Geologic Map and Coal Bed Stratigraphy of the Fruitland Formation in Western Archuleta County, Colorado

Geologic Unit Descriptions

Qrms Reclaimed Mine Surface (Latest Holocene) —Fill material consisting of spoils from the inactive Chimney Rock and Martinez coal mines (Sec. 30 T34N R4W). This surface mine was reclaimed after closing in 1985. The mine produced 1.23 million short tons of coal during its five years of operation (Carroll and Bauer, 2002). It was the largest coal mine to ever produce from the Fruitland Formation in Colorado. Four coal beds were mined from the lower and middle part of the Fruitland and are mapped where known and inferred where covered by Qrms on the map.

Qac Alluvium and Colluvium: undivided stream channel, younger terrace alluvium and fluvial deposits (Holocene and late Pleistocene)—Includes fluvial stream deposits in the valleys of the Piedra River, Stollsteimer Creek, Beaver Creek, and their tributary drainages. Also includes alluvium deposited as glacial outwash and underlying terraces that range from 5 to 30 ft above the Piedra River. The unit consists of poorly to well sorted, clast-supported, unconsolidated silt, sand, gravel, and boulders with a sandy and silty matrix. Clasts are mainly subrounded to rounded and composed of igneous and sedimentary rocks eroded from San Juan Mountain parent material north of the map area. Units in the Beaver Creek drainage are primarily composed of sandstone from Mesaverde Group and Dakota Sandstone bedrock sources. Qac units along Archuleta Creek, Cabezon and Deep Canyons are only composed of Upper Cretaceous and Lower Tertiary sedimentary strata. Maximum thickness about 100 ft. Unit is a source of sand and gravel and is currently being quarried from several gravel pits along the Piedra River south of US 160.

Qg Moderate to high-level gravel (middle or early Pleistocene)—Consists of fluvial gravel deposits about 30 to 400 ft above the Piedra River and Beaver Creek. These units are unstratified, poorly sorted, clast-supported, cobble and pebble gravels in a sandy matrix. In Beaver Creek the clasts are subrounded to rounded, and consist of about 60% hard sandstone derived from the Dakota Sandstone and Burro Canyon Formation, 20% dark-red to reddish-brown and dark-gray sandstone derived from the Morrison Formation, 10% soft yellowish-brown sandstones derived from local outcrops such as the Kirtland Shale, Fruitland Formation, Pictured Cliffs Sandstone and the Mesaverde Group, and 10% vari-colored sandstone and metamorphic or igneous rocks.

Qls Landslide deposit (latest Holocene and Pleistocene?)—Heterogeneous unit includes older dissected landslides and recently active landslides with fresh morphological features that have undergone movement during the past 100 years. Only one large landslide is mapped. This feature is mapped in Sec. 13, T.34N, R.5W. It is a rotational feature with earth flows and an extensive slope failure toe. This landslide prominently displays the Farmington Sandstone beds of the Kirtland Shale in the headwall. These features frequently occur on bedrock dip slopes as translational landslides in shale beds that overlie sandstone or conglomeratic beds where mass wasting of rock debris advances down slope, creating listric detachment planes parallel to bedding. Heterogeneous deposits consist of unsorted, unstratified rock debris, clay, silt, and sand. Thickness is a maximum of about 30 ft. Small landslip or minor landsliding faces of erosion on the Lewis Shale just beneath the Pictured Cliffs Sandstone in cliffs along the Piedra River are common but not mapped individually.

Tg Mafic intrusive rocks (Tertiary, Absolute age unconstrained)—At several locations southwest of Deep Canyon (se ¼ Sec. 31 T.34N R.4W), the Animas Formation is cut by gabbroic dikes and sills up to 6 ft thick and exposed on strike for tens of feet. These gabbroic dike rocks are greenish-black to black, and aphanitic with few discernable igneous fabrics and structures. In a few samples, a poorly preserved porphyritic texture was noted. The intrusive rocks in the area are spatially related to Tertiary mafic intrusive rocks exposed from Durango to Pagosa Springs along the northern edge of the San Juan Basin (e.g., Wood and others, 1948; Fassett and Hinds, 1971; Condon, 1990). There are no radiometric age constraints on these dikes, but many were emplaced into Eocene sedimentary rocks in the area.

Ta Animas Formation (Paleocene) —Gray-green to olive-brown and light- to dark-reddish-brown volcaniclastic conglomerate, sandstone, and shale. Pebble conglomerates are poorly sorted, have rounded porphyritic igneous clasts, and are silica cemented. Sandstones are fine to medium grained, quartzose, and include assorted minerals such as magnetite. Bedding is massive to planar crossbedded in sets of variable thickness. Sandstones range from well sorted to poorly sorted and have well-rounded grains with siliceous cement. Pebble conglomerates more common in the northern part of the study area. Rare coal clasts (2 to 5 in. diameter) were found nearby on Ludwig Mountain quadrangle along US 160 (Carroll and others, 1998).

Reeside (1924) suggested that the upper part of the Animas Formation is unconformable with all underlying units. There may be a regional unconformity at the boundary between Tertiary and Cretaceous rocks in the San Juan Basin. The Cretaceous McDermott Member of the Animas pinches out 20 miles west of Archuleta County. Hence, only the upper part of the Animas Formation exists in Archuleta County, and is therefore considered only Tertiary in age.

The contact with the overlying San Jose Formation was not recognized in the field and therefore was not mapped. The contact with the underlying Kirtland Shale is unconformable and easily distinguished. Unconformable contact between the Animas

Formation and the Fruitland Formation in a pendant east of Archuleta Creek shows complete erosion of the Kirtland Shale. Prominent sedimentary features such as trough crossbedding and clay rip-up clasts in the Animas Formation indicate deposition in a high-energy fluvial environment. Volcanic clasts were probably eroded from uplands to the north and northwest, possibly from around the La Plata Mountains area (Zapp, 1949), but may also be locally from the northeast. Maximum preserved thickness in the quadrangle is about 1,000 ft, on the basis of subsurface information from gas wells drilled in the study area.

Kk Kirtland Shale, undivided (Upper Cretaceous)— Light brown, greenish-brown, yellowish-brown in upper units, tan, weathers to bleached white or dark brown or orange sandstone, and dark greenish-brown and olive-gray shale. Sandstone beds are fine- to medium-grained, well sorted and rounded to subrounded grains, feldspar and mafic minerals common with clay rip-up clasts. Silica cemented, silica grains, less than 10% mafic minerals. Bedding is massive to faintly thick bedded. Trough cross-bedding is common in thinner sandstone beds, noted especially along US 160 near Wagon Gulch. Forms large, steeply dipping sandstone fins east of Yellowjacket Pass. The unit is predominantly sandy along the west side of the study area, but in the southeast corner (se ¼ se ¼ Sec. 36 T34N R4W) full exposure of the Kirtland Shale shows about 80% shale and only 20% sandstone. Shale interbeds are non-carbonaceous for the most part.

Unit is mapped throughout the study area as an undifferentiated unit because the Farmington Sandstone member is not easily recognized. Barnes (1953) mapped the Farmington Sandstone in the northwest part of this study near Yellowjacket Pass, but this member was not easily distinguished in this study by Gonzales due to multiple sandstones in both the Upper Kirtland and the middle or Farmington Sandstone Member, a feature similarly observed on Ludwig Mountain Quadrangle (Carroll and others, 1998). A dark olive-green lower Kirtland Shale unit was observed east of Wagon Gulch (MS A-8) and in many other parts of this study area but not mapped separately due to its inconsistent preservation. The upper and middle parts of the Kirtland Shale are fluvial in origin, and where preserved, the lower Kirtland Shale is interpreted as overbank and channel fluvial in origin on a coastal plain landward of the coal mire environments. Combined thickness of the formation is about 650 ft.

The formation contact with the underlying Fruitland Formation is gradational but probably unconformable, as denoted by sharp lack of carbonaceous shale at the base. In this project, the contact criteria was marked by several mappable features:

1. All coal and carbonaceous shale were assigned to the upper Fruitland.
2. Thickly bedded, white to buff-brown lithic sandstones were all assigned to the Kirtland.
3. A thick, non-carbonaceous, olive-green to dark olive gray shale with thin lenses of dark brown to greenish-gray chloritic sandstone present intermittently throughout the map area is similar to the Lower Kirtland Shale member mapped on geologic quadrangles nearby in La Plata County and assigned to the Kirtland Shale.

4. Where the contact is whitish sandstone overlying brownish sandstone, an arbitrary contact is drawn placing all brown sandstones in the Fruitland Formation and all white sandstones in the Kirtland Shale.
5. Uppermost Fruitland most often picked at the top of the highest coal bed or carbonaceous shale zone.

Kf **Fruitland Formation (Upper Cretaceous)—**Unit consists of interbedded shale, sandstone, coal, carbonaceous shale, siltstone, and mudstone. The sandstone beds are light gray, tan, light brown to olive brown, well indurated, very fine to fine-grained, occasionally medium-grained, crossbedded, well sorted, calcareous and siliceous cement, and consists predominantly of sub-angular quartz grains with rare plant debris. Coal is charcoal gray to black, bituminous high luster, well cleated, with rare moullions, laterally grades into carbonaceous shale beds. Brown oblong siderite nodules 0.25-in. to 4-in diameter are common in the middle part of the unit. The Fruitland Formation sandstones are highly fractured and have well developed, regular joint sets within the map area. Interbedded shale is dark gray to black, carbonaceous, micaceous, locally sandy, and contains interbedded coal beds and altered volcanic ash (tonsteins). Coal beds are more common in the basal part of the Fruitland, while carbonaceous shales dominate the upper Fruitland. Non-carbonaceous siliceous shales are gray and occur throughout the formation. Thin limestone layers less than two-inches thick observed at MS A22 in Archuleta Creek.

The lower Fruitland consists predominantly of bituminous coal, sandstone, and shale beds. Coal beds vary from 0.1 in. to over 22 ft thick, and trend for tens of ft to over 3,000 ft in length. A basal coal bed C1 usually lies in contact with the top of the Pictured Cliffs Sandstone. Clinkers were noted in several areas covering large dipslope coal bed areas in at least two areas in Sec 9 T34N R5W along US 160, and in south Peterson Gulch at Secs. 13U and 24 T34N R5W. Clinker is a unit composed of baked and fused rocks resulting from thermally altered or baked coal beds and interbeded sandstone and shale. An abundance of bivalve fossils were observed in the lower Fruitland claystones at the top of coal beds in Cabezon Canyon.

The upper part of the Fruitland Formation is a sequence of fluvial sandstones and carbonaceous shales with lesser, thinner coal beds. The sandstone beds generally are lenticular and pinch out within a few hundred ft laterally. Discrete sandstone beds are more correlative than the upper Fruitland coal beds, but not as contiguous as the basal Fruitland coals. Individual coal beds are thickest and most numerous at the Shamrock Mine, near the north end of Fosset Gulch Road, and south of US 151 one mile southeast of the Chimney Rock coal mine. Combined thickness of all the coal beds (or net coal thickness) ranges from 13.5 ft (Measured Section (MS) A-21) to as much as 45.5 ft (MS A-1) in the study area.

The lower part of the Fruitland Formation was deposited in nonmarine brackish-to fresh water lagoon and swampy coastal plain environments called mires; it grades upward into well-drained coastal plain environments (Condon, 1990). Lateral accretion surfaces are common in the middle section of the Fruitland, showing point bar migrations in the

fluvial section (MS A-9). The Fruitland Formation conformably overlies and intertongues with the Pictured Cliffs Sandstone regionally. Thickness ranges from 193.7 ft east of Wagon Gulch (MS A-8) to 90.3 ft (MS A-21) at the head of Archuleta Creek.

The Fruitland Formation is the main source of coalbed methane production in the San Juan Basin and is also a reservoir for natural gas. Thirteen Fruitland coal prospect pits or mines are located in the map area. Geologic hazards include methane gas leakage along the Fruitland outcrop, including local explosive conditions along river drainages in La Plata County. Methane contamination of water wells has also been reported.

Kpct Pictured Cliffs Sandstone Tongue (Upper Cretaceous) —Unit consists of light gray to bleached white sandstone that overlies the Fruitland Formation Tongue (Kft). The sandstone is massive, forms rounded ledges, and is rarely thick-bedded with light grayish-blue shale interbeds. Unit is mapped in Cabezon Canyon underlying the Fruitland Formation C1 coals, but overlying the Kft C0 coal beds. *Ophiomorpha* is uncommon, and t*eredolites* trace fossils in woody material found at contact with Kft on a small, Kpct sandstone too small to map near US 160.

Kft Fruitland Formation Tongue (Upper Cretaceous) —Unit consists of coal, carbonaceous shale, clinker, carbonaceous sandstone, and altered volcanic ash. The coal is black, subbituminous, medium ash, and the interbedded shale is dark gray to black, carbonaceous, locally ashy with several thin tonsteins. The Fruitland tongue consists of that part of the basal Fruitland Formation coal deposited in a wedge between the Kpct and the Kpc in Cabezon Canyon. This interfingering of formations is denoted on the map by a special line symbol and is labeled 'Kft' for the C0 coal beds. The thickest C0 coal is 5 ft thick at Sec. 28 T34N R4W. The lower coal bed can be followed to the overlook of the canyon incised by Archuleta Creek where it thins and grades into a light bluish gray carbonaceous sandstone, then lenses out within the Pictured Cliffs Sandstone. Some thin bedded, tan with orangish-brown weathering, clay rip-ups, well sorted, fine-grained fine lamilar sandstone beds are layered between the C0a and C0b coal beds.

Kpc Pictured Cliffs Sandstone (Upper Cretaceous)—Light gray to white, tan and grayish-orange sandstone interbedded with dark-gray shale in lower part. The sandstone is siliceous, well sorted, and has rounded sand grains. Locally contains abundant *Ophiomorpha* burrows that are characteristic of the unit (Fassett and Hinds, 1971; Aubrey, 1991; Pemberton and others, 1992). The unit forms a platform shelf upon which the Fruitland Formation is deposited. A distinct outcrop of Kpc extends northwest-southeast along the west bank of the Piedra River as a steep cliff-forming hogback ridge. The outcrop form displays rounded ledges with fractures less well developed than those in the Fruitland Formation sandstones.

The Pictured Cliffs Sandstone was deposited in shallow marine water as a shoreface deposit (Fassett and Hinds, 1971; Aubrey, 1991). There are two distinct zones in the Kpc: an upper shoreface unit and a lower shoreface unit. The contact with the underlying Lewis Shale is conformable and gradational. Thickness is 246 ft at the Shamrock Mine

and over 300 ft thick in the canyon with Archuleta Creek. The formation stratigraphically rises about 1,100 ft in a southwest to northeast direction across the San Juan Basin (Fassett, 1988).

Kl Lewis Shale (Upper Cretaceous)—Dark-gray fissile shale containing thin sandstone beds at top and gray, rusty-weathering concretionary limestone in the lower part. Volcanic beds in the Lewis Shale, most notably the Huerfanito Bentonite Bed, have been used as time-stratigraphic markers throughout the San Juan Basin (Fassett and Hinds, 1971, Fassett and Steiner, 1997). The Huerfanito Bentonite bed was not observed in this study because only the upper Lewis Shale was mapped and the Huerfanito Bed is 1100 ft below the Pictured Cliffs Sandstone locally (Fassett and Hinds, 1971). The unit weathers easily and is extensively covered by surficial deposits except where protected by a caprock of Pictured Cliffs Sandstone. The contact with the underlying Mesaverde Group is conformable. The Lewis Shale was deposited in a low-energy, offshore, marine environment, and represents the highest marine shale sequence in the San Juan Basin (Fassett and Hinds, 1971). Thickness ranges from 2,100 ft on the east side of the quadrangle to 1,800 ft thick on the west side. It is a reservoir for natural gas in the San Juan Basin. The Lewis Shale may be prone to landsliding and is susceptible to shrink-swell problems where it contains expansive clays.