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GSA Data Repository item 2007281: Appendices 1–3 and SEM images and spectra from a gas-vent mineral deposit, South Cañon Number 1 Coal Mine fire, Glenwood Springs, Colorado, and representative gas analyses.

APPENDIX 1: DENVER TO GLENWOOD SPRINGS, COLORADO

Locations along the Interstate 70 (I-70) are keyed to mileposts. East to west from Denver to Glenwood Springs, the numbers along I-70 decrease from ~280 to ~115. Recreational hiking and biking trails parallel the highway most of the way between Denver and Glenwood Springs. Appendix 2 includes: a regional map of the field-trip route from Denver to west of Vail (Fig. A2-1); a cross section of the Gore Range and Blue River graben (Fig. A2-2); a map illustrating the Ancestral Rockies uplifts (Fig. A2-3); geologic maps of the Vail Pass Stop (Figs. A2-4 and A2-5); a geologic map of the Glenwood Canyon Stop 1 (Bair Ranch Rest Area, Fig. A2-6); a geologic map of the Glenwood Canyon Stop 2 (No Name Rest Area, Fig. A2-7); and a geologic map and legend of the South Canyon area (Figs. A2–A8, A and B). Appendix 3 includes satellite images (Figs. A3-1 to A3-8) of select milepost stops and other locations along I-70, from Denver to Glenwood Springs.

Field-Trip Overview

The field-trip route (Fig. A2-1) follows I-70 west from Denver, climbing out of the Denver Basin and passing through the Front Range monocline into Precambrian rocks that core the Front Range uplift. Paleozoic and Mesozoic strata are preserved in grabens atop the Laramide uplifts. The route passes under the continental divide of the Gore Range (Fig. A2-2) at Eisenhower Tunnel, then through Pennsylvanian-Permian strata (Figs. A2-3, A2-4, and A2-5) along the Eagle River, and down through the vacation resort of Vail, Colorado. After joining the Colorado River, we pass into Glenwood Canyon (Figs. A2-6 and A2-7) and through the anticlinal White River uplift, down section into Precambrian rocks, then up section again into Paleozoic and Mesozoic rocks around the town of Glenwood Springs, Colorado. The South Cañon Number 1 Coal Mine fire is located in South Canyon (Figs. A2-8, A and B), a small tributary canyon south of I-70 a few km (11 miles) west of Glenwood Springs.

Geologic History

Our route passes through units ranging in age from Proterozoic to Quaternary (Table A1), affected by at least three major periods of deformation. The deformed and metamorphosed Precambrian basement has been considered the result of arc collision against the Wyoming Province to the north (Van Schmus et al., 1993), but a more complex origin involving rifting and reworking of older crust is suggested by new isotopic ages and chemical data (Bickford and Hill, 2007). The oldest rocks along our route, 1900–1700 Ma Proterozoic gneisses and schists, represent metavolcanic and metasedimentary rocks of the Colorado Province (Bickford et al., 1986; Condie, 1986), or the Inner Accreted Belt of Van Schmus et al. (1993). Ductile shear zones trending east-northeast that developed ca. 1700 Ma eventually localized Late Cretaceous–Tertiary plutonism and hydrothermal mineralization, producing the Colorado mineral belt. Proterozoic granitic intrusions include three suites (Table A1): ca. 1700 Ma syntectonic plutons related to the development of a magmatic arc, ca. 1400 Ma plutons with minor deformation, and ca. 1000 Ma anorogenic plutons (Fisher and Fisher, 2004; Kellogg et al., 2004).

The Precambrian rocks were uplifted and deeply eroded before subsidence and development of a continental seaway led to deposition of the lower Paleozoic strata. In the late Paleozoic, Ancestral Rocky Mountain orogeny produced basement-cored uplifts separated by basins. As uplifted strata were eroded down to the Proterozoic crystalline rocks, synorogenic detritus was deposited in the adjacent basins, burying remnants of the lower Paleozoic sequence under as much as 5 km of Pennsylvanian and Permian strata (Kellogg et al., 2004). Fluvial, eolian, and shallow marine deposits of Permian through Middle Jurassic age gave way to lacustrine and fluvial deposits of the Upper Jurassic Morrison and Lower Cretaceous Dakota Formations (Table A1), famous for their dinosaur fossils. In late Early Cretaceous, rising sea level led to marine deposits of the Western Interior Seaway. In Late Cretaceous–early Tertiary, the Laramide orogeny produced contractional faults, monoclines, and basement-cored uplifts associated with scattered igneous activity. Hydrothermal activity associated with 68–27 Ma Laramide dikes and stocks was the source of most of the important metallic mineral deposits in the Colorado mineral belt. Progressive erosion of the Laramide uplifts is recorded by Upper Cretaceous and Tertiary clastic deposits. At the end of the Laramide orogeny in the Eocene, the Rocky Mountains may not have been more topographically distinct than at the beginning of the orogeny. Much of the topography we will cross today is thought to have developed since the Paleogene, perhaps since the Neogene (Kellogg et al., 2004).

Structures produced during the Laramide orogeny are attributed to contractional strain and vertical uplift, recorded by numerous strain orientations (e.g., Brown, 1993; Bump, 2003; Sterne, 2006). A number of models for the causes of the Laramide orogeny continue to inspire debate; a good review is that by English and Johnston (2004).

Environmental Issues

Much of the route passes through ecologically sensitive mountains and canyons that provide irreplaceable and fragile habitat for Colorado's wildlife. Large mammals that may be seen along the route include big horn sheep, elk, and mule deer. Small mammals include striped golden mantled ground squirrels, coyotes, river otters, and beavers. The latter are evidenced by their brush dams and ponds, but they are seldom seen in the daytime. Higher elevations are populated by seldom-seen black bear and mountain lion (puma or cougar), and alpine meadows by marmots. Common birds are the black and white magpie, the blue scrub jay, and the red-breasted American robin, as well as less common eagles and hawks.

Constructing an all-weather interstate highway through high mountains and sheer-walled narrow canyons was an enormous challenge. Glenwood Canyon was a particular challenge because of its beauty and ecological sensitivity, sparking a number of battles between environmentalists and proponents for development in the 1970s. The lengthy planning process involved public comment as well as ecologists, wildlife specialists, and engineering geologists to preserve as much as possible of the canyon's scenery and ecosystem during construction. Designers studied every meter of the canyon, created computer simulations, and built scale models before the first shovel was turned. In some cases, special equipment was used to minimize environmental impact. In the narrowest parts of the canyon, westbound lanes are stacked vertically above eastbound lanes to minimize the highway's footprint. Their goal was to build a divided four-lane highway that would complement the spectacular canyon rather than detract from it. Did they succeed? You can judge for yourself.

Road Log: Interstate 70 (I-70) from Denver to Glenwood Springs

Milepost	***Description***
266	I-70 climbs out of the Denver Basin. Table Mountain (Fig. A2-1), to the north, is capped by Tertiary basalt flows (66–64 Ma) overlying Upper Cretaceous to Paleocene fluvial deposits of the Denver Formation (Table A1) (Van Horn, 1972). Within the Denver Formation the Cretaceous-Tertiary (K-T) boundary is mapped at the highest occurrence of Triceratops (Fisher and Fisher, 2004).
262	Good views of Table Mountain to the north. To the southwest is Green Mountain (Fig. A2-1), type locality of the Paleocene Green Mountain Conglomerate (Table A1) (Scott, 1972).
261	Town of Golden, Colorado. In the valley to the north, is the Colorado School of Mines. Founded in 1874, it is one of the oldest U.S. institutions devoted to mineral sciences and engineering.
260	Gray outcrops of Late Cretaceous Laramie Formation and Fox Hills Sandstone (Table A1); the valley is underlain by Cretaceous Pierre Shale, Niobrara Formation (consisting of chalks and shales of the Smoky Hill Member, underlain by limestone of the Fort Hays Member), and Benton Formation (consisting of Carlile, Greenhorn, and Graneros members) (Birkeland et al., 2004). The north-trending Golden fault system crops out within the Benton Formation (Scott, 1972); at this location it represents a backthrust associated with the Front Range uplift (Sterne, 2006).
259	Large exposures on either side of I-70 where it cuts through the north end of Green Mountain (Scott, 1972). The highway passes rapidly down-section through the Lower Cretaceous Dakota Group into the Jurassic Morrison Formation and Sundance Sandstone. Trails from parking areas on either side of I-70 provide access. The Dakota Group consists of yellow sandstone and gray shale with thin coal layers; the major hogback in the Dakota Group consists of Lytle Sandstone (Birkeland et al., 2004; LeRoy, 1992). Maroon and green lacustrine shales dominate the Morrison Formation. The Dakota Group and Morrison Formation contain dinosaur bones (LeRoy, 1992; Lockley, 1992). Colorado Route 93 leads south from Exit 259 to Red Rocks Park, where red beds of the Permian-Triassic Lykins Formation and Permian Lyons Sandstone overlie the Pennsylvanian-Permian Fountain Formation (Table A1). The sequence rests nonconformably on Proterozoic gneiss (Scott, 1972). Alameda Parkway leads from Route 93 over Dinosaur Ridge, the Dakota Group hogback that is continuous with the I-70 road cut. This park is an outdoor museum featuring dinosaur bones and tracks in the Lytle Sandstone (Birkeland et al., 2004; Weimer and LeRoy, 1987).
258	Eastern contact of Precambrian rocks (Fig. A2-1) consisting of dark gray amphibole-rich gneiss and augen gneiss, cut by pinkish to yellowish granitic dikes and sills. The upper amphibolite facies gneisses formed 1900–1700 Ma as part of a volcanic arc terrane, the Colorado Province, which accreted to the Archean Wyoming craton to the north (Bickford et al., 1986; Condie, 1986). The gneisses

record ductile deformation and were partially melted, producing granitic dikes and migmatites. Historically, these gneisses and the related schists, quartzites, marbles, metacherts and iron formations were termed the "Idaho Springs Formation" (Weimer and LeRoy, 1987) but recent work suggests that the name should be revised because the "Idaho Springs" package represents many different environments that formed over a long period of time (Fisher and Fisher, 2004; Kellogg et al., 2004). The granitic rocks record 3 ages of intrusion (Table A1): ~1700 Ma Boulder Creek plutons that are syntectonic with the volcanic arc gneisses, ~1400 Ma Silver Plume plutons, and ~1000 Ma Pikes Peak plutons (Fisher and Fisher, 2004; Kellogg et al., 2004). Many of the dikes and sills are granitic pegmatites.

249 Large outcrop of Proterozoic migmatites (Sheridan et al., 1972a, b); see milepost 258.

246 The "Idaho Springs Formation" is strongly foliated, isoclinally folded, and locally
239 migmatitic (Sheridan and Marsh, 1976). A large quarry for crushed rock at milepost 244.5 provides a view of fresh exposures.

242.5 Tunnel.

241 The historic mining town of Idaho Springs, type area of the "Idaho Springs
239 Formation", occupies an alluvial terrace along Clear Creek (Widmann et al., 2000). Mine tailings are still visible above the town. The town is named for hot mineral springs that were first used by Native people thousands of years ago. The first major gold strike in Colorado was made here in 1859 (Walton, 2006); the town has been a popular spa since the 1880s. Active mines in the area still produce gold, lead, molybdenum, silver, tungsten, uranium, and zinc.

239 West of Idaho Springs, Clear Creek canyon narrows, passing through "Idaho Springs" metavolcanic and metasedimentary rocks and younger intrusions, partially covered by Quaternary stream gravels (Widmann et al., 2000). Mine tailings are preserved along the canyon walls, and avalanche chutes on the canyon walls are marked by stripes of white-barked aspen trees between dark green conifers.

229 Georgetown Reservoir and the historic mining town of Georgetown (Widmann and Miersemann, 2002). George Griffith discovered gold at the head of Clear Creek in 1859, but the town named for him died when the gold was mined out. In 1864 Colorado's first major silver discovery was made nearby and the town boomed again, briefly becoming the world's largest producer of silver (Walton, 2006). More than 200 original buildings still stand in Georgetown's historic district. Leadville took over as the premier silver mining area in 1878. The Georgetown Loop Railroad and Lebanon Silver Mine offer train rides and mine tours.

226 Historic silver mining town of Silver Plume, developed in 1870 during the same silver boom that revitalized Georgetown (Walton, 2006). Good outcrops of "Idaho Springs" metavolcanics cut by younger intrusions, notably the Silver Plume Granite (ca. 1400 Ma) (Fig. A2-1). Old mine tailings, landslides, and avalanche chutes line the canyon.

216 Exit 216 to Loveland Pass. This 2-lane highway follows the old Ute Indian trail over the continental divide, providing a spectacular view of the glaciated high country. The pass elevation is ~3655 m (11,990 ft.).

215.5	East portal of the Eisenhower (westbound lanes) and Johnson tunnels (eastbound lanes), elevation 3,353 m (11,000 ft.).
213.5	West portals of the Eisenhower-Johnson tunnels, located at timberline.
213 208	Outcrops of yellowish white Proterozoic granite and dark gray “Idaho Springs” gneiss. The reddish brown conifers on the canyon walls are evidence of pine beetle disease. Dead and dying trees increase the risk of wildfires.
208	Entering an area of nonresistant Cretaceous Pierre Shale (Table A1) preserved in the Blue River half-graben (Figs. A2-1 and A2-2), which forms the floor of a broad scenic valley (Kellogg, 2002). Local deposits of Pleistocene glacial gravels and Quaternary alluvium overlie the Pierre Shale.
205	Exit to Silverthorne and Dillon, resort towns.
203.5	Scenic viewpoints are on both sides of I-70 with views of mountain peaks across Dillon Reservoir, a major component of the Denver water system. Water is transferred by tunnel across the continental divide to the South Platte River Basin. The glacial gravels in road cuts include upper Pleistocene till of the Pinedale glaciation, which overlies middle Pleistocene till of the Bull Lake glaciation (Kellogg et al., 2002).
203	The town of Frisco occupies a site along Tenmile Creek, used by the native Ute people for at least 7000 yr. European settlers founded the town in 1873 and the town prospered through the late 19th century from nearby gold and silver mines. After World War II, Frisco became a winter ski resort and summertime recreational center for mountain biking, hiking, fishing, and sailing.
201	Near Frisco, I-70 crosses the Blue River normal fault (Figs. A2-1 and A2-2) and passes into Precambrian rocks of the Gore Range (milepost 198; Kellogg et al., 2002). Numerous avalanche chutes can be seen on the canyon walls.
198	Officers Gulch exit: a large rockfall is visible to the south.
195	Eastern mouth of a narrow canyon carved by Tenmile Creek into the “Idaho Springs” gneiss. Beaver dams and ponds dot the meadows south of I-70.
194.5	The town of Copper Mountain, founded as a ski resort in the early 1970s, is a popular year-round entertainment center.
193.5	Gore Fault (Figs. A2-1 and A2-2), along which Precambrian rocks are thrust westward over Pennsylvanian-Permian alluvial red beds of the Maroon Formation (Bergendahl, 1969; Tweto, 1979). The Pennsylvanian-Permian Fountain Formation and its correlative units (Table A1) were derived from the Ancestral Rockies uplifts (Fig. A2-3). I-70 continues in Pennsylvanian-Permian strata to milepost 183.
190	Take exit 190 to the rest area (accessible to both eastbound and westbound lanes).

Vail Pass Stop (Figs. A2-3, A2-4, and A2-5)

Walk along the paved path to the top of the small rise above the restrooms to examine boulders of Pennsylvanian-Permian red beds (Table A1). According to Tweto (1979), pinkish red conglomerate and coarse sandstone of the Pennsylvanian-Permian Maroon Formation overlie pinkish red sandstone and shale of the Middle Pennsylvanian Minturn Formation (Mallory, 1971; Tweto and Lovering, 1977). The contact here is locally faulted (Tweto, 1979). To the west, I-70 passes through grayish green, pink, and maroon conglomerate, sandstone, shale and marine limestone of the Minturn Formation (Kellogg et al., 2003) and through gypsum, marine limestone, and gray shale of the Eagle Valley Formation (Mallory, 1971). West of Vail the basal

Pennsylvanian unit is the Belden Formation (Scott et al., 2002). These units, equivalent to the Fountain Formation exposed along the Front Range (Table A1), record the unroofing of the Ancestral Rocky Mountains (Fig. A2-3), a late Paleozoic uplift located approximately where the present Rocky Mountains lie. The red color is due to diagenetic alteration of iron to hematite in an oxidizing environment; greenish white to white colors probably formed later during leaching by reducing fluids (Birkeland et al., 2004). ***Caution: because of heavy traffic on the entrance road, it is not advisable to walk along the road to the outcrops.***

Signs at this location describe typical flora and fauna, a nearby archaeological site, the Mount of the Holy Cross, and local history including Camp Hale where the Tenth Mountain Division trained before taking part in the Apennine Mountains campaign in 1944–1945. After World War II, veterans of the Tenth Mountain division returned to Colorado and founded several ski resorts, including Vail and Frisco.

Return to I-70 westbound.

Milepost	***Description***
189	Vail Pass (Figs. A2-4 and A2-5), elevation 3231 m (10603 ft.).
188	High peaks of the Rocky Mountains are visible to the east and southeast. The highest elevations were shaped by alpine glaciers during the Pleistocene. Excellent exposures of Pennsylvanian-Permian red beds are on both sides of I-70.
183	Contact between Paleozoic and Precambrian rocks (Tweto and Lovering, 1977).
181.5	Outcrop of Precambrian rocks: Early Proterozoic migmatitic biotite gneiss and Cross Creek Granite (Fig. A2-1), that is 1.667–1.750 Ma (Kellogg et al., 2003).
180	East edge of the resort town of Vail, Colorado, founded in 1962. The rocks here consist of poorly exposed Pennsylvanian Minturn Formation (Fig. A2-5), covered by numerous landslides, many of them currently active (Scott et al., 2002; Kellogg et al., 2003; Carroll et al., 2004). Pine beetle disease has turned many of the conifers brown.
173	West edge of Vail, Colorado.
170	Exposures of the Middle Pennsylvanian Eagle Valley Formation (Table A1) (Scott et al., 2003).
169	Eagle River.
167.5	Town of Avon, Colorado.
163	Exit to rest area and town of Edwards, Colorado.
162	Scenic overlook, eastbound lanes, with view to south of Rocky Mountains.
160	Good exposures of the Pennsylvanian Minturn Formation (Tweto and Lovering, 1977).
159.7	Scenic pullout (westbound only) with good exposures of Pennsylvanian Minturn Formation.
159	Eagle River.
158.5	Fault contact between Minturn and Maroon Formations (Tweto and Lovering, 1977).
156	Passing through a syncline (Lidke, 1998). Exposures of yellowish, cross-bedded
155	Cretaceous Dakota Sandstone with coal interbeds; maroon and green shale of the Jurassic Morrison Formation (Table A1) across the Eagle River.
154	Eagle River.
153.5	Contact with red beds of the Triassic Chinle Formation (Table A1) (Lidke, 1998).

151	Contact with the Eagle Valley Formation (Table A1), consisting of highly contorted Middle Pennsylvanian clastic sedimentary rocks with minor limestone (Mallory, 1971; Lidke, 2002). Folding is due to diapiric flow of gypsum, anhydrite, and halite from the underlying Eagle Valley Evaporite (Mallory, 1971; Lidke, 2002).
147	Town of Eagle. The Eagle Valley Formation is 2743 m (9000 ft.) thick here in the center of the Eagle Basin, a landlocked sea within the Ancestral Rockies (Mallory, 1971; Lidke, 2002). From the parking lot at the rest area/visitor's center, deformed Eagle Valley Formation can be seen in road cuts across I-70.
146	Eagle Valley Formation (Table A1); locally with alluvial gravels in stream terraces (milepost 140).
139	A fault at the town of Gypsum emplaces Cretaceous units against Pennsylvanian-Permian red beds and gypsiferous shales. American Gypsum drywall plant and mine, located in the town of Gypsum, is visible from I-70.
138	I-70 passes along the axis of the Eagle River Anticline in the Pennsylvanian-Permian
136	strata (Table A1); limbs dip to the north and south (Streufert et al., 1997). Eagle Valley Formation evaporites crop out on the cliffs above. The Eagle River is alongside.
135.5	Dotsero Basalt crops out in the valley along the river. From Frontage Road between Exits 139 and 133, you can see basalt on the hill to the north, dark brown against the lighter brown Eagle Valley Formation. The basalt extends along the valley floor from here to Exit 133.
135	The Dotsero volcano lies ~1.5 km north of I-70. The volcano erupted Holocene (4150 ± 300 yr old) lapilli tuff, cinders, and upper Pleistocene? to Holocene trachybasalt which flowed down and ponded on the Eagle Valley floor (Streufert et al., 1997). I-70 crosses the trachybasalt lava flow.
133	Town of Dotsero, Colorado, where the Eagle River joins the Colorado River. Exit onto Frontage Road and turn east for closer views of Dotsero Basalt.
131	Outcrops of Pennsylvanian gypsiferous shale.
129.5	Alluvial terrace to the south across the Colorado River.
129	East end of Glenwood Canyon. Outcrops of Mississippian Leadville Limestone.

Glenwood Canyon Stop 1: Bair Ranch Rest Area (Fig. A2-6)

Take Exit 129 to the rest area, park, and walk to the river overlook in front of the restrooms. Visible across the Colorado River is the historic Bair Sheep Ranch, now a resort. According to the informational signs here, Bair Ranch was founded in 1919. The sheep graze on several thousand acres of high pasture during the summer; the ranch trucks them to a winter range in western Utah.

The Colorado River cut through the White River Uplift to form Glenwood Canyon. To the west, the canyon walls (Kirkham et al., 1995) consist of Paleoproterozoic biotite-muscovite gneiss (2000–1700 Ma) and granite (1700–1600 Ma). The Precambrian rocks are overlain nonconformably by ~170 m of Cambrian Sawatch Quartzite, then ~30 m of Cambrian Dotsero Formation sandstone and ~50 m of Ordovician Manitou Formation limestone. About 80 m of the Upper Devonian Chaffee Group rests disconformably on the limestone, forming grayish green slopes. Above the Chaffee Group, the Lower Mississippian Leadville Limestone forms massive gray cliffs ~80 m thick. Capping the Glenwood Canyon sequence is the Pennsylvanian Belden

Formation, consisting of shale, limestone, and sandstone. The bedrock units are overlain by a variety of surficial deposits (Fig. A2-6).

Return to I-70 and continue westbound.

Milepost	***Description***
128	I-70 crosses over a tributary, French Creek, on stacked viaducts. The westbound French Creek Viaduct, 1220 m (4000 ft.) long, is high on the canyon wall; the eastbound viaduct is shorter and lower on the canyon wall (Salek, 2002).
127.5	The westbound lanes of the new I-70 alignment enter the Reverse Curve Tunnel, a short single bore tunnel (Salek, 2002). The eastbound lanes follow the original highway alignment around the outside of a double curve in the river.
126	Westbound lanes are stacked vertically above the eastbound lanes of I-70.
125.5	All lanes pass through the Hanging Lake Tunnel. The east end of this tunnel is on the basal contact of the Cambrian Sawatch Quartzite; its west end is in Precambrian gneiss. The tunnel consists of two individual two-lane bores in rock south of the river that are entered on both ends by flying viaducts (Salek, 2002). The flying viaducts are highway lanes that emerge from the tunnel directly over the river and cross on a viaduct tied to bedrock on the other side of the river. This high-technology tunnel is 1889 m (3900 ft.) long, with a Colorado Department of Transportation control center between the portals (Salek, 2002). Cameras and electronic message signs allow highway personnel to warn motorists of emergencies and to post speed limits for any situation.
125	Hanging Lake Rest Area, Exit 125. The canyon walls consist of Precambrian gneiss with lower Paleozoic strata. Shoshone Dam, located here, diverts water from the Colorado River into a diversion tunnel carved through the rock of the north canyon wall and carries it 3.2 km (two miles) downstream to the Shoshone Power Plant (Salek, 2002).
122.5	The standpipes lead to the Shoshone hydroelectric power plan, built on gray Precambrian granite. The plant is located under the highway, which crosses over it on twin viaducts (Salek, 2002).
122	Eastbound lanes are stacked over westbound lanes to conserve space in the narrow canyon.
121	Grizzly Creek Rest Area, Exit 121. The sheer canyon walls display lower Paleozoic strata (see Glenwood Canyon Stop 1 at milepost 129) dipping gently southeast, above dark gray Precambrian gneiss cut by bands of pink granite. In October and November, Grizzly Creek is a spawning area for native whitefish. I-70 crosses Grizzly Creek on twin viaducts (Salek, 2002).
119	No Name Rest Area, Exit 119.

Glenwood Canyon Stop 2: No Name Rest Area (Fig. A2-7)

Take Exit 119 to the rest area, park, and walk east past the restrooms entrance and up the stairs to the elevated overlook. The restroom building is an excellent example of the efforts made to intrude as little as possible on the natural beauty of Glenwood Canyon; it is nearly invisible from the freeway above.

The rest area is located within the southeast-trending No Name Graben (Fig. A2-7), where the canyon widens as the Colorado River goes around two fault-controlled bends. Paleozoic strata within the graben are visible to the north and east. The south side of the graben is bounded by the No Name Fault, which juxtaposes the Paleozoic section against Precambrian granite (Kirkham et al., 1997). The Paleozoic sequence consists of Cambrian Sawatch Quartzite, Cambrian Dotsero Formation (sandy dolomite and dolomitic sandstone), Ordovician Manitou Formation (limestone, conglomerate, dolomite, and shale), and Upper Devonian Chaffee Group, which includes in ascending order: the Parting Formation (orthoquartzite, shale, and dolomite), the Dyer Dolomite (dolomite and limestone), and the Gilman Sandstone (dolomitic sandstone). To the north, the sequence is capped by Lower Mississippian Leadville Limestone and to the east it is capped by Belden, Eagle Valley, and Maroon formations (Table A1) (Kirkham et al., 1997).

Milepost	***Description***
118	No Name Tunnels have their east ends in lower Paleozoic rocks downdropped on the No Name Fault (milepost 117.8), and their west ends in Precambrian rocks. These twin bore tunnels cut across the neck of a large meander called Horseshoe Curve (Salek, 2002). West of the tunnels, the recreation trail crosses overhead from the north to the south side of the freeway.
117.5	Precambrian/Cambrian contact.
117	Leadville Limestone exposed at road level.
116	Exit 116 to Glenwood Springs and Yampah hot springs.

Yampah Hot Springs Stop (Fig. A2-7)

After our visit to the South Cañon Number 1 Coal Mine, we will return here and visit the Yampah hot springs. The hot mineral springs and steam vapor caves were used by the Native Ute people for over 7000 yr. The gold and silver mining boom of the late nineteenth century made this area a popular destination for newly rich Americans. The present warm swimming pool at Yampah hot springs is one of the largest in the world. It is maintained at 32 °C (90 °F), and a smaller therapy pool is kept at 40 °C (104 °F). The Iron Mountain tramway at the west edge of Glenwood Springs takes visitors up Iron Mountain, where Glenwood Caverns has developed within the Leadville Limestone (Kirkham et al., 1997).

Milepost	***Description***
116 115	Fluvial gravel terraces lie unconformably over folded Paleozoic strata to the north.
114	Eagle Valley Formation is visible on the hills to the north; to the south are outcrops of the Pennsylvanian-Permian Maroon Formation (Kirkham et al., 1997).
113	Outcrops of Pennsylvanian-Permian Maroon Formation.
111	Exit 111 to South Canyon, location of the South Cañon Number 1 Coal Mine.

Grand Hogback Stop (Figs. A2-8A and B)

Turn left at the bottom of the off ramp and drive under I-70 to South Canyon Road. Pull off the road and get out. Visible on the horizon to the west (down river) are west-dipping strata of the Grand Hogback monocline. The Grand Hogback formed during the later part of the Laramide orogeny (Middle to Late Eocene) and extends from McClure Pass in Pitkin County north to the town of Meeker in Rio Blanco County. The monocline separates the Colorado Plateau to the west from the southern Rocky Mountains to the east (Tweto, 1979; Rushworth et al., 1989; Kirkham and Matthews, 2000). The base of the visible stratigraphic sequence consists of red beds of the Middle Pennsylvanian-Lower Permian Maroon Formation (Table A1). These are overlain by the Permian-Lower Triassic State Bridge Formation, Upper Triassic Chinle

Formation, Middle Jurassic Entrada Sandstone, and Upper Jurassic Morrison Formation (on skyline). Not visible here are the overlying Lower Cretaceous Dakota Sandstone, and the Upper Cretaceous Mancos Shale, Iles Formation, and Mesaverde Group (Bryant et al., 2002). The South Canon Coal Mine is located in the Williams Fork Formation of the Mesaverde Group. From here we will drive south through the monoclinal limb of the Grand Hogback, and up section to the Williams Fork Formation.

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TABLE A1. STRATIGRAPHIC CORRELATION CHART FOR I-70 FROM DENVER TO SOUTH CANYON, COLORADO

Time	Front Range	Blue River Graben	South Canyon
	Sedimentary Rocks		
Neogene	Various glacial and alluvial deposits		
Paleogene	Green Mountain Conglomerate Denver Formation Arapaho Formation		Wasatch Formation Various older clastic deposits
Cretaceous (Upper)	Laramie Formation Fox Hills Sandstone Pierre Shale	Pierre Shale	Mesaverde Group Mancos Shale
Cretaceous (Lower)	Niobrara Formation Benton Formation Dakota Formation Purgatoire Formation	Niobrara Formation Benton Shale Dakota Sandstone	Dakota Sandstone
Jurassic	Morrison Formation Ralston Creek Formation	Morrison Formation Entrada Sandstone	Morrison Formation Entrada Sandstone
Triassic (Upper)	(None)	Chinle Formation.	Chinle Formation
Triassic-Permian	Lykins Formation		State Bridge Formation
Permian (Upper)	Lyons Sandstone		
Permian-Pennsylvanian	Fountain Formation	Maroon Formation Eagle Valley Formation Eagle Valley Evaporite Minturn Formation	Maroon Formation Eagle Valley Formation Eagle Valley Evaporite Belden Formation
Mississippian	Leadville Limestone	Leadville Limestone	Leadville Limestone
Devonian	Williams Canyon Limestone	Chaffee Group	Chaffee Group
Silurian	(None)	(None)	(None)
Ordovician	Manitou Dolomite	Manitou Dolomite	Manitou Formation
Cambrian	Sawatch Quartzite	Peerless Formation Sawatch Quartzite	Dotsero Formation Sawatch Quartzite
	Igneous and Metamorphic Rocks		
Neogene (<20 Ma)	Basalt flows	Basalt flows	Basalt flows
Paleogene (20–40 Ma)	Intrusions (mainly intermediate to felsic)		
Paleogene-Cretaceous (64–66 Ma)	Table Mountain basalt		
Paleogene-Cretaceous (40–72 Ma)	Laramide intrusions (mainly intermediate to felsic)		
Neo-Mesoproterozoic (ca. 1000 Ma)	Anorogenic	granitic intrusions	
Mesoproterozoic (ca. 1400 Ma)	Postorogenic	granitic intrusions	
Paleoproterozoic (ca. 1700 Ma)	Syntectonic	granitic intrusions	
Paleoproterozoic (1700–1900 Ma)	“Idaho Springs Formation” gneiss and schist		

Note: From Stracher et al. (2007).

APPENDIX 2: Maps for Denver to Glenwood Springs, Colorado, Route (Stracher et al., 2007)

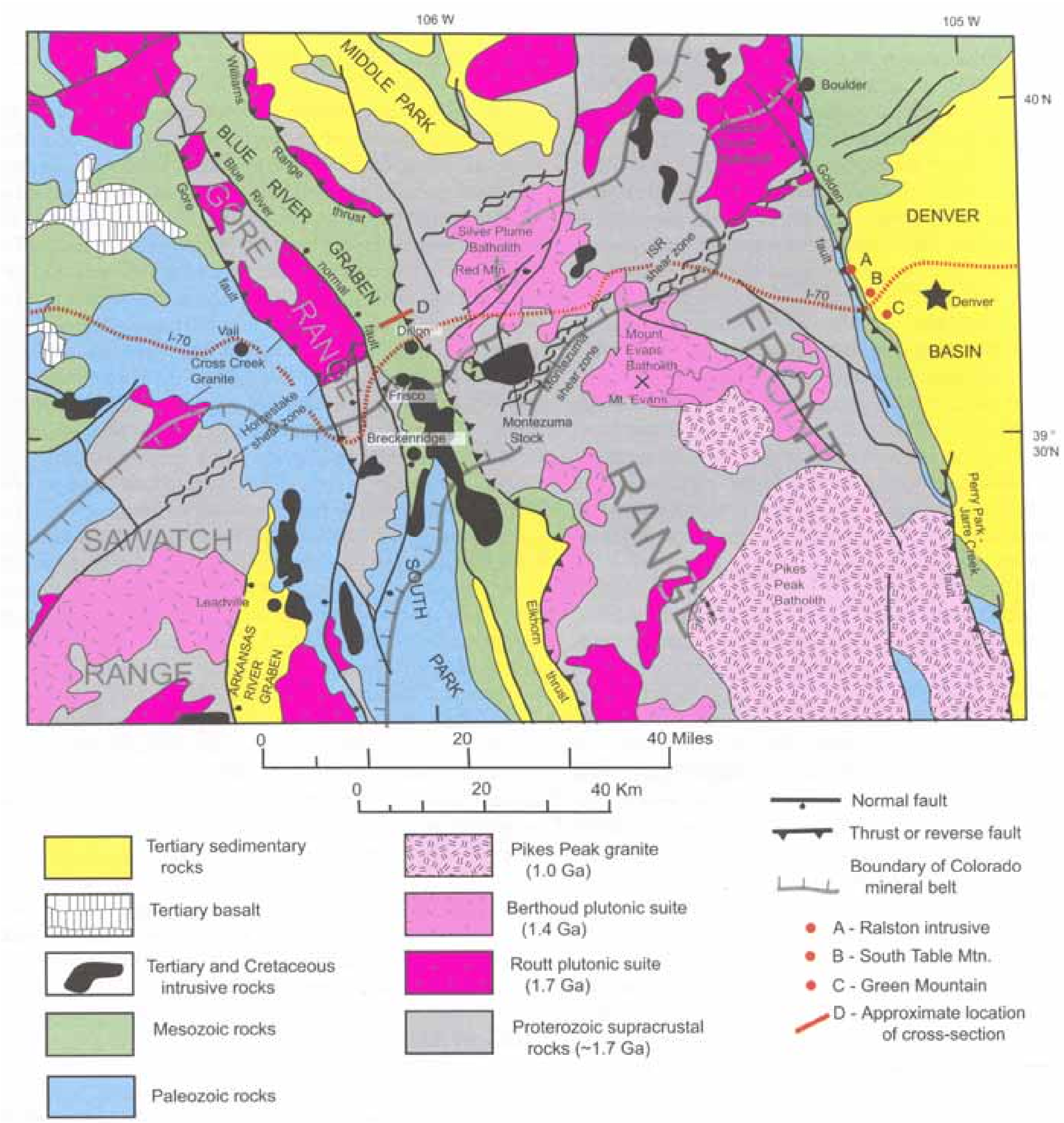

Figure A2-1. Geologic map of the central Colorado Rocky Mountains (modified from Figure 1 of Kellogg et al., 2004). Interstate 70 (red bars) passes out of the Denver Basin into the Front Range, then across the Blue River half-graben, the Gore Range, and the Central Colorado trough-South Park basins (continuation of the Rio Grande Rift). ~1.7 Ga Proterozoic metavolcanic and metasedimentary rocks intruded by 3 suites of granitic plutons comprise the Front Range and Gore Range uplifts. The 1.7 Ga granitoids were syntectonic, the 1.4 Ga plutons exhibit only minor deformation, and the 1.0 Ga plutons were anorogenic (Fisher and Fisher, 2004; Kellogg et al., 2004). The Colorado Mineral Belt formed when Late Cretaceous-Tertiary plutonism and hydrothermal metamorphism was localized along ~1.7 Ga Montezuma and Homestake ductile shear zones.

APPENDIX 2: Maps for Denver to Glenwood Springs, Colorado, Route (Stracher et al., 2007)

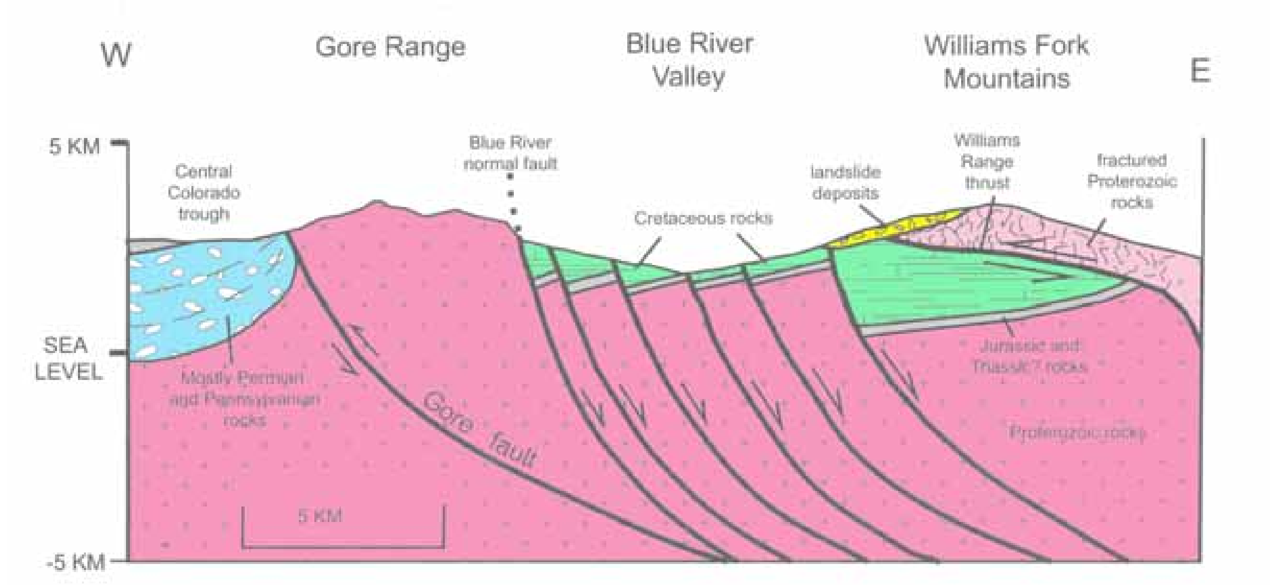

Figure A2-2. Cross section across the Blue River half graben and the Gore Range uplift (modified from Fig. 7B of Kellogg et al., 2004). Line of section is indicated by "D" in Figure A2-1. Pennsylvanian-Permian rocks of the Eagle Basin underlie the Central Colorado trough west of the Gore Range.

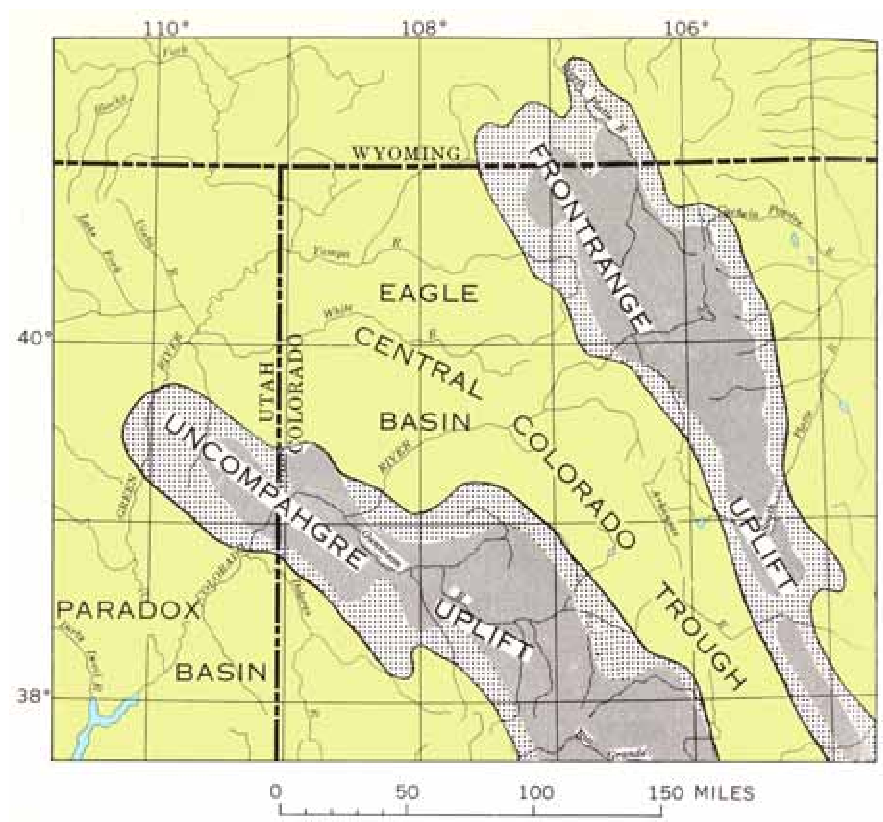

Figure A2-3. Ancestral Rockies and the Eagle Basin (after Mallory 1971). The Eagle Basin was a landlocked sea between two Ancestral Rockies uplifts, the Front Range uplift to the east and northeast, and the Uncompahgre uplift to the southwest. The Eagle Basin marks a major facies change, interfingering with Middle Pennsylvanian red beds of the Minturn Formation to the east and with overlying, Pennsylvanian-Permian red beds of the Maroon Formation to the west. The Eagle Valley Evaporite is 2743 m (9000 feet) thick in the center of the Eagle Basin, but thins to zero at the edge of the basin 40 km (25 miles) to the northeast (Mallory, 1971).

APPENDIX 2: Maps for Denver to Glenwood Springs, Colorado, Route (Stracher et al., 2007)

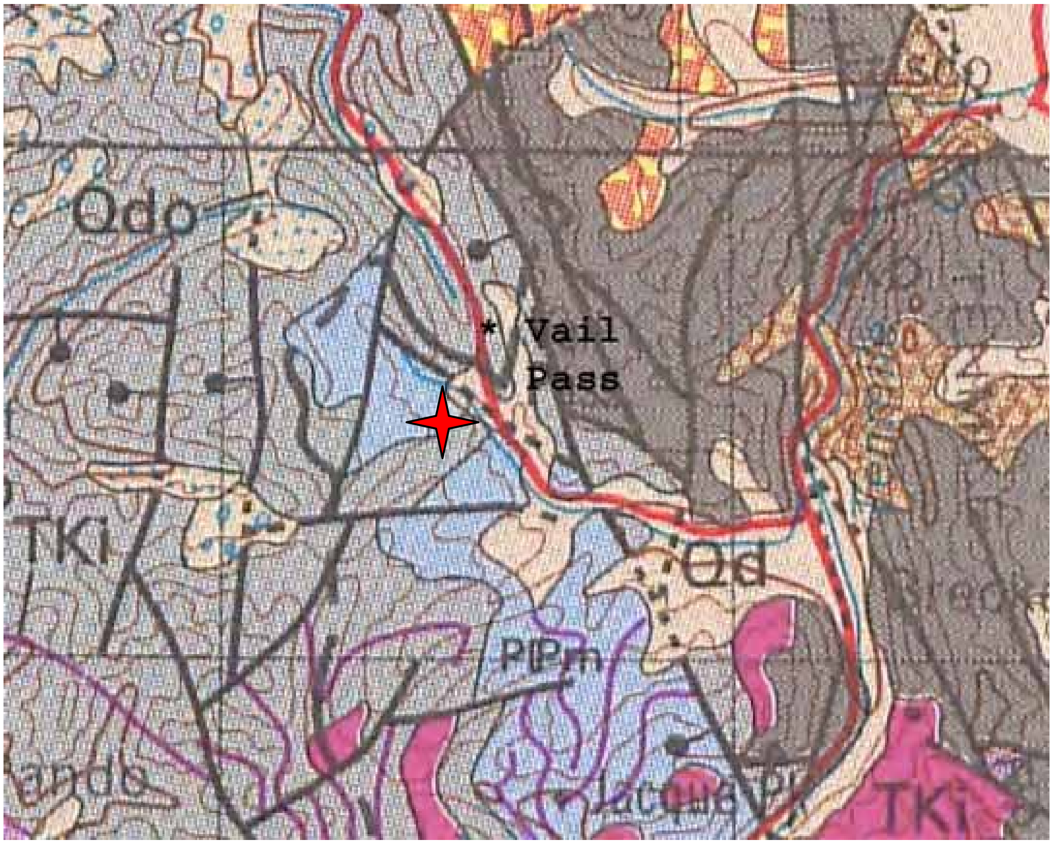

Figure A2-4. Vail Pass area (after Tweto, 1979); red arrow indicates location of Vail Pass stop at the rest area. PPm (blue) = Pennsylvanian-Permian Maroon Formation (red arkosic conglomerates and sandstones), Pm (gray) = Middle Pennsylvanian Minturn Formation (red arkosic sandstones, siltstones, shales). The Vail Pass rest area lies on the contact between the two units.

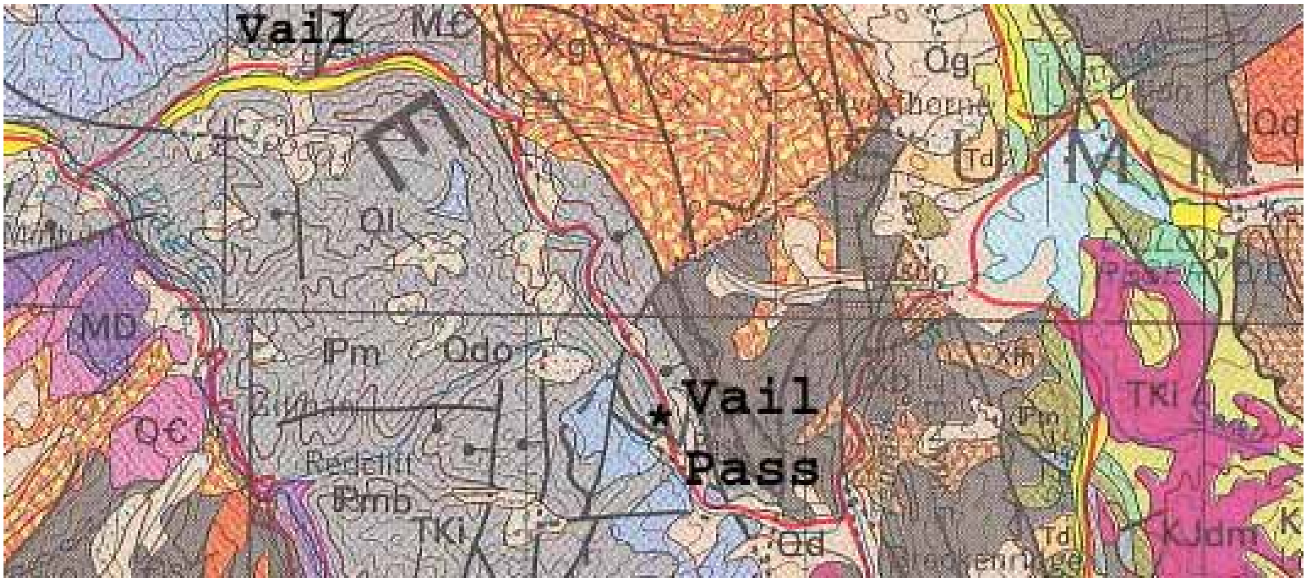

Figure A2-5. Vail Pass to Vail area (after Tweto, 1979). I-70 descends through Minturn Formation (gray, Pm) with Maroon Formation (blue, PPm) overlying it. Xb = ~1.7 Ga metasedimentary rocks, Xg = 1.7 Ga Cross Creek Granite, MD = Devonian-Mississippian strata, OC = Manitou Limestone and Sawatch Quartzite, TKi = Laramide plutons (~72-40 Ma).

APPENDIX 2: Maps for Denver to Glenwood Springs, Colorado, Route (Stracher et al., 2007)

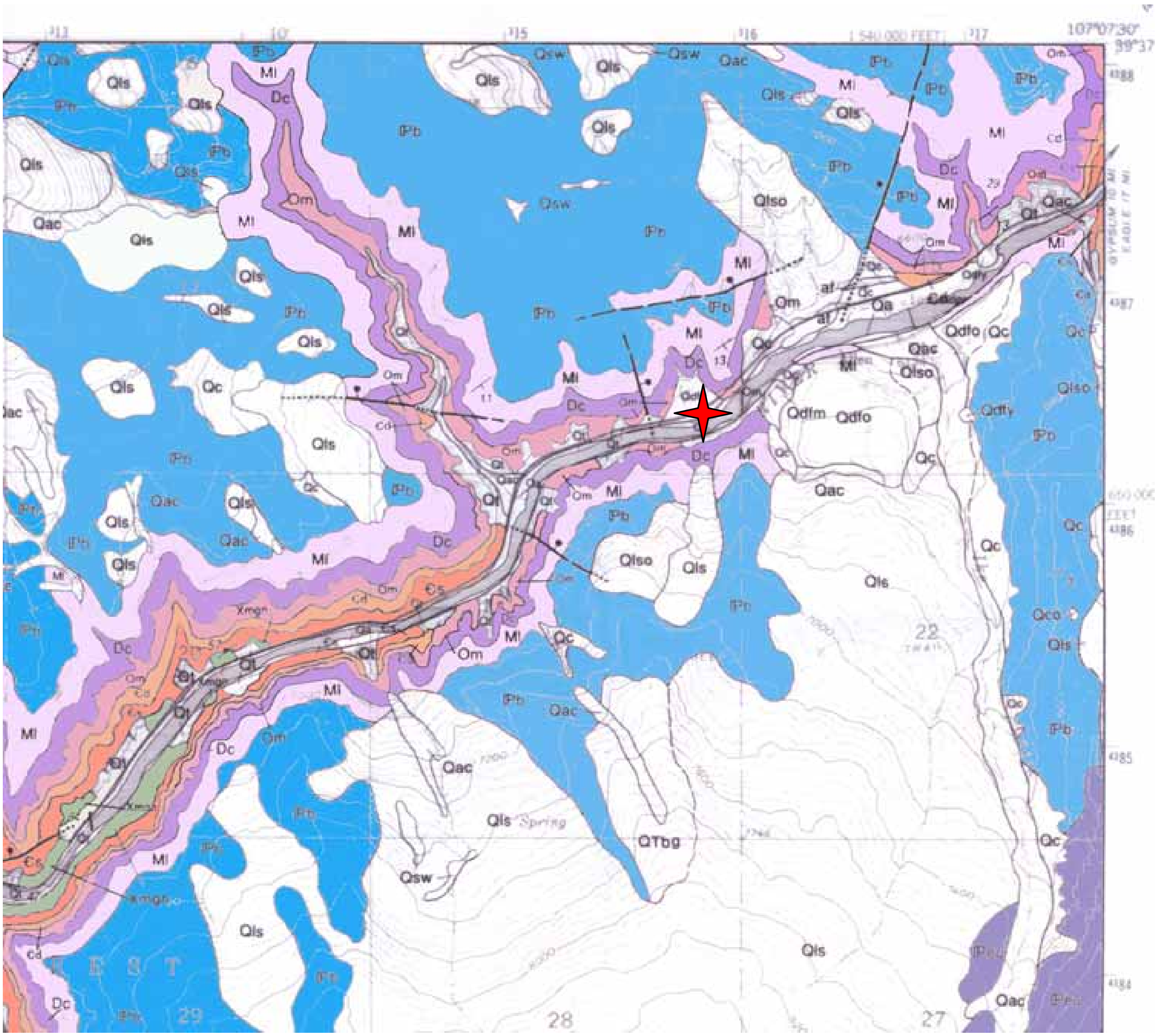

Figure A2-6. Geologic map of Glenwood Canyon Stop 1, Bair Ranch Rest Area (modified after Kirkham et al., 1995). Red star indicates location of rest stop; French Creek Canyon is to the west and Tie Gulch to the east.

Colored bedrock units include: Xmgn (green) = Proterozoic biotite muscovite gneiss; Cs (dark orange) = Upper Cambrian white to tan Sawatch Quartzite; Cd (light orange) = Upper Cambrian Dotsero Formation – brown to tan thin bedded sandy dolomite and dolomitic sandstone with abundant glauconite; Om (pink) = Lower Ordovician Manitou Formation – flat pebble limestone conglomerate, brown and tan crystalline dolomite, greenish gray calcareous shale; Dc (purple) = Upper Devonian Chaffee Group; Ml (lavender) = Mississippian Leadville Limestone; Pb (blue) = Lower Pennsylvanian Belden Formation – medium gray to black calcareous shale and fossiliferous limestone with interbeds of fine-grained micaceous sandstone; and Peu (blue violet) = Middle Pennsylvanian Eagle Valley Formation and Eagle Valley Evaporite, undivided.

Uncolored Quaternary and Quaternary-Tertiary units include(in alphabetical order): af = artificial fill; Qa = stream channel, floodplain, and low terrace deposits (Holocene and late Pleistocene); Qac = alluvium and colluvium undivided (Holocene and late Pleistocene); Qc = colluvium; Qco = older colluvium (Pleistocene); Qdfm = intermediate debris flow deposits (Holocene and late Pleistocene); Qdfy = younger debris flow deposits (Holocene); Qls = landslide, Qlso = older landslide deposits (Pleistocene and late Pliocene?); Qsw = sheetwash deposits (Holocene and late Pleistocene); Qt = talus; QTbg = high-level basaltic gravel (early Pleistocene or Pliocene).

APPENDIX 2: Maps for Denver to Glenwood Springs, Colorado, Route (Stracher et al., 2007)

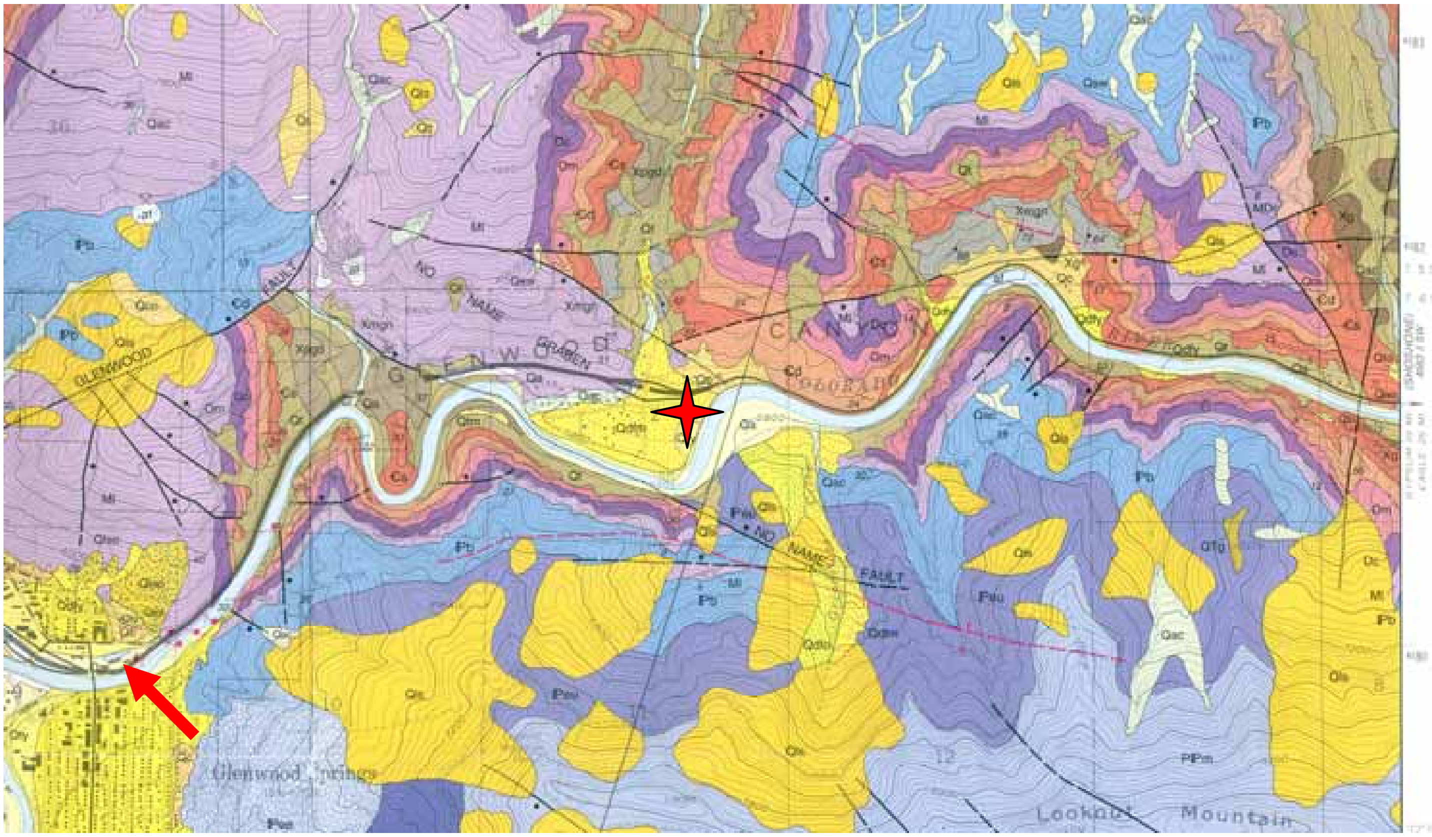

Figure A2-7. Geologic map of Glenwood Canyon Stop 2, No Name Rest Area (after Kirkham et al., 1997). Red star indicates location of rest stop in the No Name Graben, at the mouth of No Name Canyon. Red arrow points to Yampah hot springs in the town of Glenwood Springs.

Proterozoic bedrock units include: Xmgn (greenish gray) = biotite muscovite gneiss (2000-1700 Ma); Xqm (brown) = gneissic quartz monzonite of Mitchell Creek; Xpgd (light brownish gray) = Proterozoic porphyroblastic biotite granodiorite of No Name Canyon; Xg (dark brown) = biotite granite (1700-1600 Ma).

Paleozoic bedrock units include: Cs (dark orange) = Upper Cambrian white to tan Sawatch Quartzite; Cd (light orange) = Upper Cambrian Dotsero Formation – brown to tan thin bedded sandy dolomite and dolomitic sandstone with abundant glauconite; Om (pink) = Lower Ordovician Manitou Formation – flat pebble limestone conglomerate, brown and tan crystalline dolomite, greenish gray calcareous shale; OCr = Ordovician-Cambrian units undivided; Dc (purple) = Upper Devonian Chaffee Group; Ml (lavender) = Mississippian Leadville Limestone; MDr = Mississippian-Devonian rocks undivided; Pb (blue) = Lower Pennsylvanian Belden Formation – medium gray to black calcareous shale and fossiliferous limestone with interbeds of fine-grained micaceous sandstone; and Peu (blue violet) = Middle Pennsylvanian Eagle Valley Formation and Eagle Valley Evaporite, undivided; Pee = Middle Pennsylvanian Eagle Valley Evaporite; PPm = Pennsylvanian-Permian Maroon Formation.

Quaternary and Quaternary-Tertiary units include(in alphabetical order): af = artificial fill; Qa = stream channel, floodplain, and low terrace deposits (Holocene and late Pleistocene); Qac = alluvium and colluvium undivided (Holocene and late Pleistocene); Qc = colluvium; Qco = older colluvium (Pleistocene); Qdfm = intermediate debris flow deposits (Holocene and late Pleistocene); Qdfo = older debris flow deposits (late, middle, early? Pleistocene); Qdfy = younger debris flow deposits (Holocene); Qls = landslide, Qlso = older landslide deposits (Pleistocene and late Pliocene?); Qsw = sheetwash deposits (Holocene and late Pleistocene); Qt = talus; QTbg = high-level basaltic gravel (early Pleistocene or Pliocene), Qtm = intermediate terrace alluvium (late Pleistocene); Qty = younger terrace alluvium (late Pleistocene).

APPENDIX 2: Maps for Denver to Glenwood Springs, Colorado, Route (Stracher et al., 2007)

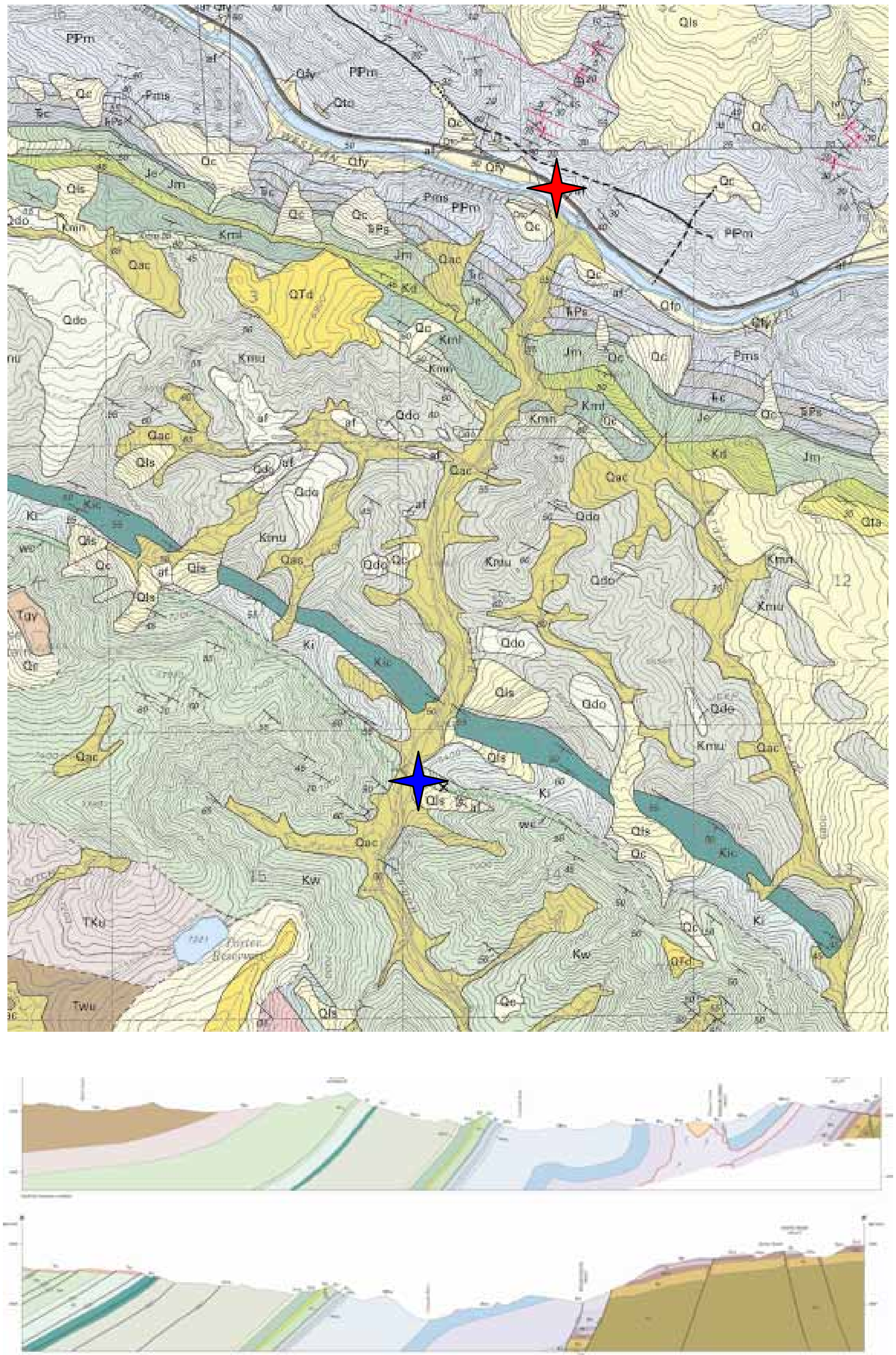

Figure A2-8A. Geologic map and cross sections of the South Canyon area (after Bryant et al., 2002). Red star indicates location of the Grand Hogback Stop; blue star next to "adit" symbol indicates location of the South Cañon Number 1Coal Mine. The South Cañon Number 1Coal Mine lies within the Williams Fork Formation (Kw), Mesaverde Group, in the central limb of the Grand Hogback monocline. See legend in Figure A2-8B for other rock units.

APPENDIX 2: Maps for Denver to Glenwood Springs, Colorado, Route (Stracher et al., 2007)

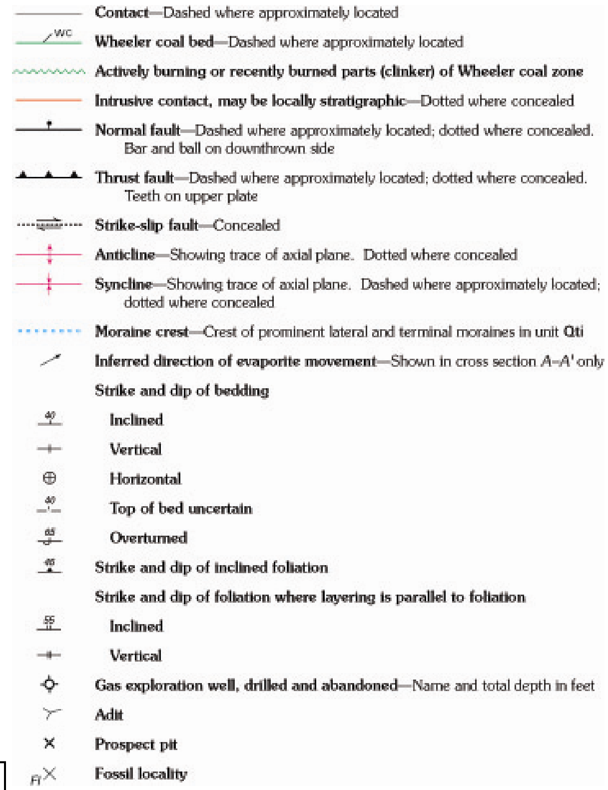

Figure A2-8B. Map legend for South Canyon area (after Bryant et al., 2002).

APPENDIX 2: Maps for Denver to Glenwood Springs, Colorado, Route (Stracher et al., 2007)

GEOLOGIC MAPS ALONG I-70, DENVER TO GLENWOOD SPRINGS

Bergendahl, M.H., 1969, Geologic map and sections of the southwest quarter of the Dillon quadrangle, Eagle and Summit Counties, Colorado: U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-563, scale 1:24000.

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Colorado Geological Survey, Geologic map of the Morrison quadrangle near Denver, draped over a digital elevation model with a geologic cross section below: http://geosurvey.state.co.us/Default.aspx?tabid=37 (accessed October 2007).

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Sheridan, D.M., Reed, J.C., Jr., and Bryant, B., 1972a, Geologic map of the Evergreen quadrangle, Jefferson County, Colorado: U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-786-A, scale 1:24,000.

Sheridan, D.M., Reed, J.C., and Bryant, B., 1972b, Explanation for geologic map of the Evergreen quadrangle, Jefferson County, Colorado: U.S. Geological Survey, Open-File Report OF-72-1711, scale 1:24,000.

Streufert, R.K., Kirkham, R.M., Schroeder II, T.J., and Widmann, B.L., 1997, Geologic map of the Dotsero quadrangle, Eagle and Garfield Counties, Colorado: Colorado Geological Survey, Open-File Report OF-97-2, scale 1:24,000.

Streufert, R.K., Kirkham, R.M., Widmann, B.L., and Schroeder II, T.J., 1997, Geologic map of the Cottonwood Pass quadrangle, Eagle and Garfield Counties, Colorado: Colorado Geological Survey, Open-File Report OF-97-4, scale 1:24,000.

Tweto, O., 1973, Reconnaissance geologic map of the Dillon 15-minute quadrangle, Summit, Eagle, and Grand Counties, Colorado: U.S. Geological Survey, Open-File Report OF-73-285, scale 1:62,500.

Tweto, O., 1979, Geologic map of Colorado: U.S. Geological Survey, scale 1:500,000; http://ngmdb.usgs.gov/ngm-bin/ILView.pl?sid=68589_1.sid&vtype=b; http://geosurvey.state.co.us/portals/0/tweto.pdf (accessed October 2007).

Tweto, O. and Lovering, T.S., 1977, Geology of the Minturn 15-minute quadrangle, Eagle and Summit Counties, Colorado: U.S. Geological Survey, Professional Paper 956, scale 1:48,000.

Tweto, O., Bryant, B., and Williams, F.E., 1970, Mineral resources of the Gore Range - Eagles Nest Primitive Area and vicinity, Summit and Eagle Counties, Colorado: U.S. Geological Survey, Bulletin 1319-C, scale 1:48,000.

Van Horn, Richard, 1972, Surficial and bedrock geologic map of the Golden quadrangle, Jefferson County, Colorado: U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-761-A, scale 1:24,000; http://ngmdb.usgs.gov/ngm-bin/ILView.pl?sid=q24_9511_us_1.sid&vtype=b (accessed October 2007).

Widmann, B.L., 1997, Geologic map of portions of the Dotsero, Gypsum and Cottonwood Pass 7.5 minute quadrangle, (Colorado): Golden, Colorado School of Mines, M.S. Thesis, scale 1:24,000.

Widmann, B.L. and Miersemann, U., 2002, Geologic Map of the Georgetown 7.5 Minute Quadrangle, Clear Creek County, Colorado: Colorado Geological Survey, Open-File Report OF01-05, scale 1:24,000.

Widmann, B.L., Kirkham, R.M., and Beach, S.T., 2000, Geologic map of the Idaho Springs quadrangle, Clear Creek County, Colorado: Colorado Geological Survey, Open-File Report OF-00-2SR, scale 1:24,000.

APPENDIX 3. Select Milepost Stops and Additional Points of Interest, Interstate 70 (I-70) from Denver to Glenwood Springs, Colorado (Stracher et al., 2007).

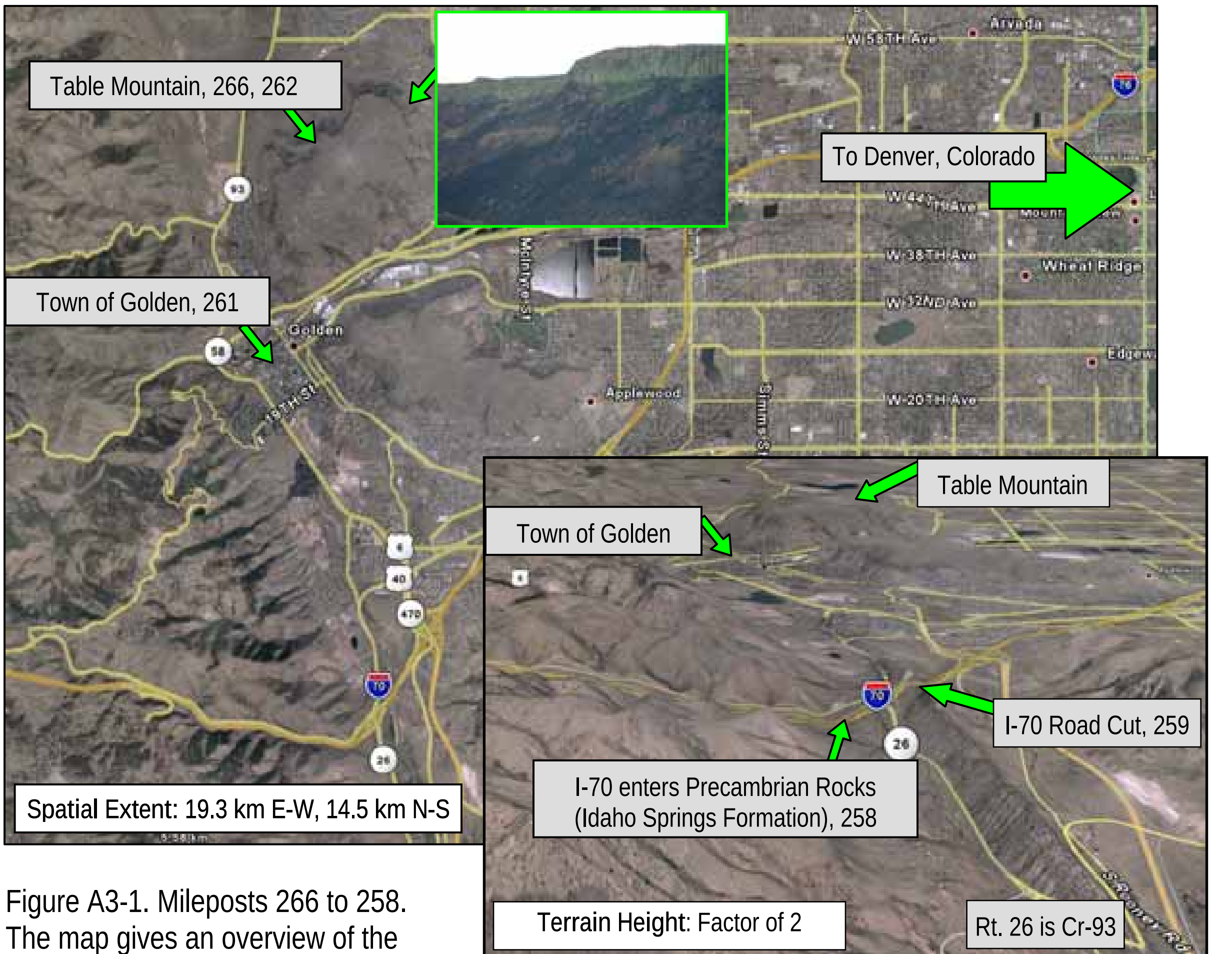


Figure A3-1. Mileposts 266 to 258. The map gives an overview of the location of Table Mountain, the town of Golden, the I-70 road cut and the Red Rock and Dinosaur Ridge Parks. Table Mountain is 1990 meters (~6529 ft) high. The population of Golden is about 17,000. Note that the elevation in the two 3D views to the right is exaggerated by a factor of 2, providing better visualization of the terrain. Modified from Google Earth, 2007.

Figure A3-2. Quarry in the Idaho Spring Formation, 3.2 - 4.8 km (~2 - 3 mi) east of the mining town of Idaho Springs. Modified from Google Earth, 2007.

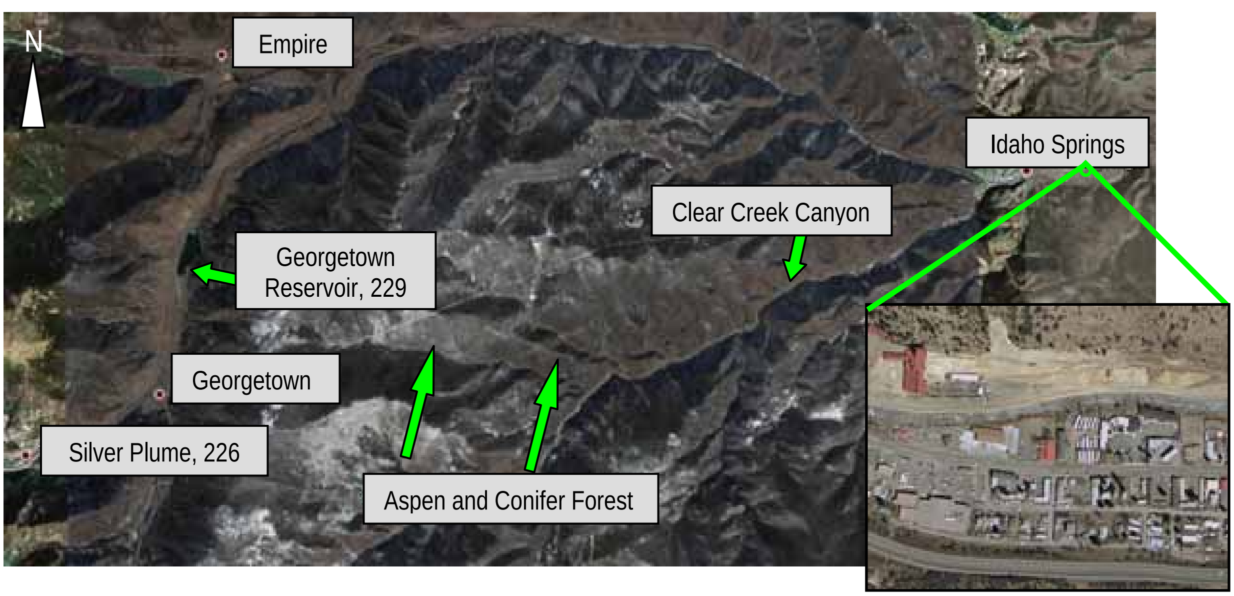


Figure A3-3. Stretch of I-70 between Idaho Springs and Silver Plume (high resolution satellite images during the winter). Spatial extent of large map: 19.3 km (~12 mi) east to west, 10.5 km (~6.5 mi) north to south. Right: Quarry in Idaho Springs, north of I-70. Modified from Google Earth, 2007.

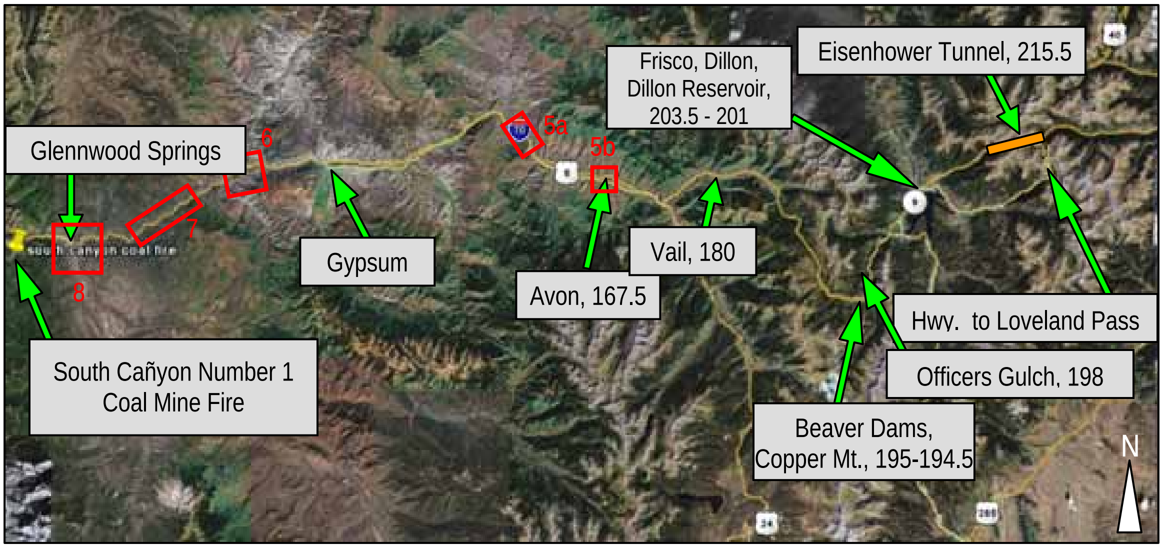


Figure A3-4. Stretch of I-70 between Silver Plume in the east and the South Cañon Number 1 Coal Mine fire in the west. Spatial extent: 145 km (~90 mi) east to west and 64.4 km (~40 mi) north to south. Along this stretch of the interstate, only a few high resolution satellite data exist in Google Earth; therefore, detailed views are only presented (figures A3-5 - A3-8) for locations outlined by the red boxes. Modified from Google Earth, 2007.

Figure A3-5. View of the town of Avon (right) and the area around “ONeill Holland Ditch” about 14.5 km (9 mi) northwest of Avon on I-70. Here, Paleozoic rocks of different colors can be recognized. Modified from Google Earth, 2007.

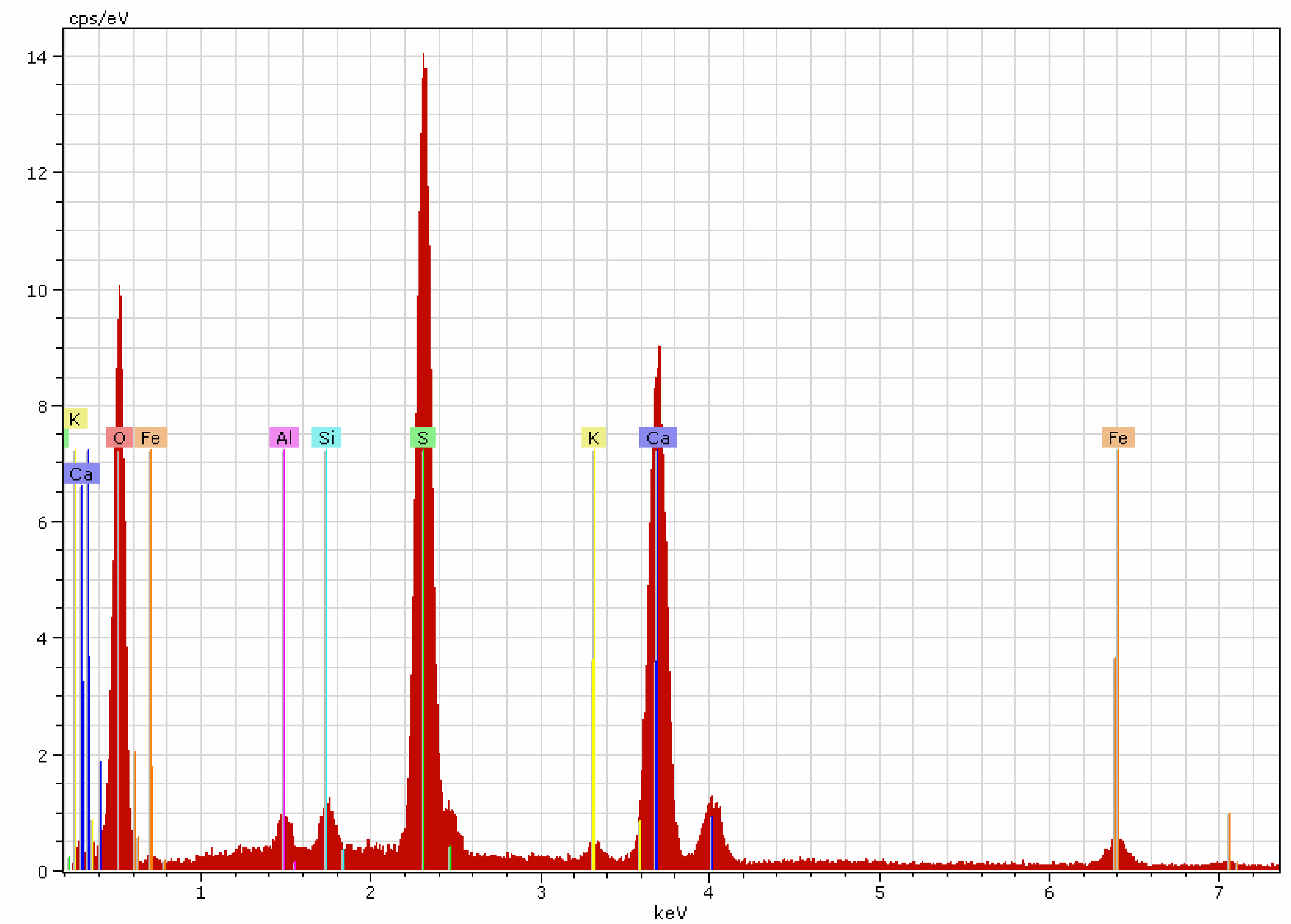
Figure A3-6. Quarry, ~8 km (5 mi) east of the town of Gypsum. Modified from Google Earth, 2007.

Figure A3-7. Stretch of I-70 about 11.3 km (7 mi) northwest of Glenwood Springs. Modified from Google Earth, 2007.

Figure A3-8. Glenwood Springs as seen from the south, along Colorado Route 154. Modified from Google Earth, 2007.

Stracher, G.B., Lindsley-Griffin, N., Griffin, J.R., Renner, S., Schroeder, P., Viellenave, J.H., Masalehdani, M.N.-N., and Kuenzer, C., 2007, Revisiting the South Cañon Number 1 Coal Mine fire during a geologic excursion from Denver to Glenwood Springs, Colorado, *in* Raynolds, R.G., ed., Roaming the Rocky Mountains and Environs: Geological Field Trips: Geological Society of America Field Guide 10, doi: 10.1130/2007.fld010(06).

Several SEM Images and Spectra from a gas-vent mineral deposit, South Cañon Number 1 Coal Mine fire, Glenwood Springs, Colorado.

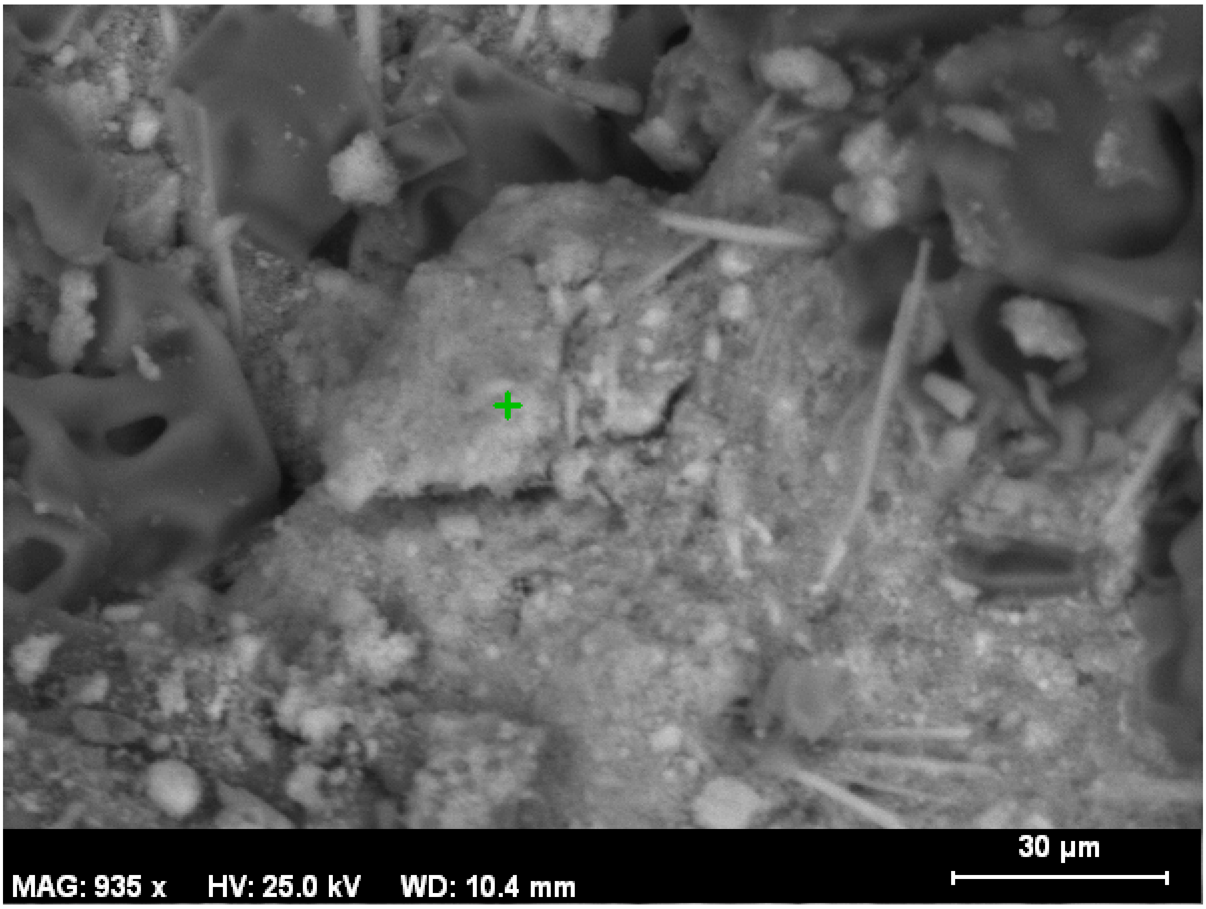


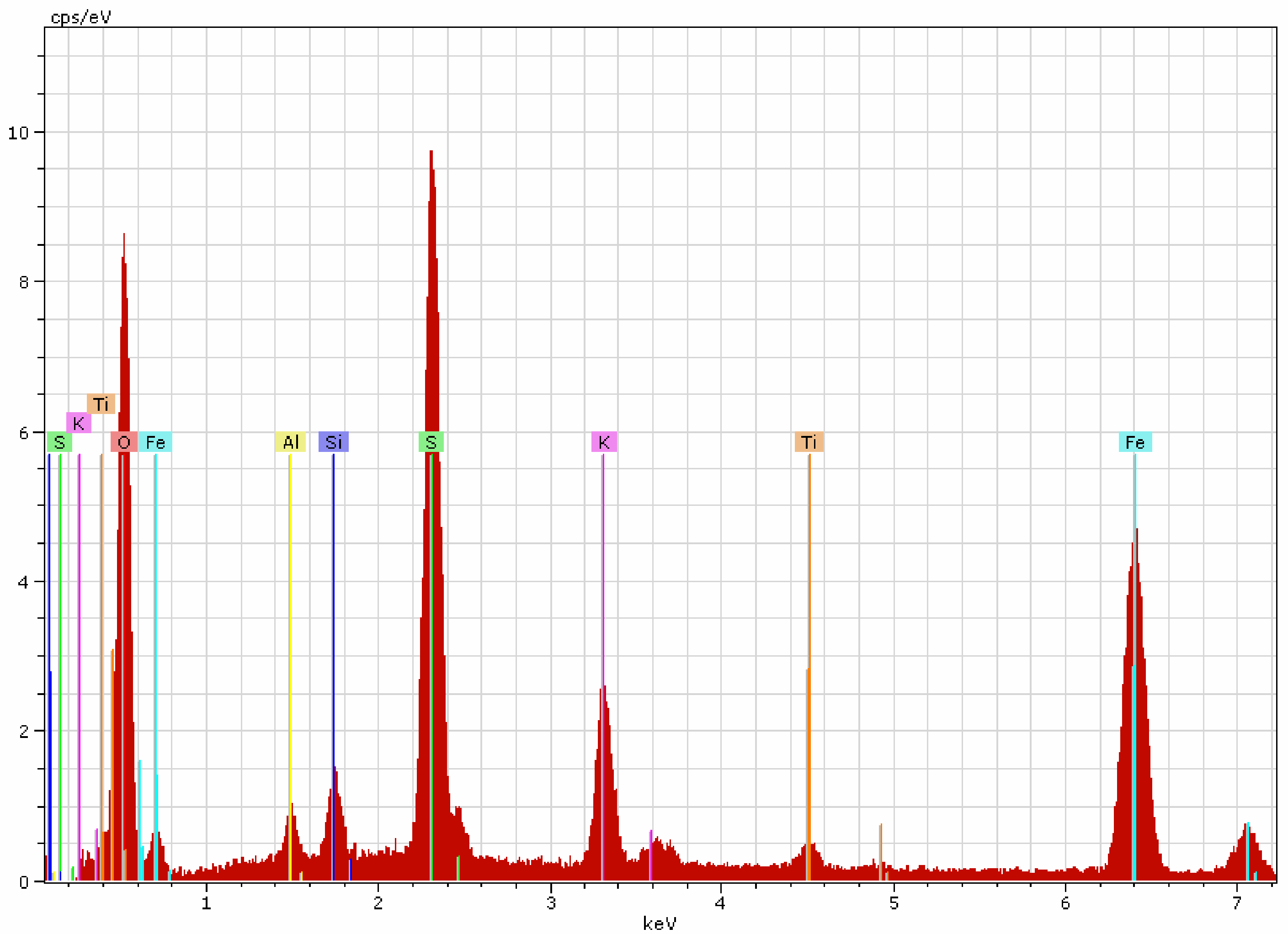
Spectrum: Acquisition (Gypsum)

Element	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Oxide	Oxid. C [wt.-%]
Sulfur	K-series	16.36	15.79	9.98	SO4	60.01
Calcium	K-series	18.30	17.67	8.93	CaO	31.36
Silicon	K-series	1.00	0.97	0.70	SiO2	2.63
Aluminium	K-series	0.80	0.77	0.58	Al2O3	1.85
Potassium	K-series	0.33	0.32	0.16	K2O	0.48
Iron	K-series	2.33	2.25	0.82	FeO	3.67
Oxygen	K-series	64.48	62.24	78.83	O	26.86
	Total:	103.60	100.00	100.00		

Spectrum: Acquisition (Gypsum)

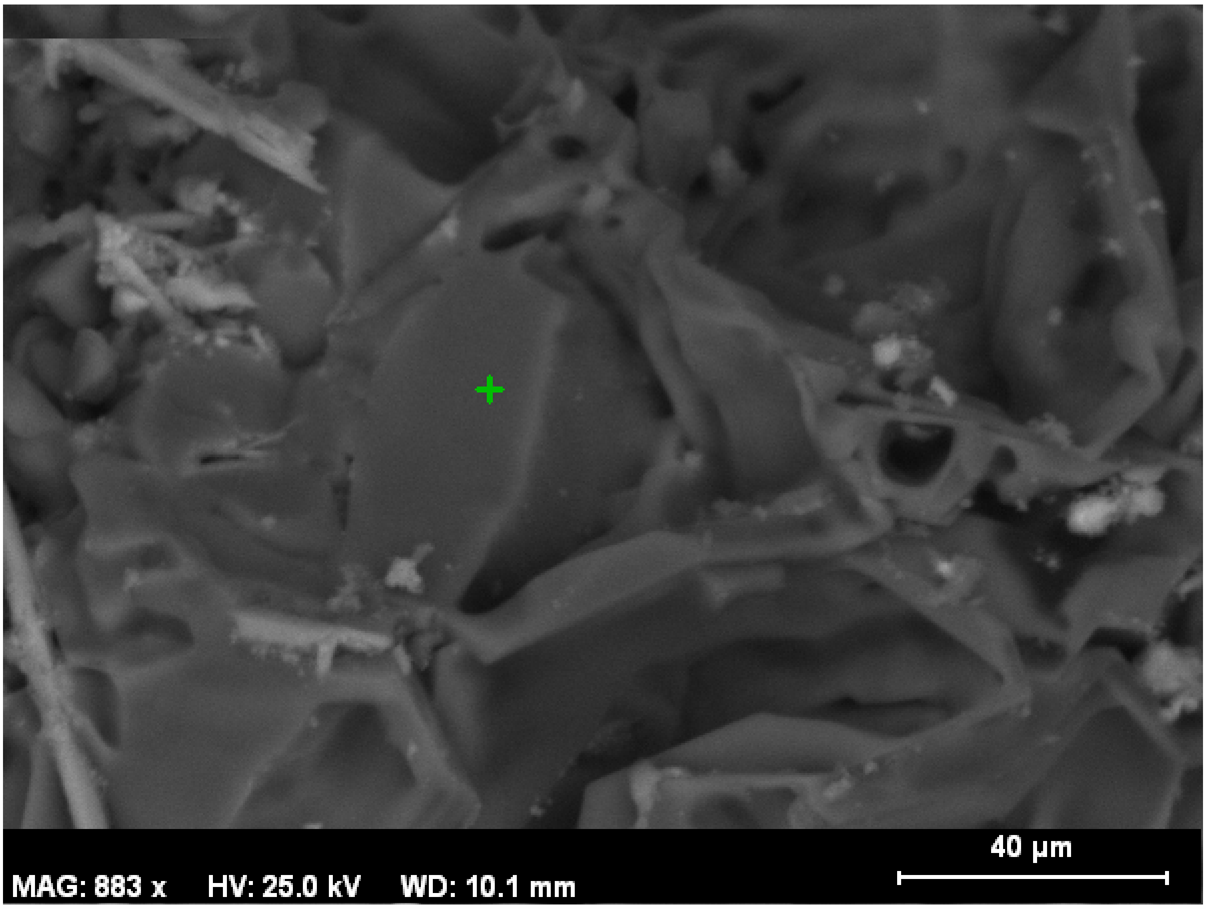
Element	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Oxide	Oxid. C [wt.-%]
Sulfur	K-series	20.22	18.70	11.59	SO4	70.33
Calcium	K-series	18.26	16.89	8.38	CaO	29.67
Oxygen	K-series	69.66	64.41	80.03	O	25.55
	Total:	108.15	100.00	100.00		

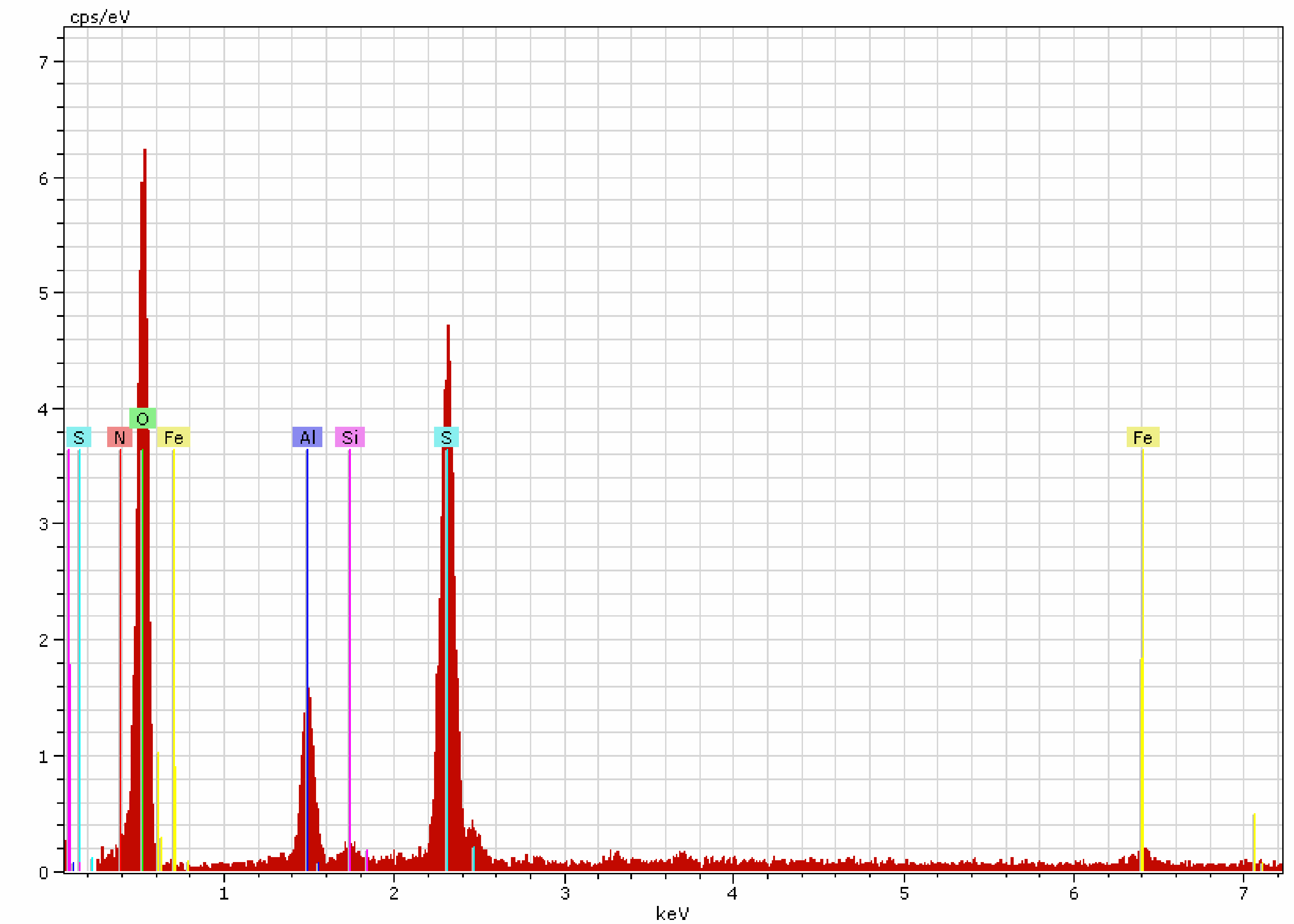

30 µm
MAG: 935 x HV: 25.0 kV WD: 10.4 mm


cps/eV
10
8
6
4
2
0
S
K
Ti
O
Fe
Al
Si
S
K
Ti
Fe
1
2
3
4
5
6
7
keV

Spectrum: Acquisition ($FeKSO_4$ + H_2O)(other minerals are impurities)

Element	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Oxide	Oxid. C [wt.-%]
Sulfur	K-series	14.31	16.09	11.89	SO4	49.50
Iron	K-series	23.71	26.66	11.31	FeO	35.22
Potassium	K-series	5.07	5.70	3.45	K2O	7.05
Silicon	K-series	1.65	1.86	1.57	SiO2	4.09
Aluminium	K-series	1.01	1.14	1.00	Al2O3	2.21
Titanium	K-series	1.00	1.13	0.56	TiO2	1.93
Oxygen	K-series	42.20	47.43	70.23	O	2.71
	Total:	88.96	100.00	100.00		


40 µm
MAG: 883 x HV: 25.0 kV WD: 10.1 mm

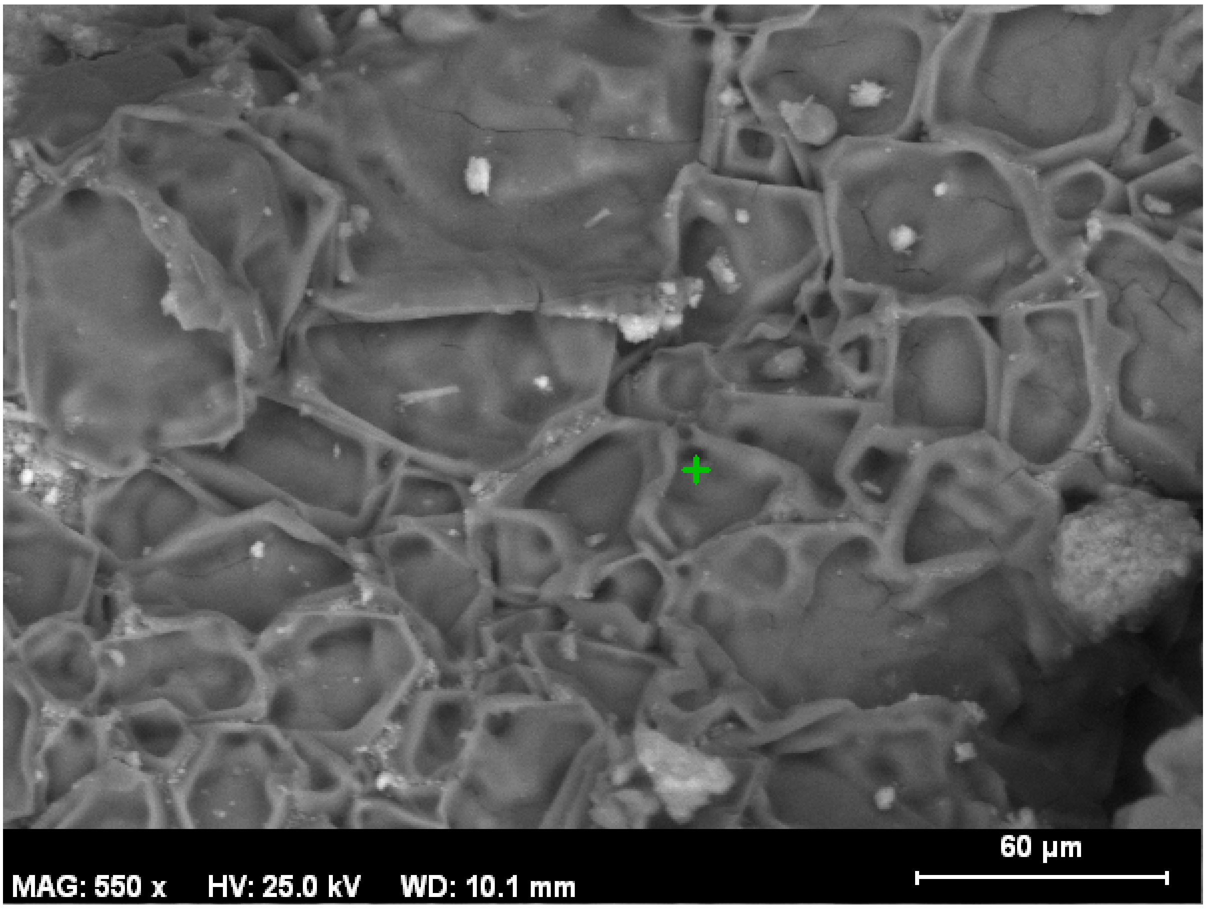

cps/eV
S
N
O
Fe
Al
Si
S
Fe
keV

Spectrum: Acquisition

Element	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Oxide	Oxid. C [wt.-%]
Aluminium	K-series	6.02	6.30	4.22	Al2O3	19.27
Sulfur	K-series	15.19	15.92	8.96	SO4	77.16
Silicon	K-series	0.50	0.52	0.34	SiO2	1.81
Iron	K-series	0.81	0.85	0.27	FeO	1.77
Oxygen	K-series	72.95	76.41	86.21	O	61.82
	Total:	95.47	100.00	100.00		

Spectrum: Acquisition (Tschermigite)

Element	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Oxide	Oxid. C [wt.-%]
Aluminium	K-series	5.93	5.77	3.78	Al2O3	16.36
Sulfur	K-series	15.01	14.61	8.05	SO4	65.71
Silicon	K-series	0.49	0.47	0.30	SiO2	1.52
Iron	K-series	0.79	0.77	0.24	FeO	1.49
Nitrogen	K-series	6.50	6.32	7.98	N2O	14.91
Oxygen	K-series	74.08	72.06	79.64	O	50.17
	Total:	102.80	100.00	100.00		


60 µm
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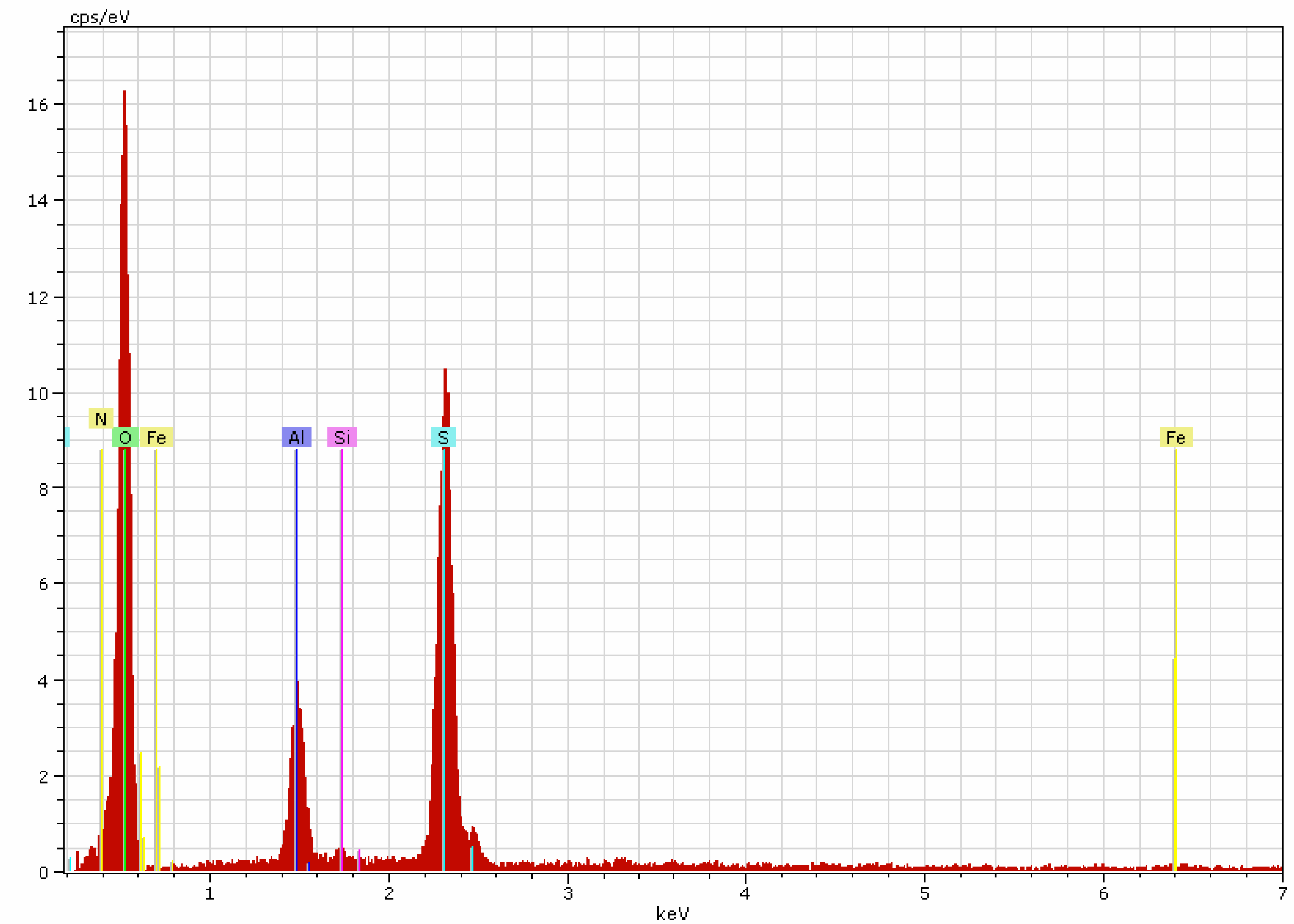
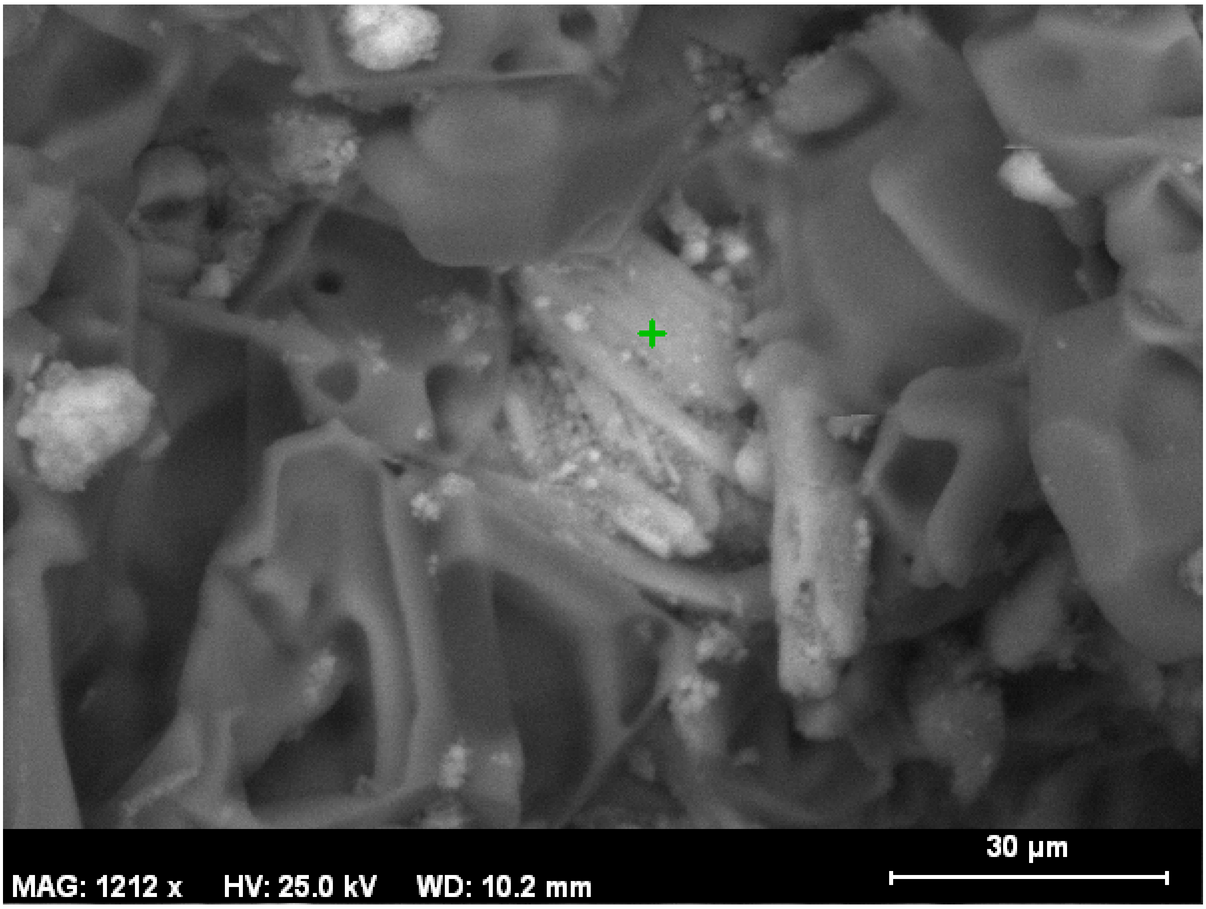
HV: 25.0 kV
WD: 10.1 mm


cps/eV
16
14
12
10
8
6
4
2
0
N
O
Fe
Al
Si
S
Fe
1
2
3
4
5
6
7
keV

Spectrum: Acquisition (Tschermigite)

Element	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Oxide	Oxid. C [wt.-%]
Aluminium	K-series	6.48	5.38	3.46	Al2O3	14.57
Sulfur	K-series	16.71	13.87	7.52	SO4	59.60
Silicon	K-series	0.27	0.22	0.14	SiO2	0.68
Iron	K-series	0.40	0.33	0.10	FeO	0.61
Nitrogen	K-series	13.13	10.89	13.51	N2O	24.55
Oxygen	K-series	83.53	69.31	75.27	O	43.44
	Total:	120.51	100.00	100.00		


30 µm
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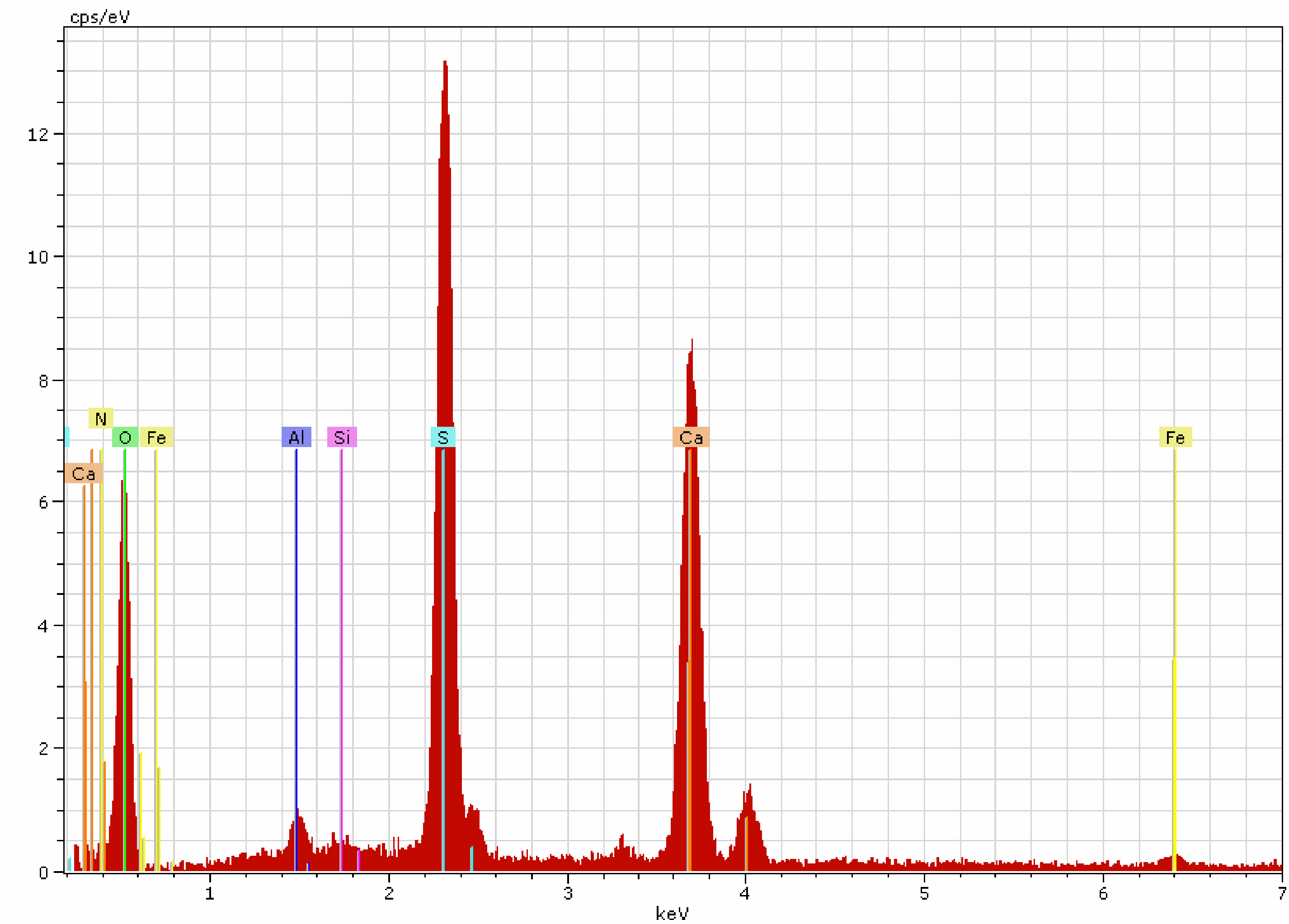
cps/eV
N
O
Fe
Ca
Al
Si
S
Ca
Fe
keV

Spectrum: Acquisition (Gypsum)

Element	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Oxide	Oxid. C [wt.-%]
Aluminium	K-series	1.09	1.03	0.77	Al2O3	2.03
Sulfur	K-series	19.21	18.21	11.47	SO4	56.87
Silicon	K-series	0.26	0.25	0.18	SiO2	0.56
Iron	K-series	0.82	0.78	0.28	FeO	1.05
Nitrogen	K-series	7.35	6.97	10.05	N2O	11.41
Calcium	K-series	19.93	18.89	9.52	CaO	27.56
Potassium	K-series	0.44	0.42	0.22	K2O	0.53
Oxygen	K-series	56.39	53.46	67.51	O	4.27
	Total:	105.48	100.00	100.00		

Compound		D-VENT GAS: BURNING D COAL SEAM	D-VENT SOIL GAS: BURNING D COAL SEAM
Methane	ppbv	12014	21921
Ethane	ppbv	169	705
Ethylene	ppbv	172	8502
Propane	ppbv	52	445
Propene	ppbv	77	5659
I-Butane	ppbv	17	42
N-Butane	ppbv	20	201
Butene	ppbv	46	2152
I-Pentane	ppbv	25	69
N-Pentane	ppbv	85	203
Pentene	ppbv	0	826
I-Hexane	ppbv	72	49
N-Hexane	ppbv	68	81
Hexene	ppbv	0	1977
I-Heptane	ppbv	18	1
N-Heptane	ppbv	0	66
Heptene	ppbv	0	0
I-Octane	ppbv	0	1
N-Octane	ppbv	0	1
Acetone	ppbv	351	39411
Butanone	ppbv	71	120
Hexanone	ppbv	0	416
CS2	ppbv	3	454
Benzene	ppbv	1	838
Toluene	ppbv	2	49
Ethyl Benzene	ppbv	1	7
Xylenes	ppbv	2	26
Styrene	ppbv	0	3
C3Benzenes	ppbv	2	10
C4Benzenes	ppbv	0	11
Naphthalene	ppbv	1	112