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Geologic Map of the Rules Hill Quadrangle, La Plata County, Colorado

Description of Map Units, Economic Geology, and References

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INTRODUCTION

Geologic mapping of the 7.5-minute Rules Hill quadrangle was undertaken by the Colorado Geological Survey as part of the National Cooperative Geologic Mapping Act-STATEMAP component program. The Rules Hill quadrangle was selected as the first quadrangle to be mapped in the Durango area because of the rapid population growth, geologic hazards such as methane seepage and natural gas resources found within it. The Colorado Geological Survey plans to map the geology of several other 7.5-minute quadrangles in this area in future years. Our understanding of the geology of this region will likely evolve as future mapping is completed.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Surficial deposits shown on the map are generally more than 5 ft thick, but may be thinner locally. Residuum and some artificial fills were not mapped. Contacts between surficial units may be gradational, and mapped units occasionally include deposits of another type. Divisions of the Pleistocene correspond to those of Richmond and Fullerton (1986). Relative age assignments for surficial deposits are based primarily on the degree of erosional modification of original surface morphology, height above modern stream levels, and relative degree of weathering and soil development. Some of the surficial deposits are calcareous and contain varying amounts of both primary and secondary calcium carbonate.

HUMAN-MADE DEPOSITS—Materials placed by humans

af — **Artificial fill (latest Holocene)**—Consists of fill and waste rock placed during construction of roads and small dams. Composed mostly of unsorted silt, sand, and rock fragments, but may include construction materials. Maximum thickness is about 40 ft. Artificial fill may be subject to settlement when loaded, if not adequately compacted

ALLUVIAL DEPOSITS—Silt, sand, and gravel deposited in stream channels, flood plains, outwash terraces, and sheetwash areas along Los Pinos and Florida Rivers and their tributaries

Qa — **Stream-channel, flood-plain, and low-terrace deposits (Holocene and late Pleistocene)**—Includes various alluvial deposits in the valleys of Los Pinos River and Florida River. Consists of unconsolidated silt, sand, gravel, and occasional boulders, deposited in main-stem river beds and flood plains. Clast lithologies include sedimentary, metamorphic, and igneous rocks eroded from the San Juan Mountains north of the map area and from local sedimentary bedrock sources within or near the map area. Boulders and cobbles derived from the Vallecito Conglomerate are found only along Los Pinos River. Alluvial deposits in this valley are extremely hard because of the dense rocks derived from the provenance area. Low-lying areas are subject to flooding. Unit is a good source of sand and gravel.

Qsw — **Sheetwash deposits (Holocene and late Pleistocene)**—Includes deposits derived from weathered bedrock and unconsolidated surficial materials transported predominantly by sheetwash and deposited in small intermittent stream valleys, on gentle hillslopes, or in basinal areas which lack external drainage. Common on gentle to moderate slopes and in landslides. Typically consists of clayey, pebbly, silty sand, and sandy silt. Maximum thickness probably about 25 ft but may be thinner locally.

Qt_2 **Younger terrace outwash (late Pleistocene)**—Chiefly stream alluvium deposited as glacial outwash and underlying terraces that range from about 20 to 30 ft above Los Pinos River. The unit is mostly a poorly sorted, clast-supported, occasionally bouldery, pebble and cobble gravel in a sand matrix. Also includes fine-grained overbank deposits. Clasts are mainly subround to round and are composed of a variety of lithologies reflecting the diverse types of bedrock found in the drainage basin. Clasts of Precambrian Vallecito Conglomerate are locally common only along Los Pinos River. Clasts of Vallecito Conglomerate are generally unweathered or only slightly weathered. Estimated thickness is about 20 to 30 ft. Unit is a good source of sand and gravel.

Qt_1 **Older terrace outwash (late or middle? Pleistocene)**—Composed of stream alluvium deposited as glacial outwash. Underlies a single terrace about 55 to 65 ft above Los Pinos River and two terraces along the Florida River, one about 60 to 70 ft above the river and a second about 95 to 105 ft above it. Older terrace outwash is fairly well exposed in a gravel pit located along Los Pinos River at the confluence with Texas Creek. At this locale the deposit consists of interbedded, moderately well-sorted to poorly sorted, very silty, medium- to coarse-grained sand and poorly sorted silty or sandy cobble gravel with occasional rounded boulders up to about 3 ft in diameter. Clast lithology is diverse and includes distinctive clasts of Vallecito Conglomerate along Los Pinos River. Vallecito Conglomerate is a Precambrian rock that contains purple, white, whitish-red to dark-red clasts in a dark-gray silica matrix and is very hard. A white to tan, well-rounded quartzite rock is also found in abundance in this deposit. Micaceous sedimentary and igneous clasts are moderately weathered, but harder clasts are sound. Deposits along Florida River are very poorly exposed but appear to be more silty than those along Los Pinos River. Thickness ranges from about 15 to 50 ft. Unit is a good source of sand, gravel, and decorative rock.

COLLUVIAL DEPOSITS—Silt, sand, gravel, and clay on valley sides, valley floors, and hillslopes that were mobilized, transported, and deposited primarily by gravity, but frequently assisted by sheetwash, freeze-thaw action, and water-saturated conditions that affect pore pressure

Qlsr **Recent landslide deposits (latest Holocene)**—Includes recently active landslides with fresh morphological features such as headscarps, undulatory landscapes, and distal-end debris fans. Frequently occur on bedrock dipslopes where mass wasting of rock debris advances downslope, creating listric detachment planes parallel to bedding. Heterogeneous material consisting of unsorted, unstratified rock debris, clay, silt, and sand. Texture and clast lithology are dependent upon provenance area. Includes rotational slides, translational slides, and complex slope failures. Thickness probably a maximum of about 60 ft. Deposit shown on map in Sec. 31, T. 36 N., R. 7 W. slid during the 1950s on the Menefee Formation dipslope. This area is prone to renewed or continued landsliding. Deposits may be susceptible to settlement when loaded. Shallow groundwater may be present within areas mapped as recent landslide deposits.

Qc **Colluvium (Holocene and late Pleistocene)**—Ranges from clast-supported, pebble to boulder gravel in a sandy matrix to matrix-supported gravelly sand or clayey silt. Derived from weathered bedrock and surficial deposits and transported downslope primarily by gravity. Deposits are usually coarser grained in upper reaches and finer grained in distal areas. Deposits derived from thick, shaly bedrock tend to be clayey and matrix supported. Colluvial deposits are unsorted or poorly sorted with weak or no stratification. Clast lithology is variable and dependent upon local surface exposures. Locally includes talus, landslide deposits, sheetwash deposits, and debris-flow deposits that are too small or too indistinct on aerial photographs to be mapped separately. Colluvium grades into younger fan deposits (Qfy), and alluvium and colluvium, undivided (Qac), and sheetwash deposits (Qsw) in many tributary drainages. Thickly vegetated slopes mantled with surficial deposits are also mapped as colluvium, unless evidence of landsliding was observed. Maximum thickness is probably about 100 ft.

Qls

Landslide deposits (Holocene and Pleistocene)—Highly variable deposits similar in texture and lithology to recent landslide deposits (Qlsr). Include rotational landslides, translational landslides, earth flows, and extensive slope-failure complexes. Deposits range from slowly creeping landslides to long-inactive middle Pleistocene or perhaps even early Pleistocene landslides. Most landslides involve the Mancos Shale, but sliding on the Dakota dipslopes such as the one in secs. 28, 29, and 33, T. 36 N., R. 7 W. appears to be a slope failure within the Dakota Sandstone. Landslide deposits may be subject to future movement but deeply dissected deposits probably are stable. Maximum thickness about 100 ft. Large blocks of Dakota Sandstone found within many of these deposits may hinder excavation. Locally unit may settle when loaded. Shallow groundwater may occur within landslide deposits.

Qco

Older colluvium (Pleistocene)—Occurs on hillslopes, ridge lines, and drainage divides as erosional remnants of formerly more extensive deposits that were transported primarily by gravity and locally aided by sheetwash processes. Texture, bedding, and clast lithology similar to colluvium (Qc). Maximum thickness probably is about 50 ft. Area generally is not subject to significant future colluvial processes, except when adjacent to steep, eroding hillslopes.

ALLUVIAL AND COLLUVIAL DEPOSITS—

Silt, sand, gravel, and clay in debris fans, stream channels, flood plains, and adjacent hillslopes along tributary valleys. Depositional processes in stream channels and on flood plains are primarily alluvial, whereas colluvial and sheetwash processes are commonly predominant on alluvial fans, hillslopes, and along the hillslope/valley floor boundary.

Qfy

Younger fan deposits (Holocene)—Includes hyperconcentrated-flow, debris-flow, alluvial, and sheetwash deposits in fans and tributary drainages. Consists of crudely stratified deposits that range from poorly sorted, clast-supported, cobble and boulder gravel in a clayey silt or sand matrix to matrix-supported gravelly, clayey silt. Frequently bouldery, particularly near the heads of fans whose provenance is predominantly sandstone. Deposits tend to be finer grained in the distal ends of fans, where sheetwash and mudflow processes become more dominant. Clasts range from angular to subround. Maximum thickness is about 40 ft. Area is subject to future, potentially catastrophic depositional events.

Qac

Alluvium and colluvium, undivided (Holocene and late Pleistocene)—Chiefly stream-channel, low-terrace, and flood-plain deposits along minor drainages and valley floors about 0.1 to 0.6 miles wide, with colluvium and sheetwash locally common on valley sides. Alluvial and colluvial component deposits typically interfinger. Unit is a poorly to well sorted and stratified pebbly sand and sandy gravel interbedded with sand (the alluvial component), but may range to poorly sorted, unstratified or poorly stratified clayey, silty sand, bouldery sand, and sandy silt (the colluvial component). Clast lithologies reflect the rocks within the provenance area. Thickness is commonly 5 to 20 ft; maximum thickness estimated at about 40 ft. Low-lying areas are subject to flooding. Valley sides are prone to sheetwash, rockfall, and small debris flows. Unit may be hydrocompactive where fine grained and of low density. Unit is a potential source of sand and gravel.

Qcs

Colluvium and sheetwash deposits, undivided (Holocene and late Pleistocene?)—Composed of colluvium (Qc) on steeper slopes and sheetwash deposits (Qsw) on flatter slopes. Mapped where contacts between the two types of deposits are very gradational. Refer to unit descriptions for colluvium (Qc) and sheetwash deposits (Qsw) for textural and lithologic characteristics and for engineering geologic properties and hazards.

Qfo

Older fan deposits (late Pleistocene)—Occurs as remnants of formerly extensive fans found at the mouths of Red, Shearer, and True Creeks in the northwest part of the quadrangle. Numeric subscripts on deposits indicate relative ages of two older fans near mouth of Red Creek. Deposits labeled Qfo_2 are younger than those labeled Qfo_1. Includes hyperconcentrated, alluvial, debris-flow, and sandy sheetwash deposits that range from poorly sorted, clast-supported, occasionally bouldery cobble and pebble gravel in a silty or sandy matrix to matrix-supported gravelly sandy silt to bedded, well sorted sand and silt. Locally is interbedded with outwash gravel deposited by the Florida River at distal ends of ancient fans. Clasts are generally subangular to subround, but can be round or angular. Clast lithology is varied but predominantly reddish sandstone and reflects the diverse types of bedrock present in the provenance area. Micaceous clasts are moderately to highly weathered, but other harder clasts are generally sound. Older fan deposits lie about 80 to 240 ft above Florida River. At Shearer Creek older terrace outwash (Qt_1) was deposited as an inset terrace eroded into older fan deposits. Thickness ranges from around 15 to 50 ft. May be a source of sand and gravel.

Qaco

Older alluvium and colluvium, undivided (Pleistocene)—Stream-channel, low-terrace, and flood-plain deposits along tributary valley floors, interfingered with colluvium and sheetwash from valley sides. Typically composed of moderately well-sorted to well-sorted, stratified, interbedded sand, pebbly sand, and sandy gravel to poorly sorted, unstratified or poorly stratified clayey, silty sand, bouldery sand, and sandy silt.

BEDROCK

Animas Formation (Paleocene and Upper Cretaceous)—Includes the main body of the formation (TKa) and the basal McDermott Member (Kam)

TKa

Main body—Gray-green to olive-brown and light- to dark-reddish-brown volcaniclastic conglomerate, sandstone, and shale. Conglomerates are poorly sorted, have rounded clasts, and are silica cemented. Sandstones are fine- to medium-grained, quartzose, and include assorted mafic minerals including magnetite. Bedding is planar and crossbedded in sets of variable thickness. Sandstones range from well sorted to poorly sorted and have well-rounded grains with siliceous cement. Pebble conglomerate in Sec. 17, T. 35 N., R. 7 W. is clast supported, has hard silica cement, and has rounded to subrounded clasts (.5 to 3 in. diameter) that have iron-stained weathering rinds. The main body of the Animas Formation overlies the McDermott Member in the western part of the map area and locally intertongue in the west-central part. Reeside (1924) suggested that the upper part of the Animas Formation is unconformable with all underlying units. Fassett (1985) suggested that a regional unconformity occurs at the boundary between Tertiary and Cretaceous rocks in the San Juan Basin, but Baltz (1953) interpreted the upper part of the Animas Formation to intertongue with the McDermott Member, a relationship that was found on the map area. In the eastern part of the map area the Animas Formation conformably overlies the Kirtland Shale. Prominent sedimentary features such as trough crossbedding and clay rip-up clasts indicate a high-energy fluvial environment. Volcanic clasts were probably eroded from uplands to the north and northwest, possibly from the La Plata Mountains (Zapp, 1949). Maximum preserved thickness in the quadrangle is 1,000 ft as observed in subsurface gas wells drilled in the southern part of the map area.

Kam

McDermott Member (Upper Cretaceous)—Chiefly purple to reddish-brown volcaniclastic conglomerate, sandstone, and shale. Conglomeratic clasts consist of round to subround, poorly sorted pebbles and cobbles, with occasional boulders up to 4-ft-diameter. In the western part of the quadrangle the base of the Member contains lenses of chert and quartz pebbles. In the western part of the map area the McDermott Member comprises the base of the Animas Formation. In the west-central part of the quadrangle, it intertongues with the basal part of the main body of the Animas Formation. It wedges out one mile west of Rules Hill. A purple conglomerate bed within the main body of the Animas Formation near the top of Rules Hill (Sec. 13, T. 35 N., R. 8 W.) may be a remnant bed of the McDermott Member. The unit was deposited in a fluvial environment that may have been influenced by volcanic eruptions to the north or northwest (Condon, 1990). Maximum thickness is about 75 ft. The McDermott Member may be a source of decorative rock. It may be difficult to excavate because it is well indurated.

Kirtland Shale (Upper Cretaceous)

Kku

Upper Member—Light-yellow to white and whitish-tan sandstone with interbedded olive-green and olive-gray shale. The unit consists of roughly equal parts sandstone and shale. The sandstone is fine- to medium-grained, crossbedded and locally conglomeratic, but locally beds are massive, well indurated, form rounded ledges and display honeycomb weathering. They are well sorted, cemented with silica, have rounded grains, and fine upward in gradational sequences. The sandstone beds were derived from a fluvial source that, in part, contain andesitic volcanic clasts (S. Condon, 1997 personal commun.). The shale contains abundant mafic minerals and is slightly carbonaceous in places. The Upper Member of the Kirtland Shale represents fluvial deposition and the presence of feldspar and mafic minerals suggests deep erosion of upland areas and is interpreted as the beginning of the Laramide orogeny (Barnes, Baltz, Jr., and Hayes, 1954). Contact with the underlying Farmington Sandstone Member is gradational. The Upper Member of the Kirtland Shale is poorly exposed except where well indurated massive sandstones crop out. Thickness increases from 100 ft to 150 ft west to east across the quadrangle.

Kkf

Farmington Sandstone Member—Olive-brown to yellow and tan to light-orange sandstone and greenish-gray shale. The sandstone is fine- to medium-grained, crossbedded, well sorted, silica cemented, and has subrounded grains. The Member generally crops out as a high ridge. Gradational contact with the Lower Member of the Kirtland Shale (Kkl) is rarely well exposed; it was mapped at the lowest sandstone bed within the unit. The Farmington Sandstone Member formed as fluvial channels (possibly as an alluvial deposit) shoreward from the Fruitland coastal plain (Fassett and Hinds, 1971; Aubrey, 1991). Unit thickness is about 300 ft. May be prone to rockfall where exposed in steep cliffs. Locally may be difficult to excavate.

Kkl

Lower Member—Gray-green to dark-olive-gray shale and thin lenses of dark-brown sandstone and silty shale beds. Some carbonaceous shales in basal portion. The dark coloration in the sandstone beds occurs because of the presence of chlorite minerals. Unit is not well exposed in the quadrangle. The contact with the underlying Fruitland Formation is conformable and gradational; it is placed at the top of the highest Fruitland Formation sandstone or coal bed. The Lower Member of the Kirtland Shale was deposited in overbank and channel areas in the late Cretaceous coastal plain between the Fruitland coal swamps and the Farmington Sandstone Member fluvial channels (Fassett and Hinds, 1971). Thickness ranges from 150 to 250 ft, thinning to the north and east. Engineering problems associated with the Lower Member of the Kirtland Shale include poor foundation soils and possible shrink-swell potential. Landsliding on steeper slopes is possible. No economic mineral resources are known in this unit.

Kf

Fruitland Formation (Upper Cretaceous)—Consists of interbedded shale, sandstone, and coal. The sandstone is light gray, light-brown to olive-brown, well indurated, fine- to medium-grained, crossbedded, well sorted, and consists of predominantly subangular quartz grains. Interbedded shale is dark-gray to black, carbonaceous, micaceous, locally sandy, and it contains interbedded coal beds. The upper Fruitland Formation is a sequence of sandstone and shale. The lower portion consists predominantly of shale and bituminous, cleated coal beds and a few thin sandstone beds. The sandstone beds are lenticular and pinch out within a few hundred feet but lateral equivalent beds mark discrete sandstone zones regionally. Individual coal seams extend for thousands of feet across the quadrangle and thicken to the west. Total maximum summed thickness of coal is as much as 40 ft in the quadrangle. The lower portion of the Fruitland Formation was deposited in nonmarine brackish-water lagoonal and swampy coastal plain environments; it grades upward into well-drained coastal plain environments (Condon, 1990). The Fruitland Formation conformably overlies and intertongues with the Pictured Cliffs Sandstone regionally. Intertonguing contacts were not observed in the map area but were noted just west of the quadrangle where the formations cross the Florida River. Thickness ranges from 150 to 400 ft. The Fruitland Formation is the main source for coalbed methane production and is a reservoir for natural gas in the San Juan Basin. Geologic hazards include localized methane gas leakage (J. Lister, 1996 personal communication) and potential for landsliding or rockfall on steeper slopes.

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 grains. Contains abundant *Ophiomorpha* burrows that are distinctive to the unit. The formation extends east-west across the quadrangle as a high relief cliff-forming hogback. It was deposited in shallow marine water as a shoreface deposit (Fassett and Hinds, 1971; Aubrey, 1991). The contact with the underlying Lewis Shale is conformable and gradational. Thickness is 215 ft near Durango (Zapp, 1949) and 130 ft on east side of the map area. The formation rises stratigraphically 1,100 ft southwest to northeast across the San Juan Basin (Fassett, 1988). Pictured Cliffs Sandstone may pose rockfall hazards where exposed in high cliffs. It is a reservoir for natural gas in the San Juan Basin but may be tight in the map area.

Kl **Lewis Shale (Upper Cretaceous)**—Dark-gray fissile shale containing thin sandstone beds at top and 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). The unit weathers easily, and is extensively covered by surficial deposits except where protected by a caprock of Pictured Cliffs Sandstone. Long, linear ridges form on the outcrop perpendicular to strike, and the Lewis Shale forms a wide, north-facing valley on the map area. The contact with the underlying Cliff House Sandstone is conformable. The Lewis Shale was deposited in a low-energy, off-shore, marine environment (Fassett and Hinds, 1971). Thickness ranges from 2,100 ft on the east side of the map area to 1,800 ft thick on the west side. The Lewis Shale may be prone to landsliding and is susceptible to shrink-swell problems where it contains expansive clays.

MESAVERDE GROUP (UPPER CRETACEOUS)—Consists of three formations on the west side of the map area: the Cliff House Sandstone, Menefee Formation, and Point Lookout Sandstone. These formations are distinguished primarily by the presence of coal beds within the Menefee Formation. Contacts between the formations become less well defined toward the east side of the map area as the Menefee coalbeds thin and pinch out. The entire group is 365 to 430 ft thick in the map area.

Kch **Cliff House Sandstone**—An interbedded sequence of hard, yellowish-orange, fine- to medium-grained calcareous sandstone and softer light-gray mudstone or silty shale. Sandstone beds in the map area are less prominent than those in the Durango region approximately seven miles west of the map area. The sandstone becomes silty and discontinuous eastward where they intertongue with the Menefee Formation. Contact with the underlying Menefee Formation is conformable and gradational. The Cliff House Sandstone is a transgressive shallow marine unit deposited on the upper shoreface zone of a barrier-island beach front (Siemers and King, 1974). In this part of the San Juan Basin, the transgressive shoreface sandstone unit of the Cliff House Sandstone is not always present (Fassett, 1988). Maximum thickness in the quadrangle is about 100 ft near Elks Park. The formation is an important gas productive unit of the Mesaverde Group in the San Juan Basin.

Kmf **Menefee Formation**—Composed of interbeds of light-gray and brown sandstone and dark-gray to black shale and coal beds. Lenticular and crossbedded sandstone beds are complexly interbedded with coal seams. In the western part of the map area, irregular bedding, and frequent, abrupt lateral changes in lithology suggest deposition as crevasse-splays on a lobate delta. To the east, the entire unit changes to a marine sandstone that forms a very high ridge in the quadrangle. Contact with the underlying Point Lookout Sandstone is conformable and gradational. Thickness is variable but increases markedly toward the east. The Menefee Formation is about 130 ft thick along the western edge of the quadrangle; eastward the sandstone units thicken and the coal seams thin. The Menefee Formation hogback rises from about 100 ft above the Florida River near Elks Park to over 500 ft above the river in the east-central part, where the formation is about 300 ft thick. Total coal-bed thickness is about 28 ft in the west side of the map area. No coal was observed near Columbus in the east side of the map area but other workers have noted up to 12 ft of total coal thickness in the subsurface south of that area (Crist, Kelso, and Boyer, 1990). Geologic hazards include a potential for landsliding and rockfall problems from steep exposures.

Kpl

Point Lookout Sandstone—Light-gray to yellowish-gray sandstone and dark-gray shale. Base of unit is shaly, with increasing interbedded sandstone in the mid-section and massive sandstone at the top. Upper massive unit is prominent only in the western part of the map area near Elks Park. Basal part of the formation increases in shale content to the east as the upper massive sandstone (mapped as Kplm by Zapp, 1949) grades out. The sandstone is fine-grained, cross laminated, and well sorted, and has quartzose grains and calcite cement. *Ophiomorpha* burrows are common in the sandstone beds. Interbedded shale units are fossiliferous and carbonaceous. The contact with the underlying Mancos Shale is conformable and gradational and is placed at the base of the lowest sandstone bed within the gradational sequence. The contact is readily mappable on the west side of the quadrangle but must be inferred on the east side where the formation is composed of sandy shale. The Point Lookout Sandstone forms good outcrops in the west side of the quadrangle but not in the east. The Sandstone was deposited in a coastal shoreline environment (Wright, 1986). The Point Lookout Sandstone represents an eastward prograding shoreline between the Mancos Shale sea and the Menefee Formation coastal plain. The upper massive member in the Elks Park area is part of the deltaic plain and mouthbar depositional sequence from the Durango deltaic shoreline (Wright-Dunbar and others, 1992). Thickness is about 200 ft in Elks Park on the west side of the map area but less than 40 ft near Columbus on the east side. The unit may pose rockfall hazards where exposed in steep cliffs. The Point Lookout Sandstone is an important source of natural gas in the San Juan Basin.

Km

Mancos Shale (Upper Cretaceous)—Dark-gray to black shale and silty shale with dark-gray to blue-gray argillaceous limestone. Yellowish-brown to dark-brown weathered concretions form within the gypsiferous basal portion. A regional unconformity of Coniacian age divides the Mancos Shale into an upper and lower part (Dane, 1960; Aubrey, 1991; Molenaar and Baird, 1991). The lower part of the Mancos Shale consists in ascending order of a lower shale member (Graneros), the Bridge Creek Limestone Member (also known as the Greenhorn Limestone Member), a middle shale member (or lower Carlisle bed of Lamb, 1973), and the Juana Lopez Member. Within the quadrangle, the regional unconformity is within or at the top of the Juana Lopez Member (Aubrey, 1991; Molenaar and Baird, 1991), with the upper shale member (or upper Carlisle bed of Lamb, 1973) having been erosionally removed. A calcareous shale interval 400 to 500 ft thick overlies the unconformity. It is probably equivalent to the Smoky Hill Shale Member of the Niobrara Formation (Molenaar and Baird, 1991). The upper part of the Mancos Shale is less calcareous and tends to be fissile. The Mancos Shale is very poorly exposed in the quadrangle, and these members were not recognized at the surface in the Rules Hill Quadrangle. Contact with the underlying Dakota Sandstone is conformable. The Mancos Shale was deposited in a low-energy, far-shore marine environment. Total thickness of the Mancos Shale is about 2,400 ft. The Mancos Shale causes severe landslide problems. Bentonitic beds may cause expansive soil and heaving bedrock problems. Unit is rich in sulfate, which can be deleterious to concrete and drinking water supply wells.

Kdb

Dakota Sandstone (Upper Cretaceous) and Burro Canyon Formation (Lower Cretaceous), undivided—Dakota Sandstone is composed of white, light- to medium-gray, and yellowish-brown conglomeratic sandstone, fine- to coarse-grained sandstone, and conglomerate interbedded with dark- to medium-gray siltstone, carbonaceous shale, and thin coal beds. Conglomeratic clasts in the Dakota Sandstone usually consist of chert and quartz pebbles. Burro Canyon Formation consists of chert-pebble conglomerate and grayish-green claystone. The Dakota Sandstone may unconformably overlie the Burro Canyon Formation, which in turn unconformably overlies the Morrison Formation. Erosionally resistant beds in these formations commonly crop out as locally prominent ledges along the Dakota hogback. Where it dips moderately the Dakota Sandstone may, in places, exhibit minor crumpling, folding, and faulting due to gravity-induced slippage on underlying beds (D. Lidke, 1996, personal communication). Abrupt dip changes west of True Creek may be related to this type of phenomena. The upper and middle parts of the Dakota Sandstone were deposited in coastal swamp, lagoon, and beach environments, while the lower part of the Dakota Sandstone and Burro Canyon Formation were likely of fluvial origin (Condon, 1990). Combined thickness of the two formations averages about 160 ft. The Dakota Sandstone and Burro Canyon Formations generally serve as good foundation material, although excavations into well-cemented beds may require blasting. Where exposed in steep hillslopes, this unit may be prone to rockfall hazards. It may be subject to landsliding when slip planes develop at the contact with bedding planes in the underlying Morrison Formation. The Dakota Sandstone is an oil and gas reservoir in many parts of the San Juan Basin.

Jm

Morrison Formation (Upper Jurassic)—Consists of an upper member called the Brushy Basin Member and a lower member known as the Salt Wash Member (not mapped). The Brushy Basin Member is predominantly greenish-gray, occasionally reddish-brown, bentonitic mudstone containing thin beds of very fine-grained sandstone and rare conglomeratic sandstone. It conformably overlies and perhaps intertongues with the Salt Wash Member (Condon, 1990). The Brushy Basin Member was deposited in lacustrine and fluvial environments. Thickness of the Brushy Basin Member is estimated at 150 ft. The Salt Wash Member is mainly light-gray to white, fine- to medium-grained, lenticular sandstone locally silicified and containing thin beds of greenish-gray mudstone. Salt Wash Member conformably overlies the Junction Creek Sandstone. It was deposited in a fluvial environment and is about 200 ft thick. The Morrison Formation is very poorly exposed in the map area. It is mapped separately only west of Red Creek. Bentonitic beds within the formation may be prone to swelling soil problems. The Brushy Basin Member may be subject to landsliding where exposed on steep slopes or on dip slopes.

Jjc

Junction Creek Sandstone (Middle Jurassic)—Light-gray to tan, massive, highly crossbedded to structureless, fine-grained eolian sandstone. The Junction Creek Sandstone is very poorly exposed in most of the quadrangle. It is mapped as a separate unit only west of Red Creek. The Junction Creek Sandstone conformably overlies the Wanakah Formation and is sometimes is considered a member of that formation. It was deposited in a predominantly eolian environment (Peterson, 1972). Thickness is about 100 ft. It may create rockfall hazards where exposed in steep cliffs.

Jw

Wanakah Formation (Middle Jurassic)—Consists of an upper member composed predominantly of white to tan, reddish-orange, and reddish-brown, very fine- to fine-grained sandstone and reddish-brown to greenish-gray mudstone; and a lower member, the Pony Express Limestone Member, consisting of medium to dark-gray, very thin-bedded to laminated, micritic limestone and oolitic limestone. Formation is very poorly exposed in quadrangle, with only part of the Pony Express Limestone Member occasionally forming a limited outcrop. The Wanakah Formation conformably overlies the Entrada Sandstone. Condon (1990) suggested the upper member of the Wanakah Formation was deposited in sabkha and marginal marine environments, and the Pony Express Limestone Member was of restricted marine origin. Thickness of the upper member is estimated at about 50 ft, while the Pony Express Limestone Member is about 10 ft thick. North of Durango this member is represented by a 2- to 5-ft-thick oolitic limestone (Baars and Ellingson, 1984), whereas to the south Condon (1990) describes it as including a 5- to 15-ft-thick limestone bed and a bed of gypsum up to about 15 ft thick.

Jmw

Morrison Formation, Junction Creek Sandstone, and Wanakah Formation, undivided—Unit is mapped east of Red Creek, where poor exposures limit recognition of the contacts between these formations. Combined thickness about 500 ft.

Je

Entrada Sandstone (Middle Jurassic)—Light-gray to white, sometimes orangish-gray, fine- to medium-grained, highly crossbedded sandstone. Locally is coarse grained or conglomeratic at base. Typically has prominent large-scale crossbedding. Occasionally forms good outcrops, but generally is covered. The Entrada Sandstone unconformably overlies the Dolores Formation and was deposited in an eolian environment. Thickness averages about 250 ft.

TRd

Dolores Formation (Upper Triassic)—Dark-reddish-brown to purplish-red shale and siltstone, and light-brown, gray, and reddish-brown lenticular sandstone and limestone-pebble conglomerate containing rare thin limestone beds. Locally is well exposed on steep hillslopes, but usually is partly or completely covered on gentler slopes. The Dolores Formation unconformably overlies the Cutler Formation. It was deposited in fluvial and lacustrine environments (Condon, 1990). Thickness averages about 500 to 600 ft. The Dolores Formation may be prone to rockfall hazards where exposed in steep cliffs.

Pc

Cutler Formation (Lower Permian)—Medium- to dark-reddish-brown, medium-gray, and medium- to dark-brown sandstone, arkosic sandstone, and arkosic conglomerate and reddish-brown to purplish-brown shale and siltstone containing rare thin limestone beds. Base of formation not exposed in mapped area. Deposited in fluvial and alluvial-fan environments. Total thickness estimated at about 2,000 to 2,500 ft. The formation may be prone to rockfall hazards where exposed in steep cliffs.

ECONOMIC GEOLOGY

Mineral resources in the Rules Hill quadrangle include natural gas, coal, and sand and gravel. The northern part of the Ignacio Blanco gas field lies within the boundaries of the Rules Hill quadrangle. Sixty four natural gas wells were drilled between 1979 and 1992 in the map area. According to Colorado Oil and Gas Conservation Commission (1995), Amoco Production Company and J.M. Huber Company are the main producers in the quadrangle. Most of the production is from Fruitland Formation coalbeds. Production of methane gas in 1994 in La Plata County was 192,787,245 million cubic ft of gas, and total cumulative methane production for the county by the end of 1994 was 494,564,056 million cubic ft of gas. While significant production in Ignacio Blanco gas field is derived from the Dakota Sandstone, Mesaverde Group, Pictured Cliffs and Fruitland Sandstones, all of the production on Rules Hill quadrangle is Fruitland coalbed methane. Coalbed methane resource estimates suggest a recoverable gas volume of 4 trillion cubic ft for the Ignacio Blanco Field (Harr, 1988). There is no oil production in the area.

Other mineral fuel resources include coalbeds in the Menefee Formation that are up to 3 ft thick and coalbeds in the Fruitland Formation that are up to 12 ft thick. While there is no current coal production on Rule Hill quadrangle, some small, old, abandoned coal pits were found. Most of the coal was used locally. Uranium occurrences in the Morrison Formation are known in southwest Colorado; however, there are none in the Rules Hill area.

Sand and gravel resources are found in modern stream channels and quaternary terrace deposits. There is one small gravel pit operation located at Sec. 3, T. 35 N., R. 7 W. along Los Pinos River.

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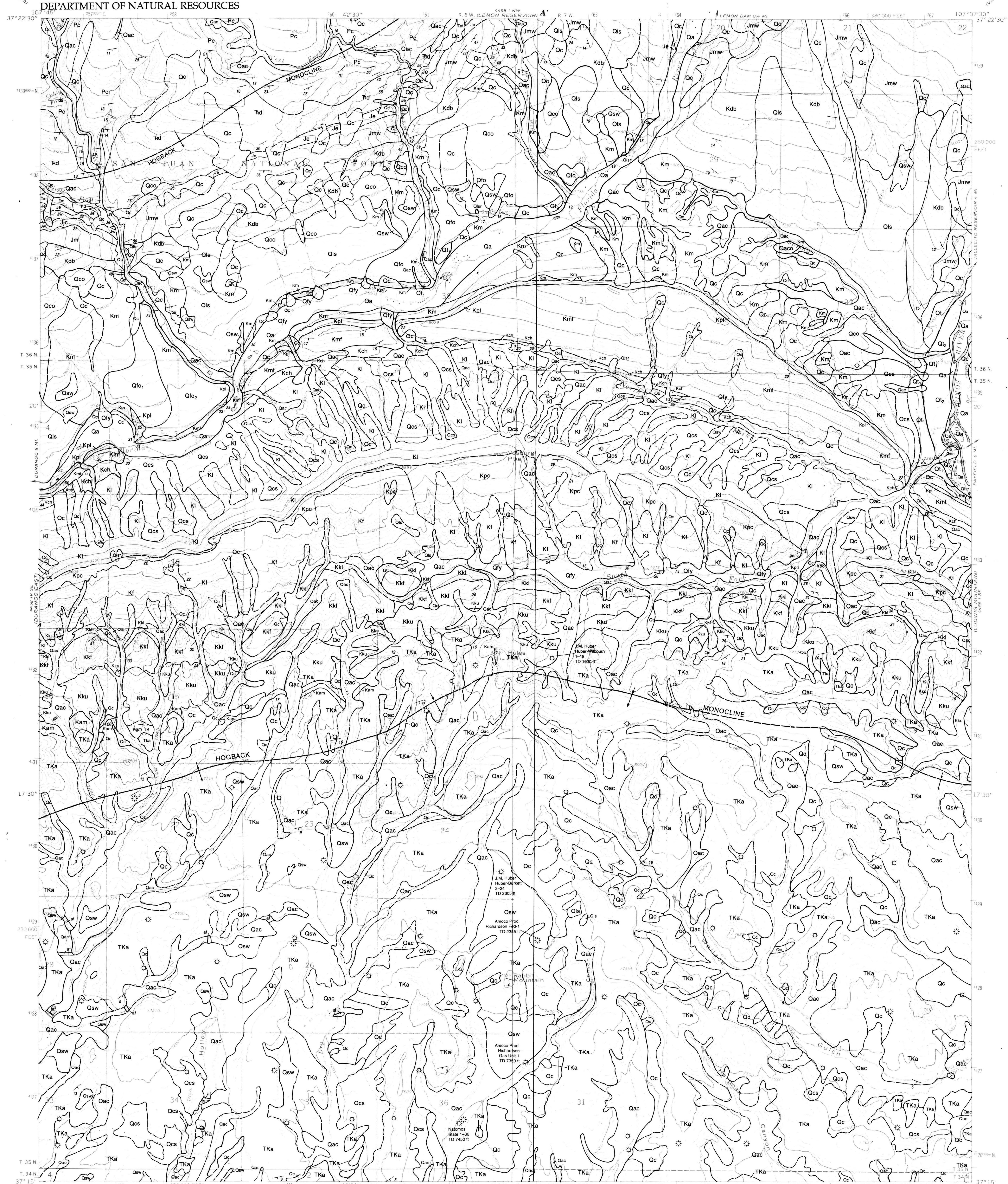
COLORADO GEOLOGICAL SURVEY
DIVISION OF MINERALS AND GEOLOGY
DEPARTMENT OF NATURAL RESOURCES

OPEN FILE MAP 97-1
GEOLOGIC MAP OF THE RULES HILL
QUADRANGLE, LA PLATA COUNTY, COLORADO
Booklet accompanies map



Base from U.S. Geological Survey, 1964

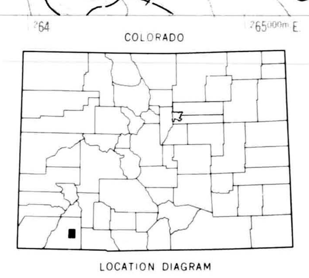
Geology mapped in 1996

SCALE 1:24,000

1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 KILOMETER



CONDENSED DESCRIPTION OF MAP UNITS

The complete description of map units and references is in the accompanying booklet.

SURFICIAL DEPOSITS

HUMAN-MADE DEPOSITS

af — **Artificial fill (latest Holocene)**

ALLUVIAL DEPOSITS—Sediments deposited in stream channels, flood plains, terraces, and sheetwash areas

Qa — **Stream-channel, flood-plain, and low-terrace deposits (Holocene and late Pleistocene)**—Poorly sorted, clast-supported gravel in a sandy matrix. Includes terraces up to about 10 ft above modern river level

Qsw — **Sheetwash deposits (Holocene and late Pleistocene)**—Sandy, clayey silt to sandy gravel deposited in intermittent and ephemeral stream valleys, on gentle hillslopes, or in basinal areas

Qt_2 — **Younger terrace outwash (late Pleistocene)**—Mostly poorly sorted, clast-supported, occasionally bouldery, pebble and cobble gravel in a sand or silt matrix. May include fine-grained overbank deposits. Underlies glacial outwash terraces 20–30 ft above Los Pinos River

Qt_1 — **Older terrace outwash (late or middle? Pleistocene)**—Deposits similar to younger terrace alluvium (Qt_2). Underlies terraces 55–65 ft above Los Pinos River and 60–70 ft and 95–105 ft above Florida River

COLLUVIAL DEPOSITS—Sediments deposited on valley sides, valley floors, and hillslopes that were mobilized, transported and deposited primarily by gravity, but frequently assisted by sheetwash, freeze-thaw action, and water-saturated conditions that affect pore pressure

Qlsr — **Recent landslide deposits (latest Holocene)**—Includes recently active landslides that have fresh morphological features. A heterogeneous unit consisting of unsorted, unstratified rock debris, gravel, sand, silt, clay, and organic material

Qc — **Colluvium (Holocene and late Pleistocene)**—Ranges from clast-supported, pebble to boulder gravel in a sandy silt matrix to matrix-supported slightly gravelly, sandy, clayey silt. Deposits usually coarser grained in upper reaches and finer grained in distal areas

Qls — **Landslide deposits (Holocene and Pleistocene)**—Similar in texture to recent landslide deposits (Qlsr). Range from active, slowly creeping landslides to long-inactive middle Plestocene or perhaps even early Pleistocene landslides. Prominent on steep dipslopes

Qco — **Older colluvium (Pleistocene)**—Texturally similar to colluvium (Qc) but generally not subject to future deposition

ALLUVIAL AND COLLUVIAL DEPOSITS—Sediments in alluvial fans, stream channels, and adjacent hillslopes along tributary valleys

Qfy — **Younger fan deposits (Holocene)**—Sediments deposited by debris flows, hyperconcentrated flows, and mudflows. Ranges from poorly sorted, clast-supported, pebble, cobble, and boulder gravel in a clayey sandy silt or silty sand matrix to matrix-supported gravelly, clayey silt. Frequently bouldery, particularly near the head of fans

Qac — **Alluvium and colluvium, undivided (Holocene and late Pleistocene)**—Stream-channel, low-terrace, and flood-plain deposits along tributary valley floors; interfingered with colluvium and sheetwash from valley sides. Typically composed of moderately well-sorted to well-sorted, stratified, interbedded sand, pebbly sand, and sandy gravel to poorly sorted, unstratified or poorly stratified, clayey, silty sand, bouldery sand, and sandy silt

Qcs — **Colluvium and sheetwash deposits, undivided (Holocene and late Pleistocene?)**—Consists of colluvium (Qc) on steeper slopes and sheetwash deposits (Qsw) on flatter slopes. Mapped where contacts between the two types of deposits are very gradational

Qfo — **Older fan deposits (late Pleistocene)**—Remnants of inactive alluvial fans found near the mouths of Red, Shearer, and True Creeks. Texturally similar to younger fan deposits (Qfy). Numeric subscripts indicate the relative age of two older fan deposits along Red Creek

Qaco — **Older alluvium and colluvium, undivided (Pleistocene)**—Deposits of undifferentiated alluvium and colluvium that underlie terraces and hillslopes 10 to 40 ft above small perennial and intermittent streams. Texture similar to alluvium and colluvium (Qac)

BEDROCK

Animas Formation (Paleocene and Upper Cretaceous)

TKa — **Main body**—Gray-green, olive-brown to dark-reddish-brown conglomerate, sandstone, and shale. Conglomeratic clasts include volcanic lithologies

Kam — **McDermott Member (Upper Cretaceous)**—Purple to reddish-brown sandstone, shale, and conglomerate. Intertongues with the basal Animas Formation

Kirtland Shale (Upper Cretaceous)

Kku — **Upper Member**—Light-yellow to white, tan to light-brown sandstone interbedded with olive-green and olive-gray shale. The sandstone is fine- to medium- grained, massive, crossbedded, and sometimes conglomeratic. Shale is sometimes carbonaceous and contains abundant mafic minerals

Kkf — **Farmington Sandstone Member**—Olive-brown to yellow, and tan to light-orange sandstone and greenish-gray shale. Sandstone is well sorted and fine to medium grained and has massive crossbedding, siliceous cementation, and subrounded grains

Kkl — **Lower Member**—Gray-green to dark-olive-gray shale containing thin lenses of dark-brown to greenish-gray sandstone and silty shale beds. Some carbonaceous shales in basal part

Kf — **Fruitland Formation (Upper Cretaceous)**—Light-gray, brown or olive-brown, fine- to medium- grained sandstone interbedded with dark-gray shale and coal. Black, carbonaceous shales and coal beds are more prevalent in basal part

Kpc — **Pictured Cliffs Sandstone (Upper Cretaceous)**—Light-gray to white, tan or grayish-orange sandstone interbedded with dark-gray shale in lower part. Sandstone is siliceous and well sorted and has rounded grains. Contains locally abundant *Ophiomorpha* burrows

Kl — **Lewis Shale (Upper Cretaceous)**—Thick sequence of dark-gray fissile shale containing thin sandstone beds in upper part and gray, rusty-weathering concretionary limestone at base. Unit weathers easily and is usually covered by surficial deposits

MESAVERDE GROUP (UPPER CRETACEOUS)—Consists of three formations, the Cliff House Sandstone, Menefee Formation, and Point Lookout Sandstone

Kch — **Cliff House Sandstone**—Yellowish-orange to white sandstone and gray silty shale. Poorly exposed in the map area. Thins to the east as it intertongues with the Menefee Formation

Kmf — **Menefee Formation**—Light-gray to brownish-gray or tan sandstone interbedded with coal seams and dark-gray carbonaceous shales. Sandstone is well cemented with silica and at times is massive. Sandstone also contains ripple marks and abundant organic debris. Cliff-forming, resistant sandstone beds form large, prominent dipslopes that generally increase in height on the east side of map area

Kpl — **Point Lookout Sandstone**—Light-gray to yellowish-gray or brown, quartzose sandstone containing numerous *Ophiomorpha* burrows, ripple marks, and organic debris. Fine- to medium-grained sandstone has fine laminations. Becomes an olive-gray siltstone or silty shale in the basal portion and has a gradational contact with the underlying Mancos Shale

Km — **Mancos Shale (Upper Cretaceous)**—Medium- to dark-gray shale and minor thin interbedded sandstone. Shale is fissile and fossiliferous. Formation includes light-gray sequences of sandy shale, calcareous shale and limestone in the basal portion which are called the Juana Lopez Member, Bridge Creek (also known as the Greenhorn) Limestone, and the Graneros Shale

Kdb — **Dakota Sandstone (Upper Cretaceous) and Burro Canyon Formation (Lower Cretaceous), undivided**—Dakota Sandstone is white, light- to medium-gray, and yellowish-brown conglomeratic sandstone, fine- to coarse-grained sandstone, and conglomerate interbedded with siltstone, carbonaceous shale, and thin coal beds. Burro Canyon Formation unconformably underlies the Dakota Sandstone and consists of chert-pebble conglomerate and grayish-green claystone

Jm — **Morrison Formation (Upper Jurassic)**—Includes an upper member, the Brushy Basin Member, consisting of vari-colored claystone and mudstone containing thin beds of fine-grained sandstone and occasional conglomeratic sandstone; and a lower member, the Salt Wash Member, composed mostly of light-gray to white, fine- to medium-grained, lenticular sandstone and greenish-gray mudstone

Jjc — **Junction Creek Sandstone (Middle Jurassic)**—Light-gray to tan, massive, highly crossbedded to structureless, fine-grained sandstone

Jw — **Wanakah Formation (Middle Jurassic)**—Consists of an upper member composed predominantly of white to tan, reddish-orange, and reddish-brown, very fine- to fine-grained sandstone and reddish-brown to greenish-gray mudstone; and a lower member, the Pony Express Limestone Member, consisting of medium- to dark-gray, very thin bedded to laminated, micritic limestone and oolitic limestone

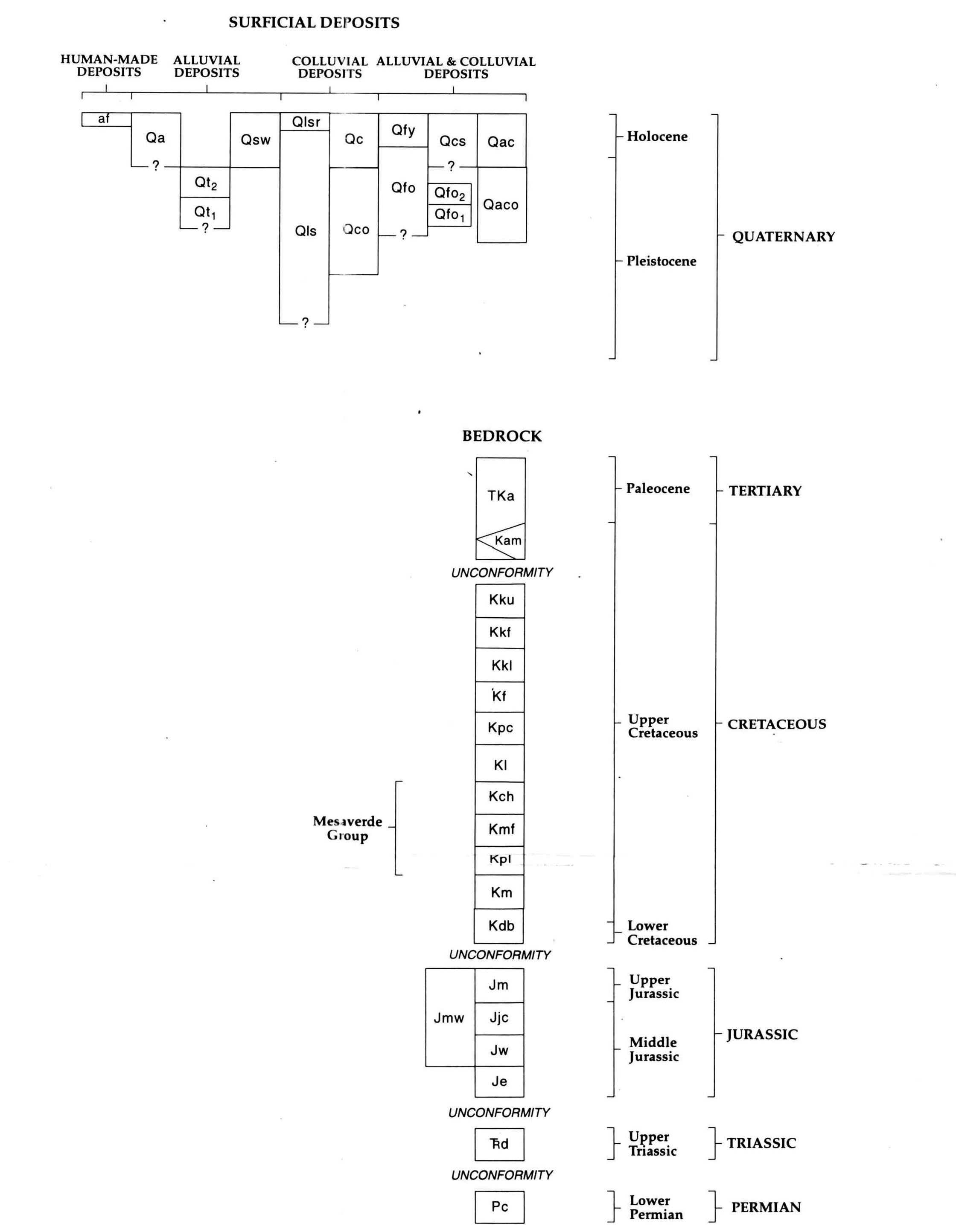
Jmw — **Morrison Formation, Junction Creek Sandstone, and Wanakah Formation, undivided**—Unit is mapped east of Red Creek, where poor exposures limit recognition of the contacts between these formations

Je — **Entrada Sandstone (Middle Jurassic)**—Light-gray to white, locally orange-gray, fine- to medium-grained, highly crossbedded sandstone

Ꞧd — **Dolores Formation (Upper Triassic)**—Dark-reddish-brown to purplish-red shale and siltstone and light-brown, gray, and reddish-brown lenticular sandstone and limestone-pebble conglomerate; contains rare thin limestone beds

Pc — **Cutler Formation (Lower Permian)**—Medium- to dark-reddish-brown, medium-gray, and medium- to dark-brown sandstone, arkosic sandstone, and arkosic conglomerate and reddish-brown to purplish-brown shale and siltstone; contains rare thin limestone beds

CORRELATION OF MAP UNITS



MAP SYMBOLS

Contact—Dashed where approximately located

Monocline—Synclinal bend; showing shorter arrow on steeper beds; dashed where approximately located; dotted where concealed; arrows point in direction of dip

Monocline—Anticlinal bend; showing shorter arrow on steeper beds; dashed where approximately located; dotted where concealed; arrows point in direction of dip

Strike and dip of beds—Angle of dip shown in degrees

Gravel pit

A——A′ **Alignment of cross section**

Gas well producer—name of operator, well, and total depth shown only for wells used on cross section

Drilled and abandoned well with oil or gas shows

Junked and abandoned well

ACKNOWLEDGMENTS

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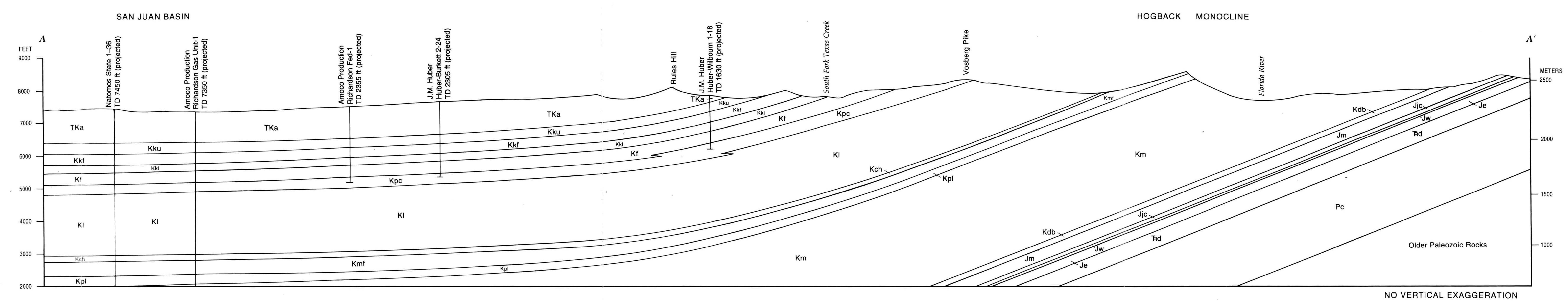

GEOLOGIC MAP OF THE RULES HILL QUADRANGLE, LA PLATA COUNTY, COLORADO

By
Christopher J. Carroll, Robert M. Kirkham, and Andrew Wracher

1997