R., and Cather, S.M., Basins of the Rio Grande Rift: Structure, Stratigraphy, and Tectonic Setting: Geological Society of America Special Paper 291, p. 5-26.

Dickinson, W. R., Klute, M.A., Hayes, M.J., Janecke, S.U., Lundin, E.R., McKittrick, M.A., and Olivares, M.D., 1988, Paleogeographic and paleotectonic setting of Laramide sedimentary basins in the central Rocky Mountain region: Geological Society of America Bulletin, v. 100, p. 1023-1039.

Fenneman, M.N., and Gale, H.S., 1906, The Yampa coal field, Routt County, Colorado: U.S. Geological Survey Bulletin 297, 96 p., 1 map plate, scale 1:125,000.

Guilinger, J.R., and Keller, J.W., 2004, Directory of active and permitted mines in Colorado – 2002: Colorado Geological Survey Information Series 68, CD-ROM.

Johnson, E.A., Roberts, L.N.R., Brownfield, M.E., and Mercier, T.J., 2000, Geology and resource assessment of the middle and upper coal groups in the Yampa coal field, northwestern Colorado, in Kirschbaum, M.A., Roberts, L.N.R., and Biewick, L.R.H., eds., Geologic assessment of coal in the Colorado Plateau, Arizona, Colorado, New Mexico, and Utah: U.S. Geological Survey Professional Paper 1625-B, Chapter P, 45 p., CD-ROM.

Keller, J.W., Phillips, R.C., Morgan, K., 2002, Digital inventory of industrial mineral mines and mine permit locations in Colorado: Colorado Geological Survey Information Series 62, CD-ROM.

Robson, S.G., and Stewart, M., 1990, Geohydrologic evaluation of the upper part of the Mesaverde Group, northwestern Colorado: U.S. Geological Survey Water-Resource Investigations Report 90-4020, 125 p., 1 map plate, scale 1:62,500.

Wray, L.L., Apeland, A.D., Hemborg, H.T., Brchan, C.A., Morgan, M.L., and Young, G.B.C., 2005, Shapefiles for the 2002 oil & gas fields map of Colorado: Colorado Geological Survey Open-File Report OF 05-09, CD-ROM.

**CROSS SECTION A-A'**

