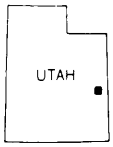
PROVISIONAL GEOLOGIC MAP OF THE SEGO CANYON QUADRANGLE, GRAND COUNTY, UTAH

By Grant C. Willis
Utah Geological and Mineral Survey



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PROVISIONAL GEOLOGIC MAP OF THE SEGO CANYON QUADRANGLE, GRAND COUNTY, UTAH

By Grant C. Willis [1]

INTRODUCTION

The Sego Canyon quadrangle, which contains significant coal deposits and has good potential for substantial hydrocarbon discoveries, is located in Grand County, Utah along the south-facing Book Cliffs. The geology of the Book Cliffs was first documented by Peale (1878) as part of the Hayden Survey. Richardson (1909) prepared a generalized map of the Book Cliffs area differentiating four units: the Dakota Sandstone, Mancos Shale, Mesaverde Formation and Eocene rocks. Fisher (1936) studied the Book Cliffs coal deposits from Sunnyside eastward to the Colorado border. Doelling (1972, p. 233-242) reviewed the coal resources of the area and prepared a generalized geologic map of the Sego Canyon quadrangle at a scale of 1:42240.

Other pertinent studies on stratigraphy or regional geology include Clark (1914), Spieker and Reeside (1925), Erdmann (1934), Spieker (1946, 1949), Young (1955, 1966), Walton (1956), Sanborn et al. (1956), Fisher et al. (1960), Gross (1961), Baars (1966), Balsley (1980), Baars and Stevenson (1981, 1982), Lawton (1983), Frahme and Vaughn (1983), and Fouch et al. (1983).

STRATIGRAPHY

The exposed rocks of the Sego Canyon quadrangle range from the upper part of the Upper Cretaceous Mancos Shale through the lower part of the Tertiary (probably Eocene) Wasatch Formation to total more than 3,300 feet (1005 m) of strata. Rocks of Precambrian to Cretaceous ages, except Ordovician and Silurian units, underlie the quadrangle according to projected drill data from surrounding areas. Drill holes near the quadrangle have penetrated into the Cambrian in the Paradox Basin and through the Precambrian on the Uncompahgre Plateau. Middle and Lower Paleozoic strata are best known from Mobil American Petrofina No. 1-30 Elba Flats well in Sec. 30, T. 21 S., R. 22 E. and from the Pacific Western-Equity No. 1 Thompson well in Sec. 33, T. 21 S., R. 21 E. Precambrian rocks were encountered in the Mobil No. 1 McCormick Federal "C" well, Sec. 11, T. 21 S., R. 22 E., which penetrated 14,000 feet (4267 m) of them. Rocks from the Pennsylvanian Paradox Formation to the Cretaceous Mancos Shale are well exposed in the Salt Valley collapsed anticline to the southwest (Doelling, 1985).

CRETACEOUS SYSTEM

Mancos Shale

The lowest exposed unit in the quadrangle is the upper Mancos Shale, which crops out along the base of the Book Cliffs in the southern part of the quadrangle. Its thickness averages 3,800 feet (1158 m) in this area, but only the uppermost 300 feet (100 m) are exposed within the quadrangle in lower Thompson Canyon. Thinner representations of the unit can be found exposed in Blaze Canyon, Sagers Canyon, and two smaller unnamed canyons between Sego and Sagers Canyons. The Mancos Shale easily erodes to a wide "badlands" topography that is utilized for highway and railway routes throughout much of the Colorado Plateau. It is often veneered with alluvial and colluvial deposits found at the tops of dissected pediments.

That part of the Mancos Shale exposed on the quadrangle coarsens upward, increasing in quantities of sand and silt and in number of sandstone beds. It is predominantly medium to dark gray to brownish-gray, gypsiferous and bentonitic mudstone. It is crumbly, lacks fissility, and weathers to a "popcorn" soil. Gypsum is common both as veinlets and as crystals on parting surfaces. Internal sedimentary structures are rarely seen in the rocks due to their crumbly weathering habit. A stringy, braided texture ranging from 0.4 to 4 inches (1-10 cm) occasionally occurs. The extent of bioturbation is difficult to determine because of the homogeneous nature of the involved materials and the

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slope-forming characteristics, but a few 1-3 mm smooth-wall burrows were found. Several 2-4 inch (5-10 cm) horizons of laterally continuous, clean, orangish to yellowish-brown bentonitic clay are interbedded in the formation. These form a sticky ball and swell considerably when moistened.

Two types of sandstone beds occur near the top of the section. The first type is dense, quartzitic sandstone occurring in laterally persistent 1-10 inch (2.5-25 cm) beds. The other type is more friable, lighter colored, more laterally variable in thickness, and has preserved sedimentary structures. The latter type occurs near the upper contact and resembles Blackhawk units.

The Mancos Shale is overlain by the Blackhawk Formation and the contact is gradational. The contact is represented by the base of the lowest laterally continuous, thick-bedded sandstone and is generally definable to within 6 feet (1.8 m). Occasionally this choice proves unusable and the horizon where sandstone becomes dominant over mudstone is substituted.

The Mancos Shale is of marine origin (Maxfield, 1976; Balsley, 1980). The part exposed in the Sego Canyon quadrangle was deposited in a prodelta environment. The fine sediment, black color, high gypsum content, and rarity of fossils suggest a muddy, hypersaline, stagnant basin in which conditions for living organisms were very harsh.

Blackhawk Formation and Castlegate Sandstone

The Blackhawk Formation and Castlegate Sandstone are resistant sandstone units which, in this area, form the escarpment at the top of the Book Cliffs. In the Price River Canyon area to the west, these two units were deposited in differing environments and are distinctive in appearance. In the Sego Canyon area both are greatly reduced in thickness, have undergone major facies changes, are part of the same depositional sequence, and are difficult to separate. As such, they are discussed together.

The Blackhawk Formation is the principal coal-bearing unit of the Wasatch Plateau to the west. It thins eastward, losing coal beds and sandstone members. At Green River, Utah, it contains three sandstone members and is 714 feet (217 m) thick. It thins to 370 feet (112 m) and two sandstone members in Tuscher Wash (about 15 miles west of the quadrangle). The Blackhawk is only 121 (37 m) feet thick in Thompson Wash in the southwest part of the quadrangle and 51 feet (16 m) thick near Sagers Wash to the southeast. It pinches out completely west of Cottonwood Creek, 10 miles (16 km) farther to the east (Fisher, et al., 1960).

The Castlegate Sandstone is 400 feet (122 m) thick near Price, Utah, and feathers out near the Colorado state line. In the quadrangle area it ranges from 66-93 feet (20-28 m) in thickness.

The contact between the two units is difficult to distinguish. Previous investigators have used the top of the uppermost thin coal horizon in the Blackhawk as the contact. In tracing this coaly horizon across the quadrangle, it becomes readily apparent that it is not a single zone but a series of shingled zones. In Sec. 6, T. 21 S., R. 21 E., near Sagers Canyon and in Sec. 5, T. 20 S., R. 21 E., in Bull Canyon, the Buck Tongue of the Mancos Shale lies directly upon a carbonaceous zone with no intervening sandstone. The Castlegate contains other carbonaceous horizons, some that exceed 1 foot (.3 m) in thickness.

The Blackhawk-Castlegate contact coincides with a prominent coal zone in the west part of the quadrangle, while eastward it is indicated by a break in the cliff face which is traceable with some difficulty to Sagers Wash. East of Sagers Wash it becomes a prominent slope between two sandstone cliffs. The lower cliff is considered the Blackhawk Formation and the slope and upper cliff the Castlegate Sandstone.

Bedding in the two formations is thick to massive with varying amounts of mudstone and thin-bedded sandstone interlayered above the gradational lower contact of the Blackhawk Formation. Grain size is typically very fine. Composition is 97 percent angular to subangular unfrosted quartz grains, 2-3 percent weathered feldspars, and 1-2 percent dark chert and other minerals. Gypsum and limonite occur as secondary minerals. The unit is generally a massive cliff-former, but mudstone zones form ledges and slopes in some areas. One to three coaly or carbonaceous shale zones are found in the sequence, each usually less than 6.6 feet (2 m) thick, and individual coal seams never exceed 12 inches (30 cm) in thickness. Carbonaceous and bituminous plant fragments occur on bedding surfaces throughout the formations. The cement is mainly iron carbonate. Extensive leaching has occurred in the highly porous units, as indicated by their friable nature and the occurrence of bivalve molds with no original material remaining.

Crossbedding is dominant throughout the formations with areas of less common laminar bedding, convolute bedding, and no apparent bedding. Hummocky bedding is very common in the lower part of the sequence. The degree of bioturbation ranges from absent to intense. Burrows are primarily 0.2-0.4 inch (0.5-1 cm) smooth-walled types, but *Ophiomorpha* occur in the upper parts of sandstone beds. Thalassinoid-type burrows are especially abundant in a thin carbonaceous shale zone that caps the coal horizons.

Channeling and scour-cut surfaces are common throughout the formations. Clay pebbles and rip-up clasts often occur near the base of the channels. These occasionally contain shark teeth and bone fragments. Inclined or shingled bedding can be observed in some areas and hardened sandstone and iron concretions are locally common. Fossils found in the Blackhawk-Castlegate Formations include various wood and leaf impressions, a few small bone fragments (none of which were identifiable), a few isolated coquinoid mounds of bivalve shells, and shark teeth. Tracks of an unidentifiable three-toed dinosaur measuring 3-4 inches (7-10 cm) in length were observed near the top of the Castlegate Sandstone.

The contact with the overlying Buck Tongue is sharp with mudstone resting on the underlying Castlegate Sandstone. A prominent dip-slope bench is formed by the erosion of the non-resistant Buck Tongue mudstone. This

bench ranges to 1.8 miles (2.9 km) in width and is generally covered by alluvium, colluvium, eolian deposits, erosional remnants of the Buck Tongue, and active and beheaded pediments.

The lower part of the Blackhawk Formation was deposited along the strandline of a wave-dominated delta complex which includes the transition, lower shoreface, and upper shoreface deposits of Balsley (1980). The coal and carbonaceous shale zones of the upper Blackhawk overlie the strandline sequence and probably represent deposition in swampy or marshy areas directly behind the shoreline deposits. The area was low, stagnant, and rich in plant growth. The Castlegate Sandstone units were deposited next, possibly contemporaneous with the swampy units, as flood-plain meandering-channel sandstone beds, carbonaceous shale and mudstone units, thin to thick interbedded sandstone and mudstone units, and massive sandstone beds. Shingled or inclined bedding, crossbedding, horizontal bedding, and convolute bedding are common in these units. The Castlegate sequence is interpreted as a lower flood plain and distributary system composed of numerous small channels. The front of this system was still a wave-dominated shoreline.

Buck Tongue of Mancos Shale

The name of this unit applies westward from a point near the Utah-Colorado line where the Castlegate Sandstone feathers out, leaving the Buck Tongue strata indistinguishable from the underlying main body of the Mancos. The tongue thins westward from 236 to 121 feet (72-37 m), then dies out near Woodside, Utah. Like the main body of the Mancos Shale, the tongue consists predominantly of mudstone, with varying amounts of silt and occasional interlayered thin sandstone beds. It also has a few 2-4 inch (5-10 cm) interbedded bentonitic layers. The bedding is usually poorly preserved but appears thinly laminated to thin-bedded. Light and dark silt create a discontinuous, stringy appearance on a one-half to four-inch (1-10 cm) scale. Bioturbation is rarely observed, but occasional .04-.12 inch (1-3 mm) diameter burrows were found. A zone of large round orangish-gray mudstone concretionary balls occurs one-half to two-thirds of the way up the section and is traceable across the quadrangle. These concretions exhibit no internal structure or identifiable cores. The only megafossils found in the Buck Tongue are inarticulate brachiopods.

The Buck Tongue was deposited following a rapid transgression of the Mancos Sea over the area, under the same conditions that produced the upper part of the Mancos Shale. The underlying Castlegate Sandstone appears not to have been reworked. The upper part of the tongue slowly coarsens upward and shows shoreline progradation.

Sego Sandstone

The type locality for this unit is in Sego Canyon in the central part of the quadrangle and includes strata from the first thick-bedded sandstone overlying the Buck Tongue upward to the top of the last laterally continuous massive sandstone below the coal-bearing Neslen Formation. It is about 130 feet (39 m) thick on the quadrangle. Along the Book Cliffs the unit consists of 1 to 4 cliff-forming sandstone sequences, each separated by mudstone dominated slope-forming beds (Fisher et al, 1960, p. 15). In the Sego Canyon quadrangle it consists of three coarsening-upward sequences similar to the one at the base of the Blackhawk Formation. The lower part of each sequence is slope-forming mudstone and thin-bedded sandstone. Sandstone content and bedding thickness increase upward. The top of each sequence is a massive sandstone bed which is fine- to very fine-grained, well sorted, and composed almost entirely of quartz grains. Ironstone concretions, wood impressions, macerated bituminous plant material, and occasional clay pebbles occur in many of the units.

The Sego Sandstone contains a large variety of sedimentary structures. Hummocky bedding is common in the lower part of each of the upward-coarsening sequences. Crossbedding, convolute bedding, ripple laminations, and horizontal laminations occur higher up in the sequence. Oscillation and directional ripple marks occur in most units and individual bedding planes appear to be discontinuous. The degree of bioturbation varies from absent to intense. The trace fossils, both varied and abundant, include horizontal, vertical, and branching *Ophiomorpha*, gastropod trails, smooth tubes and trails, and *Thallasinoides*. Discontinuous mounds of bivalve coquinas are locally common near the top of the upper units. Shark teeth were found in such a coquina in Blaze Canyon.

Lateral variations are evident in the Sego Sandstone. The slope-forming portions are more prominent in the eastern part of the quadrangle and the middle cliff-former loses prominence. The middle slope-former becomes the Anchor Mine Tongue of the Mancos Shale of Erdmann (1934) in Colorado. The sandstones increase westerly; the upper two sequences are hard to separate on the western side of the quadrangle.

The three sequences (cycles) were mapped as separate members of the formation and have similar depositional histories. Each cycle began with a rapid transgression of the sea, resulting in the deposition of the slope-forming mudstones. During the regressive phase of the sea, an interbedded sandstone-mudstone zone was deposited in a transition zone. It was followed by lower shoreface, upper shoreface, and possible foreshore facies (mostly sandstone units). These cycles are usually complex, with some of the phases repeated and some completely missing.

The upper contact of the Sego Sandstone is placed at the top of the highest laterally continuous, massive sandstone and below any coal units. This contact is sharp and easily seen at the top of the Sego cliff and the base of the slope-forming Neslen Formation. Occasional staining by red oxides (coal bloom) from overlying clinkered coal zones in the Neslen Formation may be seen in the Sego Sandstone.

Neslen Formation

This unit consists of interbedded shale, sandstone, and coal that overlie the Sego Sandstone. It is the most important coal-bearing formation in the eastern Book Cliffs area or Sego coal field and is approximately 140 feet (43 m) thick in the quadrangle. It forms a slope interrupted by several channel-shaped sandstone lenses and one laterally continuous sandstone unit which is near the middle of the formation. This continuous bed has been named the Thompson Sandstone bed by Fisher (1936, p. 18). The Neslen Formation is mapped as two units (upper and lower), using the base of the Thompson Sandstone bed as the contact. The coals of the Neslen Formation are in several coal zones of which only three have commercial importance. The Palisade and Ballard coal zones are in the lower member and the Chesterfield coal zone is in the upper.

The formation is composed of slope-forming mudstone, shale, carbonaceous shale, sandstone and coal and interspersed ledge-forming sandstone lenses. Sandstones beds interbedded with the slope-formers occur in varying numbers and are thin to medium bedded. The channel-fill sandstone lenses are usually thick-bedded and are often cross-bedded, ripple-laminated, convolute bedded, and often show inclined bedding. The upper member is similar to the lower except for having a higher proportion of channel-fill sandstone lenses, especially in its upper part.

The Neslen Formation is a regressive unit, continuing from the Sego Sandstone shoreline phase, across the backshore, coastal plain, and lower delta plain, and directly to the fluvial plains of the Farrer Formation, which overlies the Neslen.

Coals of the Neslen Formation in the Sego Canyon area are upper delta-plain to lower fluvial plain coals. Lack of thick sandstone units, especially large channel-shaped beds, suggests that this area was remote from any active distributary system. The small channels were deposited by minor rivers that meandered through the swamps. The extensive sheet-like Thompson Sandstone bed is interpreted as a splay deposit originating as a flood through a levee break along a major distributary channel, probably located to the north, as suggested by current direction markers. In one drill-hole the Ballard coal zone was apparently scoured out by the Thompson Sandstone (Albee, 1979).

Farrer Formation

The Farrer Formation consists of alternating resistant sandstone ledges and slope-forming units. The ledges range to nearly 100 feet (30 m) in thickness but are usually traceable for less than a mile. The formation ranges from 230 feet (70 m) in the northeast part of the quadrangle to 676 feet (206 m) in Sego Canyon. The thinning correlates with the projected crest of the Cisco Dome and is probably due to penecontemporaneous arching which diminished the amount of sedimentation or allowed some erosion over the area.

The ledge- and cliff-forming sandstone units are typically composed of fine- to medium-grained, subangular to subrounded quartz sand with minor chert and weathered feldspar grains. Light or dark brown to orangish-brown, they display prevalent desert varnish and iron oxide stains. The bedding is usually massive, and trough and planar crossbeds, ripple laminations, convolute bedding, climbing ripples, and laminar bedding are all exhibited. Scour bases and channeling are common, especially in the lower parts of sandstone cliffs. Scour zones have abundant wood and plant impressions, poorly preserved flute casts and sole markings, and mud rip-up clasts. Current indicators suggest that flow is primarily to the south and east. The sandstone is mostly cemented by calcium and iron carbonates. The ledges gradually increase in size upward in the formation.

Slope-forming units in the Farrer Formation are usually covered by talus, soil, and vegetation, except near the base on some of the sandstone ledges and over the shoulders of a few ridges. The slope-forming units comprise about two-thirds of the formation and are primarily siltstone, mudstone, and shale. A few 3-6 feet (.9-1.8 m) sandstone beds are found interbedded with the slope-forming beds and contain sedimentary structures similar to those in the cliff-forming sandstones. The less resistant units are light to medium gray, or shades of brown, orange, or yellow. Bedding is usually absent or indistinct but is thinly laminated to thin-bedded where identifiable.

Carbonaceous and bituminous plant fragments are common, especially in the lower part of the formation, and an occasional carbonaceous shale or thin coal layer also occurs. Although evidence of rooting is common, the only fossils found in the Farrer Formation are a few fresh-water gastropods and plant and wood impressions. Calcite and gypsum occur occasionally as secondary minerals.

The Tuscher Formation overlies the Farrer. The contact was considered an unconformity by Fisher (1936, p. 20), based on variations in thickness. However I found no evidence for an unconformity in the Sego Canyon quadrangle. Fouch et al. (1983) and Lawton (1983) also suggest a continuous depositional sequence.

The Farrer Formation represents deposition in a low-relief floodplain and includes meandering and braided river systems. The thick sandstone ledges are deposits of meandering rivers which invariably thin and pinch out to rest on basal scours. These sandstone lenses can usually be traced laterally into reddish back levee or "bog iron" sandstone beds that were deposited along the edges of back swamps. Traced farther, the back levee deposits grade into lacustrine or bog deposits. Deposition in back swamps and floodplain lakes is represented by slope forming units whose low organic content suggests oxidizing conditions and sufficient energy to remove or destroy organic material. The quiet water deposits are invariably heavily rooted, often show some burrowing, and are much finer grained than the channel-fill deposits.

Tuscher Formation

The Tuscher Formation, which is the uppermost unit in the Mesaverde Group (Fisher, et al., 1960), is a slope and

ledge-forming unit which overlies the Farrer Formation. The two formations are distinctive near their type areas but are similar in the Sego Canyon area. As such they are difficult to separate and the mapped contact is mostly inferred. Observed distinctions in the Sego Canyon area include: (1) the sandstones of the Farrer have a slightly more brown to brownish-gray appearance while those of the Tuscher Formation have an orangish or brownish-orange tint; (2) sandstone beds of the Tuscher tend to be thicker and weather more rounded; (3) the lower Tuscher is more resistant than the middle and forms a pronounced slope above a steep ledgy slope, creating a recognizable pattern; and (4) the upper Tuscher sandstone beds are lighter colored and more friable than any in the Farrer Formation.

The Tuscher Formation, as mapped, is 490 feet (149 m) thick near Sego Canyon and 500 feet (152 m) thick near Left Hand Bull Canyon. The ancient rivers that deposited the Farrer and Tuscher Formations became more stable as they flowed eastward, changing from braided to meandering. There is also a gradual change from meandering to braided through the sequence. The upper contact of the Tuscher Formation is an unconformity; Fouch and Cashion (1979) call the overlying beds the "Conglomerate Beds of Dark Canyon."

TERTIARY SYSTEM

Conglomerate Beds of Dark Canyon

A 33-98 foot (10-30 m) thick conglomeratic sandstone unit, probably of late Paleocene age, unconformably overlies the Campanian Tuscher Formation. Fouch et al. (1982) assigned the conglomerate beds to a late Paleocene age on the basis of palynology. Clasts range from 0.25 to 1.5 inches (0.6-3.8 cm) in diameter, are rounded to subrounded, rest in a sandy matrix, and are clast supported. They are mostly multicolored quartzite and chert. A few chert pebbles contain fossils probably Mississippian in age. Pebbles average 50 percent light colored, 30 percent black, 10 percent pink, and 8-9 percent other colors. Some horizons contain 1-2 percent mudstone pebbles. Crossbedding, pebble imbrications, and crossbedded lenses of sandstone and conglomerate are common. Current directions vary, but most commonly have a west or south component. Channeling is evident but individual channels can rarely be identified. Bedding is massive, and the conglomerate generally forms a cliff, except in the northeast part of the quadrangle where it forms a protective cap on many ridges. The conglomerate has a distinctive olive-green to olive-gray ledge when observed from a distance.

The conglomerate generally overlies a clean, very well-sorted friable quartz sandstone in the Tuscher Formation. In a few places the upper 3-16 feet (0.9-4.8 m) of the underlying sandstone has been reworked and has some incorporated pebbles. Interbedded sandstone, conglomerate, and slope zones overlie the basal conglomerate ledge with the coarsest constituents near the base. The conglomerate unit becomes finer upwards, both in the size of pebbles and in the increasing percentage of sandstone. Near the top the unit is 95 percent sandstone with a few stringers of 0.5 inch (1.3 cm) pebbles and grit. The conglomerate occasionally can be divided into two layers separated by pale yellowish-gray friable sandstone 16-32 feet (4.8-9.7 m) thick.

The Conglomerate Beds of Dark Canyon represent a high-energy fluvial system in which gravel was transported from the rejuvenated Uncompahgre Uplift to the east. The beds have a braided-stream pattern, with numerous interfingering stringers of conglomerate and sandstone. No well-defined meander-type shingling or lensing beds with finer interchannel deposits were seen. There are many channels or scour surfaces, but most lack well-defined slip bank deposits.

The overlying Wasatch was deposited unconformably on the conglomeratic beds and follows a 5 million year erosional hiatus (Fouch et al., 1982). There is, however, no evidence for this unconformity at the contact, which appears conformable in the Sego Canyon area. The Conglomerate Beds of Dark Canyon were included with the overlying Wasatch Formation for mapping.

Wasatch Formation

Only the lower third of the total Wasatch Formation is exposed in the Sego Canyon quadrangle. The exposed part is subdivided into three units: lower and upper interbedded variegated mudstone, siltstone, and sandstone cliff- and slope-forming units, and the middle wide slope-former that supports a distinctive vegetation. The lower unit is 1,000+ feet (300+ m) thick in the central part of the quadrangle, the middle slope-former is about 121 feet (37 m) thick and the upper unit is 125+ feet (38+ m) thick. The Wasatch Formation, as a whole, fines upward in the section.

The lower member, unit 1, is composed of interbedded, variegated mudstone, siltstone, and sandstone slope-forming units, with thick to massively bedded ledge- or cliff-forming sandstone units. Slope-forming units are typically dark red to brownish-red, often with a pale yellow or orange mottling. Some horizons are purple, green, gray, or yellowish orange. Murany (1964) mentions dark gray or black beds, but such rocks were not seen on the quadrangle. Bedding is poorly preserved or destroyed while root impressions are very common and some burrows are occasionally seen. These slope-forming units weather into crumbly or chippy fragments and are poorly exposed, except where protected by overlying sandstone ledges. Silty mudstone is prevalent, while silt-free argillaceous material is rare.

The cliff-forming sandstone units are typically pale yellowish-gray to dark brownish-gray and are fine to medium grained. They are composed primarily of clear or frosted quartz grains with minor dark chert grains and kaolinized feldspars which appear as white powdery fragments. Numerous incised scour or channel surfaces occur within the sandstones. They typically have a clay pebble zone 0.5 inch to 3 feet (1.3-91 cm) thick near the base. The clay pebbles are pale gray or yellowish-gray mudstone and are subangular to subrounded. Bedding within the sandstones is trough to wedge crossbedded, or convolute. Current di-

rections vary greatly but are dominant north to northwest. Except for some plant impressions, no fossils were found in the unit.

Unit 1 was deposited in a flood plain similar to that in which the Farrer and Tuscher Formations accumulated, heavily vegetated with extensive lakes and marshes or swamps. Channel sandstones are more massive than in the Farrer and Tuscher, indicating larger, better established rivers. Both braided and meander-type fluvial deposits are seen. Silt and mud probably accumulated as overbank and backswamp deposits.

The distinctive reddish coloration of the Wasatch Formation is intriguing since the formation directly overlies beds of apparently similar lithology and depositional conditions that are not red. It is likely that the Wasatch red-beds are due to a climate change, a change in source rock, or both.

The middle Wasatch Member, unit 2, is a distinctive, but mostly covered slope-former, probably consisting mostly of mudstone similar to the mudstones of unit 1. This member was deposited when the area was not crossed by a major river and was lacustrine, marsh or swamp-dominated. The upper Wasatch Member, unit 3, is similar to unit 1 and is preserved only in the highest parts of the quadrangle where it caps a few ridges.

QUATERNARY SYSTEM

Alluvium and colluvium

Most of the washes in the quadrangle are choked with sediment, including sand, silt, clay, and fallen blocks. The stream in the lower part of Thompson Canyon has eroded laterally enough to create small alluvial areas currently used for dry-land pasture. Colluvium occurs mainly on the bench formed on the Castlegate Sandstone and overlying units. A small amount of colluvium has also collected at the base of the cliff-forming Castlegate Sandstone.

Eolian deposits

Loess and eolian sand blanket much of the bench overlying the Castlegate Sandstone and are especially thick in the graben-produced depression in the southwest part of the quadrangle. Sand up to 32 feet (9.7 m) thick forms a few small dunes which are now partially anchored by vegetation. Elsewhere the sand and loess deposits are less than 10 feet (3 m) thick and are mostly stabilized by vegetation.

Landslide deposits

These are rare in the quadrangle even though the terrain is steep. Resistant sandstone ledges and vegetation tend to anchor the slopes. A landslide, about 5/8 mile (1 km) in length, is located in a side canyon of Nash Canyon in SW ¼ Sec. 7, T. 20 S., R. 21 E. with smaller ones in Thompson and Sego Canyons. A few too small to map occur in some of the other canyons but are primarily colluvial features and do not involve the underlying bedrock.

Pediments, Beheaded Pediments, Alluvial Fans

Pediments and beheaded pediments, veneered by detritus caps that protect the less resistant Mancos Shale and Buck Tongue, occur locally at the base of the Blackhawk Formation and more extensively on the large bench. The most prominent pediments are found around the mouth of Thompson and Sego Canyons. The only significant active alluvial fans are at the mouth of an unnamed wash about 1.25 miles (2 km) east of Sego Canyon, and between Thompson and Blaze Canyons, on the large bench.

STRUCTURE

The Sego Canyon quadrangle includes parts of or is near several regional structural features that influence the local structure. The buried Uncompahgre fault projects beneath the quadrangle along a northwest-southeast line. The Paradox basin is southwest of the fault while the Uncompahgre uplift is on the northeast side. Prominent cuestas in the quadrangle are formed by north-dipping beds that rim the southern margin of the Uinta basin. Beds in the quadrangle generally have a regional dip of 1-5 degrees northward overprinted with a series of gentle northwest-trending folds that parallel the major salt anticlines of the Paradox basin. Minor faulting is associated with some of the anticlinal folds.

The extreme western flank of the elongate Cisco anticline occurs on the east edge of the quadrangle where dips are westward and northwestward to 9 degrees. These quickly flatten to 1-3 degrees. A very gentle synclinal trough roughly follows Sagers Wash and crosses the quadrangle diagonally. An anticlinal nose, the Thompson anticline, crosses the southwest part of the quadrangle. These folds are shallow and broad features that only deflect strike measurements a few degrees and are not evident on casual observation.

Faults are limited to the the southwest part of the quadrangle, except for a small fault in Left Hand Bull Canyon. The Bull Canyon fault trends east-west across the Cisco anticlinal axis and dies near the quadrangle boundary. Faults in the southwest part of the quadrangle are subparallel, high-angle, normal faults that trend N 20° W. Offsets range to nearly 90 feet (27 m). The maximum displacement is on the western boundary fault of a graben 2,000 feet (610 m) wide that is mappable through Secs. 5, 6, and 8, T. 21 S., R. 20 E., and in Secs. 31 and 32, T. 20 S., R. 20 E. The eastern boundary fault of this graben is only offset 30 feet (9 m). Four smaller grabens and several smaller faults occur to the east while similar minor faults continue into the South Floy Canyon quadrangle to the west.

The mechanism responsible for the faulting and folding is controversial. Folds south and southwest of the quadrangle are related to the salt movement in the Paradox basin (Walton, 1956, Shoemaker et al., 1958), but those to the northeast overlie Precambrian rock (Frahme and Vaughn, 1983). Thick salt deposits occur west of the quadrangle while wells on the Cisco anticline drill into Precambrian rocks without passing through Paradox Basin salt-bearing

rocks. Overall outcrop patterns suggest that the folding may have occurred between the Late Cretaceous and early Eocene. This seems likely as other structures in the region have been attributed to Laramide disturbances.

Walton (1956) suggests that the Thompson anticline is on trend with the Onion Creek-Sinbad Valley salt structures and had a similar origin. The pattern of keystone collapse faulting in the Thompson anticline is characteristic of salt structures. Mobil-American Petrofina Elba Flats unit 1-30 penetrated 178 feet (54 m) of salt a short distance east of the quadrangle, showing that salt does extend beneath the Thompson anticline. Walton also suggests that the Cisco anticline is directly related to faulting along the steep western flank of the Uncompahgre uplift and is a drape fold over that structure. He considers the Sagers Wash syncline to coincide with the eastern edge of the Paradox, Hermosa, and Cutler Formations, indicating either compaction folding or salt movement. Additional subsurface data made available since 1956 (Frahme and Vaughn, 1983) indicates that the Uncompahgre fault coincides with the Sagers Wash syncline. The syncline is probably a drape fold. The origin of the Cisco dome is unknown but it may be due to draping over faults in the underlying Precambrian crystalline rocks.

Evidence suggests that fault movements in the Sego Canyon quadrangle occurred well after deposition of units and may coincide with uplift of the Colorado Plateau. The movement appears brittle, with jagged, broken sandstone blocks and small splintery branching faults extending from the major ones. Drainage patterns also support late movement on the faults. Late movement and the graben arrangement of the faults supports the idea that salt dissolution may be responsible for their presence.

ECONOMIC GEOLOGY

Coal and hydrocarbons are the principal potential economic mineral resources in the quadrangle with sand and gravel also present. Doelling (1972) estimates that the quadrangle contains over 205 million tons of coal in seams greater than 4 feet (1.2 m) in thickness that have potential for underground mining. Mining of coal began around 1900 and was nearly continuous until 1953, was renewed in the early 1970s, and continues intermittently to the present. Hydrocarbons have been and are being produced from structures adjacent to the quadrangle and similar source structures may also underlie the Sego Canyon quadrangle.

COAL

Coal seams in the quadrangle are a part of the Sego coal field, which extends from Green River eastward to the Colorado state-line. It is differentiated from the Book Cliffs coal field to the west inasmuch as those seams occur in the Blackhawk Formation and those of the Sego field occur in the Neslen Formation (Doelling, 1972, p. 25, 37, 191). Four coal zones have been identified in the Neslen Formation of the Sego coal field: the Palisade, Ballard, Chesterfield, and Carbonera. The first three are of importance within the quadrangle.

Practically the entire historical production of coal for the Sego coal field has come from the central part of the Sego Canyon quadrangle. Coal has been removed from all three of the important zones, but dominant production is from the Chesterfield zone. To date (1985) about 2.7 million tons of coal have been produced. Most was used by the railroad as stoker coal until the early 1950s; recently only token efforts have been made to mine the coal. The coal beds in the area are relatively thin and are plagued with poor roof rock, splits, and high ash content.

The coal is of high volatile bituminous B rank as determined from proximate analyses by the Parr formula (table 1). Available analyses indicate subbituminous B to high volatile bituminous B coals, but many samples were taken at outcrop and would not represent freshly mined coal. It is basically a high ash, low sulfur, high volatile, bituminous coal.

The Palisade coal zone is the lowest and occurs 33-66 feet (10-20 m) above the base of the Neslen Formation. The principal coal bed averages 3-4 feet (0.9-1.2 m) thick and reaches a maximum measured thickness of 6.8 feet (2 m) near Thompson Canyon. It thins eastward so that in parts of Sagers Canyon and Nash Canyon the zone contains no true coal beds. It also thins to the west. Near Blaze Canyon the coal bed measured 0.9 feet (0.3 m). The Palisade Isopach map shows the thickness of the coal based upon a wave-dominated shoreline depositional model. Doelling (1972, p. 242) estimates total in-place coal resources in the Palisade zone in the Sego Canyon quadrangle at nearly 50 million short tons. Of that amount 12 million tons were calculated for seams greater than 4 feet (1.2 m) in thickness. The principal coal bed is generally overlain by thinly laminated carbonaceous shale, mudstone, and thin interbedded sandstone and mudstone, but locally it is overlain by thick to massive channel sandstone lenses.

The Ballard coal zone is located at the top of the lower member of the Neslen Formation, just below the Thompson bed. It is often exposed in a cliff face supported by the resistant Thompson Sandstone. The principal coal bed averages 4 feet (1.2 m) in thickness and has a maximum measured thickness of 7.5 (2.3 m) feet in Nash Canyon. It thins to a feather edge between Nash and Sagers Canyons but locally exceeds 4 feet (1.2 m) in Sego Canyon and Sagers Canyon. Doelling (1972) estimates the total in-place resource for the Ballard seams to be about 172 million short tons, with over 86 million tons in beds 4 feet (1.2 m) or more in thickness. The proximate analyses indicate the Ballard to be similar to the Palisade, but the average shows a slightly higher moisture and ash content, with slightly less volatile matter, fixed carbon and sulfur content. The roof rock for the Ballard coal zone is capped by the thick Thompson Sandstone bed usually with only 4 inches (10 cm) of carbonaceous shale between the sandstone and coal. The Ballard seam is often split as are all others in the Sego coal field.

The Chesterfield coal zone is located 15-30 feet (4.5-9m) above the Thompson Sandstone bed. It was the last of the three zones to be mined but eventually proved to be the

most economical, mainly because it has a greater split-free thickness (Doelling, 1972). An isopach and overburden map of the Chesterfield coal zone is given at the end of the text. It is usually poorly exposed and is overlain by a thick sequence of carbonaceous shale, mudstone, thin coal beds and thin-bedded sandstone. It is occasionally exposed in cliff-faces, otherwise it is marked by a grassy slope or a zone of coal bloom. The principal coal bed is 4-5 feet (1.2-1.5 m) thick across the quadrangle and is up to 8 feet (2.4 m) thick in Thompson Canyon with split-free intervals to 6 feet (1.8 m) in thickness. The best development occurs in the area between Thompson and Sego Canyons, near Sagers Wash, and near Nash Canyon. Thicknesses of less than a foot occur in the Bull Canyon area. Doelling (1972, p. 242) estimates an in-place resource of nearly 169 million short tons within the Chesterfield zone in the Sego Canyon quadrangle. Of this about 107 million short tons are in seams greater than 4 feet (1.2 m) in thickness. The roof rocks are similar to those overlying the Palisade zone.

Other coal beds worthy of note occur below the Palisade zone, between the Palisade and Ballard zones, and above the Chesterfield zone. These are typically lenticular and small in areal extent. The seam between the Palisade and Ballard zones is the most extensive, reaching thicknesses up to 4.3 feet (1.3 m). Doelling (1972, p. 242) estimates that 3.9 million short tons, averging 3.7 feet (1.1 m), occur in Secs. 35 and 36, T. 20 S., R. 20 E., near Sagers Wash. Some of the coal fingers or splits, besides the principal coal bed, may locally reach minable thicknesses.

HYDROCARBONS

The Book Cliffs area, containing the Sego Canyon quadrangle, has at least 28 oil and gas fields with 445 producing wells (Young, 1983, p. 4). Production has been realized from structural, salt intrusion, structural-stratigraphic, and stratigraphic traps, but to date no significant production has been realized in wells within the quadrangle. The nose of the Cisco anticline or dome, which produces just east of the quadrangle, extends into the northeast corner and has been drilled in both Nash and Left Hand Bull Canyons. Shows were reported but no significant production was achieved. The Cisco anticline or dome is a shallow field with reservoir beds (thin sandstone beds) in the Mancos Shale and Dakota Formation. Production has also been realized in the Cedar Mountain, Morrison and Entrada Formations (Young, 1983, p. 5). These units all underlie the quadrangle and may yet be found to contain commercial quantities of hydrocarbons. Faulting in the Thompson anticline is probably due to Paradox Formation salt movement. As such, the anticline shows considerble promise for shallow or deep fault-bounded or diapir-created traps. Additional potential exists for stratigraphic or stratigraphic-structural traps in several of the subsurface formations. Deeper traps related to the Precambrian faults should also be considered (Baars and Stevenson, 1982). shallow reservoirs and the Pennsylvanian Paradox Formation for deeper traps.

SAND AND GRAVEL

Eolian sand deposits and sandstone beds generally contain too much clay, silt, and iron to be utilized for quartz. There are no significant alluvial gravel deposits in the quadrangle, but small amounts occur in the bottom of Thompson and Sego Washes. The Conglomerate Beds of Dark Canyon, located at the base of the Wasatch Formation, could conceivably be crushed for gravel.

WATER RESOURCES

The Green River, 20 miles (32 km) to the west, and the Colorado River, 25 miles (40 km) to the southeast, are the largest and closest rivers to the quadrangle. There are two small perennial spring-fed streams in the quadrangle. One, in Thompson Canyon, is the water supply for the small town of Thompson, located just south of the quadrangle; the other in Nash Canyon is utilized for agricultural and ranching operations at the mouth of the canyon. Sego Canyon, Sagers Wash, and Left Hand Bull Canyon have small seeps or springs that flow intermittently. Most of the springs surface at impermeable carbonaceous shale layers near the top of the Neslen Formation. There are also a few small seeps in the higher canyons in the Wasatch and Tuscher Formations. Precipitation in the quadrangle ranges from 8.5 inches (22 cm) at the lowest elevations to about 16 inches (40 cm) in the high country (Waddell et al., 1981).

There is limited potential for subsurface water in the shallower formations because most subsurface water flows down the north-dipping slope of the Uinta Basin. Deeper subsurface potential is limited by the presence of the thick Mancos Shale, which consists of 3,800 feet (1158 m) of impervious, highly alkaline shales. Hydrocarbon exploration has located water in porous sandstone beds beneath the Mancos, but these sources are too deep to be economically pumped. Attempts have been made to locate water along the fault traces in the quadrangle, but they appear to be mostly sealed. There are no alluvial aquifers in the area.

GEOLOGIC HAZARDS

Debris flows, mud flows, flash floods, rock falls, landslides, expanding clays, swelling soils, and collapse of abandoned coal mines are the primary geologic hazards in the Sego Canyon quadrangle. However the quadrangle is located in a sparsely inhabited part of the state, reducing the risk to people. The quadrangle is in a low risk earthquake zone.

Debris flows, mud flows, flash floods

The Sego Canyon quadrangle and adjacent area consists primarily of steep-walled, narrow canyons, and high ridges. It is located in a desert climate where sudden thunderstorms accompanied by intense rainfall are common and has only sparse vegetation and considerable unconsolidated surface material. These factors combine to make the poten-

tial for flash floods, debris flows and mudflows high. Threat is primarily to the small community of Thompson located south of the quadrangle along the Thompson Creek drainage, to dirt roads in the bottom of Thompson and Sego Canyons, and to a major railroad and interstate highway which occur just south of the quadrangle and which cross several drainages.

Rock falls, landslides

The numerous steep slopes and high cliffs in the quadrangle show evidence of frequent rock falls in the recent geologic past and will undoubtedly continue to produce rock falls in the future. The absense of permanent manmade structures and sparse population make risk low. Rock falls should be considered however, especially during periods of heavy rainfall and during the spring thaw.

A few landslides have occurred in historic times in rarely visited parts of the quadrangle, the largest in SW ¼, sect. 7, T. 20 S., R. 21 E. Again risk is low due to sparse population.

Expanding clays, swelling soils

Expanding clays and swelling soils are present in much of the quadrangle, especially near outcrops of the Buck Tongue and Mancos Shale. These could become a problem if permanent structures or roads are built in the area.

Coal mine collapse

Underground coal mining in the Thompson and Sego Canyon area was begun in the early 1900s. Many of the support structures in the old mines are now in poor condition and old workings occasionally collapse.

Earthquakes

The Sego Canyon quadrangle is located in an area which has experienced no earthquakes greater than 2.0 on the Richter scale since records were first kept (Arabasz, et al., 1979). The closest major fault with Quaternary movement is the Moab fault located about 30 miles (50 km) to the southwest. It has not experienced any historic movement (Anderson and Miller, 1979). The quadrangle is in low risk zone U-1 (on a scale of 1 to 4 with 1 being lowest) (Seismic Safety Advisory Council of Utah, 1979) and in Uniform Building Code zone UBC-1.

REFERENCES

Albee, H. F., 1979, Geophysical and lithologic logs of four holes drilled in the Book Cliffs coal field, Sego Canyon quadrangle, Grand County, Utah: U.S. Geological Survey, Open-file Report 79-738, 20 p.

Anderson, L. W., and Miller, D. G., compilers, 1979, Quaternary fault map of Utah: Fugro Inc., scale 1:500,000.

Arabasz, W. J., Smith, R. B., and Richins W. D., editors, 1979, Earthquake studies in Utah 1850-1978: University of Utah Seismograph Stations, Department of Geology and Geophysics, University of Utah, special publication, 552 p.

Baars, D. L., 1966, Pre-Pennsylvanian paleotectonics—key to basin evolution and petroleum occurrences in Paradox Basin, Utah and Colorado: American Association of Petroleum Geologists Bulletin, v. 50, p. 2082-2lll.

Baars, D. L., and Stevenson, G. M., 1981, Tectonic evolution of the Paradox Basin, Utah and Colorado *in* Wiegand, D. L., ed., Geology of the Paradox Basin: Rocky Mountain Association of Geologists, p. 23-32.

Baars, D. L., and Stevenson, G. M., 1982, Subtle stratigraphic traps in Paleozoic rocks of Paradox Basin: American Association of Petroleum Geologists Memoir 32, p. 131-158.

Balsley, J. K., 1980, Cretaceous wave-dominated delta systems—Book Cliffs, east central Utah - A field guide: Amoco Production Company, Denver, Colo., 163 p. unpublished report.

Bass, N. W., Smith, H. L., and Horn, G. H., 1970, Standards for the Classification of Public Coal Lands: U.S. Geological Survey Circular 633, 10 p.

Clark, F. R., 1914, Coal near Thompson, Grand County, Utah: U.S. Geological Survey Bulletin 541, p. 453-477.

Doelling, H. H., 1972, Sego Coal field *in* Doelling, H. H., and Graham, R. L., Eastern and Northern Utah Coal Fields: Utah Geological and Mineral Survey Monograph 2, p. 230.

Doelling, H. H., 1985, Geologic map of Arches National Park and vicinity, Grand County, Utah: Utah Geological and Mineral Survey Map 74, 1:50,000.

Doelling, H. H., Smith, A. D., Davis, F. D., and Hayhurst, D.L., 1979, Observations on the Sunnyside Coal Zone *in* Coal Studies: Utah Geological and Mineral Survey Special Studies 49, p. 44-68.

Erdmann, C. E., 1934, The Book Cliffs coal field in Garfield and Mesa Counties, Colorado: U.S. Geological Survey Bulletin 851, p. 23-32.

Fisher, D. J., 1936, The Book Cliffs coal field in Emery and Grand Counties, Utah: U.S. Geological Survey Bulletin 852, 104 p.

Fisher, D. J., Erdmann, C. E., and Reeside, J. B., Jr., 1960, Cretaceous and Tertiary formations of the Book Cliffs, Carbon, Emery, and Grand Counties, Utah, and Garfield and Mesa Counties, Colorado: U.S. Geological Survey Professional Paper 332, 80 p.

Fouch, T. D., and Cashion, W. B., 1979, Preliminary chart showing distribution of rock types, lithologic groups and depositional environments for some lower Tertiary, upper and lower Cretaceous and Upper and Middle Jurassic rocks in the subsurface between Altamont oil field and San Arroyo gas field, north-central to southeastern Uinta Basin, Utah: U.S. Geological Survey Open-file Report 79-365, 2 sheets.

Fouch, T. D., Lawton, T. F., Nichols, D. J., Cashion, W. B., and Cobban, W. A., 1982, Chart showing preliminary

correlation of major Albian to middle Eocene rock units from the Sanpete Valley in central Utah to the Book Cliffs in eastern Utah *in* Nielson, D. L., ed., The Overthrust Belt of Utah: Utah Geological Association Guidebook, p. 267-272.

Fouch, T. D., Lawton, T. F., Nichols, D. J., Cashion, W. B., and Cobban, W. A., and others, 1983, Patterns and timing of synorogenic sedimentation in Upper Cretaceous rocks of central and northeast Utah *in* Reynolds, M. W., and Dolly, E. D., eds., Mesozoic paleogeography of west-central United States: Rocky Mountain Section, Society of Economic Paleontologists and Mineralogists, p. 305-336.

Frahme, C. W., and Vaughn, E. B., 1983, Paleozoic geology and seismic stratigraphy of the northern Uncompahgre front, Grand County, Utah *in* Lowell, J. D., ed., Rocky Mountain Foreland Basins and Uplifts: Rocky Mountain Association of Geologists, p. 201-211.

Gross, L. T., 1961, Stratigraphic analysis of the Mesaverde Group, Uinta Basin, Utah: University of Utah M. S. thesis, 115 p. and appendix.

Lawton, T. F., 1983, Late Cretaceous fluvial systems and the age of foreland uplifts in central Utah *in* Lowell, J. D., ed., Rocky Mountain Foreland Basins and Uplifts, Rocky Mountain Association of Geologists, p. 181-199.

Maxfield, E. B., 1976, Foraminifera from the Mancos Shale of east-central Utah: Brigham Young University Geology Studies, v. 23, pt. 3, p. 67-162.

Murany, E. E., 1964, Wasatch Formation of the Uinta Basin *in* Sabatka, E. F., ed., Guidebook to the Geology and Mineral Resources of the Uinta Basin - Utah's Hydrocarbon Storehouse: Intermountain Association of Petroleum Geologists Guidebook, 13th Annual Field Conference, p. 145-155.

Peale, A. C., 1878, Geological report on the Grand River district: U.S. Geological and Geographic Survey, 10th Annual Report, p. 170-185.

Richardson, G. B., 1909, Reconnaissance of Book Cliffs coal field between Grand River, Colorado and Sunnyside, Utah: U.S. Geological Survey Bulletin 371, 54 p.

Sanborn, A. R., Hill, J. D., and Arnold, D. E., 1956, Correlative chart, east-central Utah *in* Peterson, J. A., ed., Geology and Economic Deposits of East-central Utah: Intermountain Association Petroleum Geologists Guidebook, 7th Annual Field Conf., p. 12.

Seismic Safety Advisory Council of Utah, 1979, Seismic Zones for construction in Utah: Seismic Safety Advisory Council of Utah.

Shoemaker, E. M., Case, J. E., and Elston, D. P., 1958, Salt anticlines of the Paradox Basin *in* Sanborn, A. F., ed., Geology of the Paradox Basin: Intermountain Association Petroleum Geologists Guidebook, 9th Annual Field Conf., p. 39-55.

Spieker, E. M., 1946, Late Mesozoic and Early Cenozoic history of central Utah: U.S. Geological Survey Professional Paper 205-D, p. 117-161.

Spieker, E. M., 1949, Sedimentary facies and associated catastrophism in the Upper Cretaceous of central and eastern Utah: Geological Society of America Memoir 39, p. 55-81.

Spieker, E. M., and Reeside, J. B., Jr., 1925, Cretaceous and Tertiary Formations of the Wasatch Plateau, Utah: Geological Society of America Bulletin, v. 36, p. 429-454.

Waddell, K. K., Kay Contratto, P., Sumsion, C. T., and Butler, J. R., 1981, Hydrologic reconnaissance of the Wasatch Plateau-Book Cliffs coal fields area, Utah: U.S. Geological Survey Water Supply Paper 2068, 45 p.

Walton, P. T., 1956, Structure of the north Salt Valley-Cisco area, Grand County, Utah *in* Peterson, J. A., ed., Geology and Economic Deposits of East-central Utah: Intermountain Association of Petroleum Geologists Guidebook, 7th Annual Field Conference, p. 186-189.

Wood, G. H. Jr., Kehn, T. M., Carter, M.D., Culbertson, W. C., 1983, Coal Resource Classification System of the U.S. Geological Survey: U.S. Geological Survey Circular 891, 65 p.

Young, R. G., 1955, Sedimentary facies and intertonguing in the Upper Cretaceous of the Book Cliffs - Utah, Colorado: Geological Society of American Bulletin, v. 66, p. 177-202.

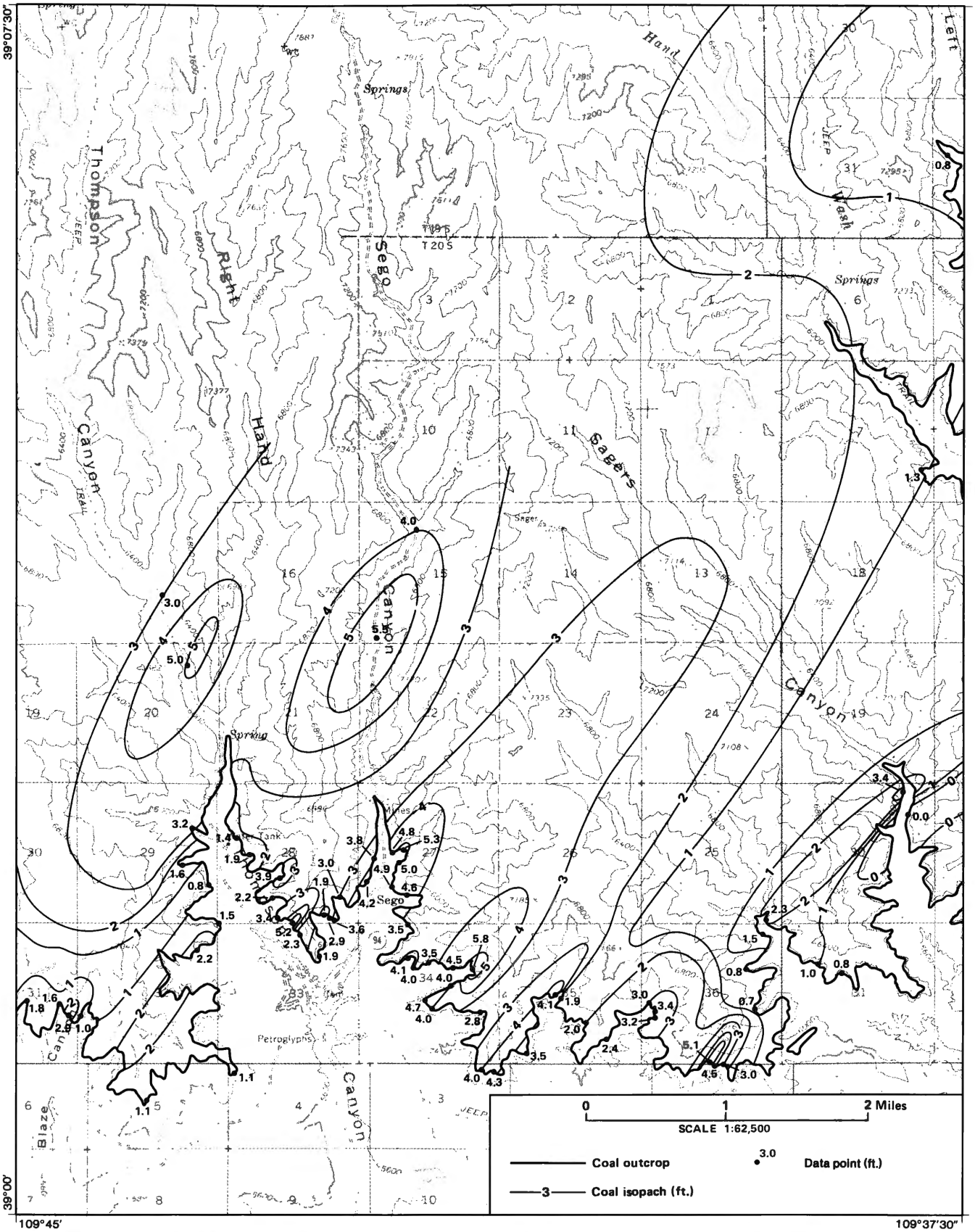
Young, R. G., 1966, Stratigraphy of coal-bearing rocks of Book Cliffs, Utah Colorado *in* Central Utah Coal: Utah Geological and Mineral Survey Bulletin 80, p. 7-22.

Young, R. G., 1983, Petroleum in northeastern Grand County, Utah *in* Averitt, W. R., ed., Northern Paradox Basin-Uncompahgre Uplift: Grand Junction Geological Society Guidebook, p. 1-8.

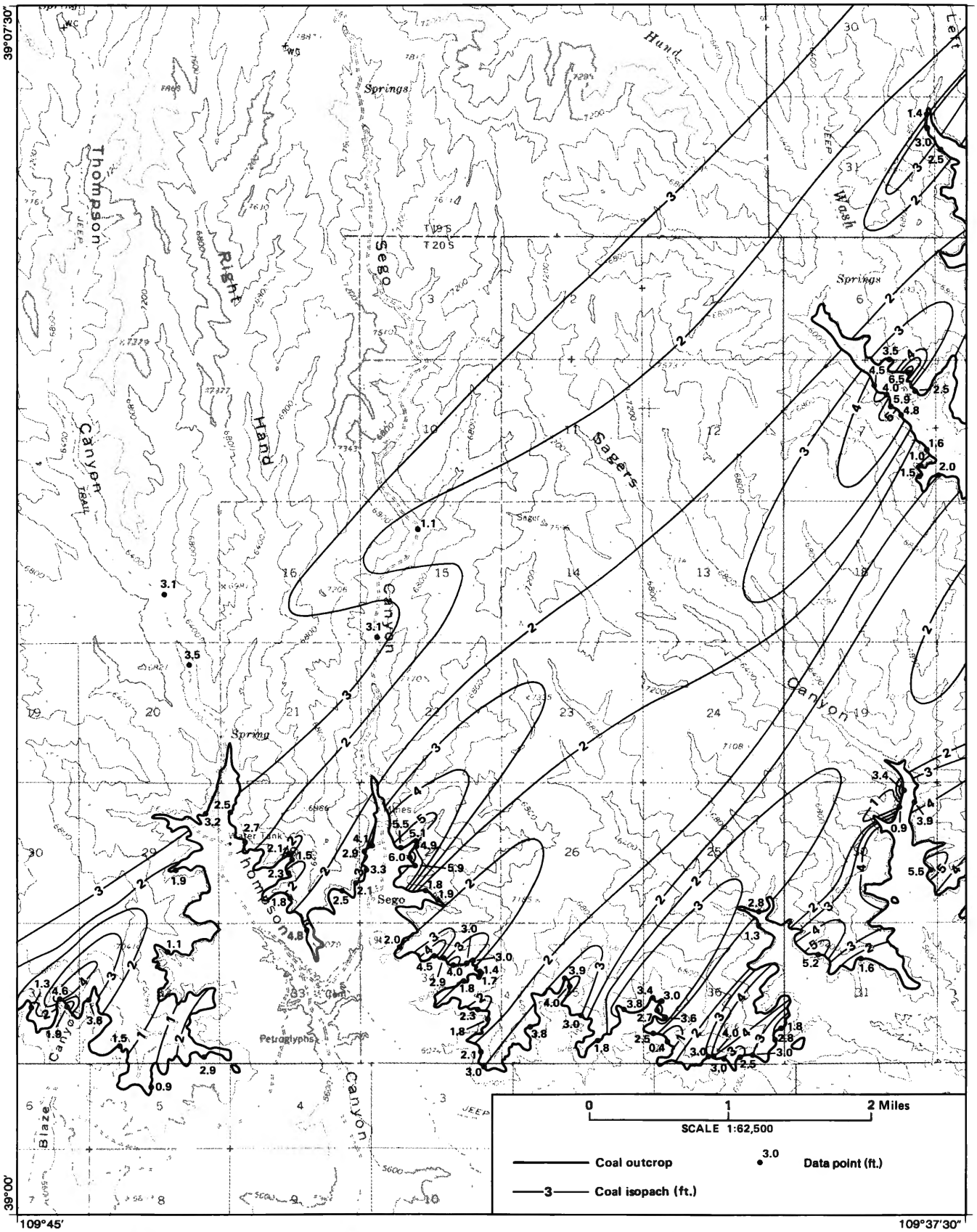
TABLE 1

Location	Seam	M	VM	FC	Ash	S	Moist Mm-Free BTU/lb
NW15, 20S, 20E	C	4.2	36.9	47.6	11.3	0.6	13712
NW15, 20S, 20E	C	4.4	38.4	49.4	7.8	0.5	13891
NW15, 20S, 20E	B?	4.3	39.3	47.7	8.7	0.7	14012
SE17, 20S, 20E	B(u)	6.3	39.2	51.8	2.7	0.6	13461
SE17, 20S, 20E	B(l)	5.3	38.4	44.8	22.5	0.6	13528
SE17, 20S, 20E	P	5.1	36.4	47.1	11.2	0.6	13719
NW27, 20S, 20E	C	8.5	35.6	49.9	12.0	0.7	13992
NW27, 20S, 20E	C	2.5	37.2	48.7	11.0	0.6	13931
NW27, 20S, 20E	C	2.3	37.6	48.4	11.0	0.7	13888
NW27, 20S, 20E	C	2.8	37.9	49.2	9.5	0.6	13880
NW27, 20S, 20E	B	4.1	32.6	43.8	19.5	0.6	13764
NW27, 20S, 20E	B	1.9	35.0	46.8	15.7	0.6	13685
NW27, 20S, 20E	B	5.3	37.8	46.3	10.6	0.67	13513
NW27, 20S, 20E	P	5.1	38.3	45.9	10.7	0.62	13608
NW17, 20S, 20E	P	2.0	38.2	49.4	9.7	0.7	13928

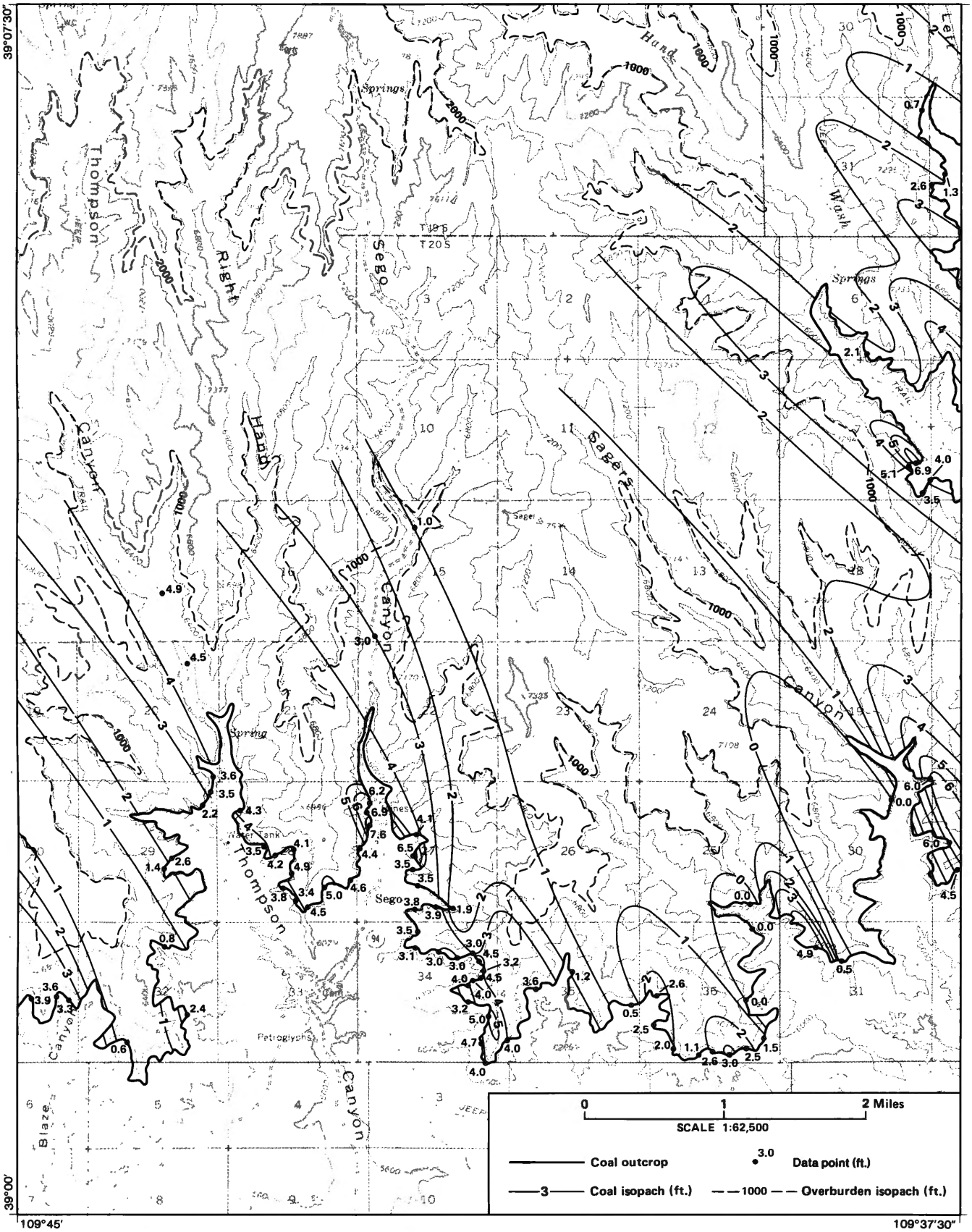
Proximate analyses of selected coal samples from the Sego Canyon quadrangle. All BTU measurements are calculated on the basis of moist, mineral/matter-free samples (Wood et al., 1983). The first six samples are from Doelling et al. (1979). The remaining samples are calculated from analysis "B", Doelling (1972, p. 230). Seams are: C - Chesterfield, B - Ballard, u - upper, l - lower, P - Palisade.



Isopach and overburden map of Palisade Coal Zone corrected for resource calculation, using method of Bass et al., 1970.



Isopach of Ballard Coal Zone corrected for resource calculation, using method of Bass et al., 1970.



Isopach of Chesterfield Coal Zone corrected for resource calculation, using method of Bass et al., 1970.

UTAH GEOLOGICAL AND MINERAL SURVEY

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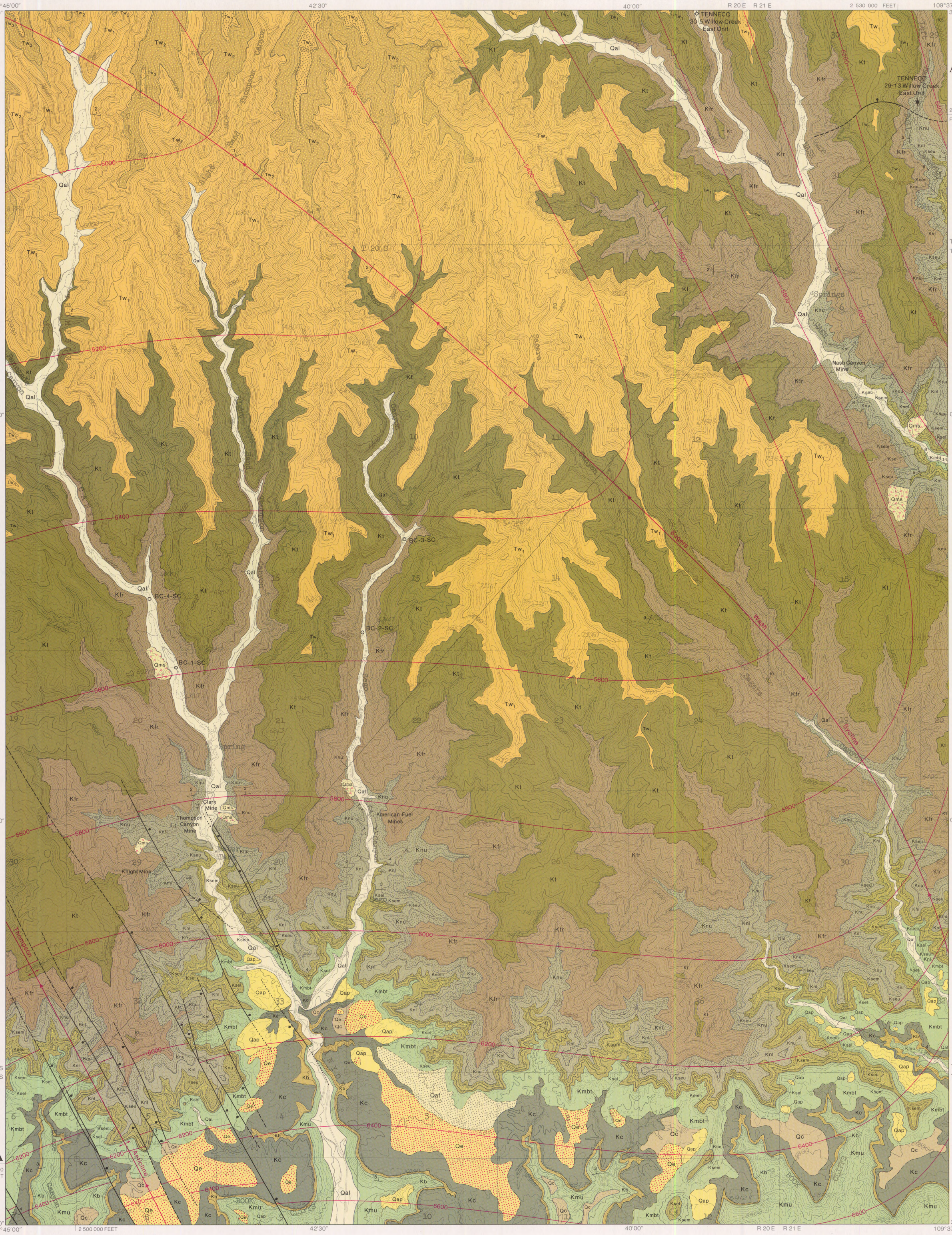
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Plate 1
Utah Geological and Mineral Survey Map 89
Provisional Geologic Map of the Sego Canyon Quadrangle

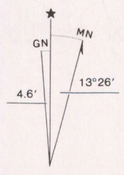


Base from U.S. Geological Survey: Florence Canyon 4 SW, 1963

SCALE 1:24 000

1 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

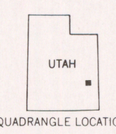


1986 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

PROVISIONAL GEOLOGIC MAP OF THE SEGO CANYON QUADRANGLE, GRAND COUNTY, UTAH

by
Grant C. Willis
Utah Geological and Mineral Survey

1986

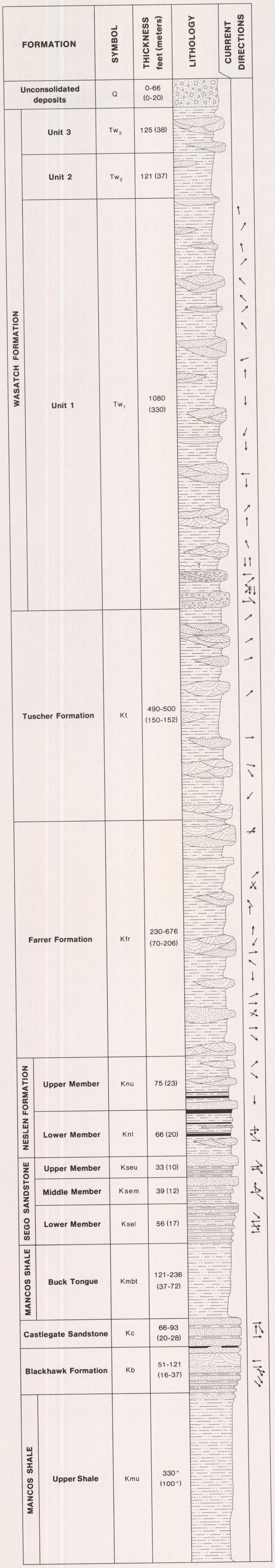


QUADRANGLE LOCATION

Field mapping by author in 1982
Dr. J. Keith Rigby, Thesis Advisor/Chairman
J. Parker, Cartographer

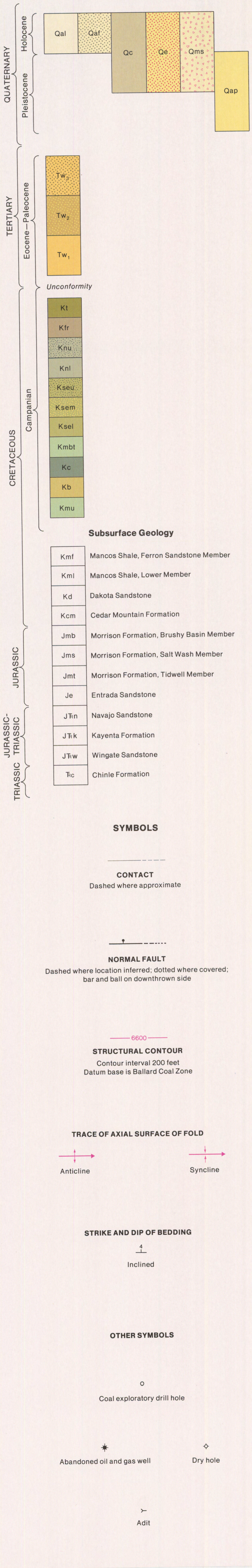
STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES
UTAH GEOLOGICAL AND MINERAL SURVEY

Utah Geological and Mineral Survey Map 89
Provisional Geologic Map of the Sego Canyon Quadrangle



CORRELATION OF MAP UNITS

Surface Geology



Subsurface Geology

Kmf	Mancos Shale, Ferron Sandstone Member
Kml	Mancos Shale, Lower Member
Kd	Dakota Sandstone
Kcm	Cedar Mountain Formation
Jmb	Morrison Formation, Brushy Basin Member
Jms	Morrison Formation, Salt Wash Member
Jmt	Morrison Formation, Tidwell Member
Je	Entrada Sandstone
JTrn	Navajo Sandstone
JTrk	Kayenta Formation
JTrw	Wingate Sandstone
Trc	Chinle Formation

SYMBOLS

CONTACT
Dashed where approximate

NORMAL FAULT
Dashed where location inferred; dotted where covered; bar and ball on downthrown side

6600

STRUCTURAL CONTOUR
Contour interval 200 feet
Datum base is Ballard Coal Zone

TRACE OF AXIAL SURFACE OF FOLD

Anticline — Syncline

STRIKE AND DIP OF BEDDING

4

Inclined

OTHER SYMBOLS

Coal exploratory drill hole

Abandoned oil and gas well — Dry hole

Adit

DESCRIPTION OF MAP UNITS

(Surface Geology)

Qal Alluvial deposits—*Poorly to moderately sorted intermittent stream deposits in small canyons and washes.*

Qaf Alluvial fan deposits—*Poorly to moderately sorted sand, mud, silt, and angular sandstone blocks. Typically have a fan-shaped morphology.*

Qc Colluvial deposits—*Angular, poorly sorted slope deposits. Some form a resistant cover and have been isolated by subsequent erosion.*

Qe Eolian deposits—*Well sorted sand and silt deposited by wind action.*

Qms Landslide deposits—*Poorly sorted debris deposited by mass movement on slopes. Primarily involving surficial material. Generally small and localized, and usually exhibiting hummocky topography.*

Qap Pediment and beheaded pediment deposits—*Poorly to moderately sorted thin cover on bevelled surface of nonresistant bedrock units. Some deposits have been stranded by subsequent stream erosion.*

Tw_3 Upper unit of the Wasatch Formation—*Interbedded yellow and brown sandstone and dark brownish-red siltstone and mudstone. Forms cliffs and steep slopes. Sandstone beds are planar to lenticular fluvial channel deposits that are generally thicker and lighter colored than the Farrer and Tuscher Formations.*

Tw_2 Middle unit of the Wasatch Formation—*Poorly exposed, slope-forming, brownish-red mudstone and siltstone and thin-bedded sandstone.*

Tw_1 Lower unit of the Wasatch Formation—*Interbedded yellow sandstone and dark brownish-red siltstone and mudstone. Forms steep slopes and cliffs. Sandstone is planar to lenticular. Basal contact is marked by an undifferentiated conglomerate and conglomeratic sandstone unit 0-100 feet (0-30 m) thick called the "conglomerate of Dark Canyon."*

Kt Tuscher Formation—*Interbedded brown, cliff-forming sandstone and yellowish-gray mudstone and siltstone. Dominated by lenticular channel sandstone. Forms steep slopes and cliffs. Often difficult to distinguish from the Farrer Formation.*

Kfr Farrer Formation—*Interbedded light- to dark-brown, cliff-forming, thin- to thick-bedded sandstone, and pale gray to brown, slope-forming mudstone and siltstone. Also has carbonaceous shale in the lower part. Sandstone beds are mostly lenticular channel deposits.*

Knu Upper member of the Neslen Formation—*Interbedded mudstone, carbonaceous shale, coal, planar thin-bedded sandstone and lenticular channel sandstone. Lenticular channel sandstone beds increase upward. Contains a few minor carbonaceous shale and coal zones and one important zone, the Chesterfield, which occurs in the lower part. The Thompson Sandstone bed occurs at the base of the unit.*

Knl Lower member of the Neslen Formation—*Interbedded mudstone, carbonaceous shale, coal, and sandstone. Forms a ledgy slope zone. Contains numerous minor carbonaceous shale and coal zones and two major coal zones: the Palisade in the lower part and the Ballard at the top.*

Kseu Upper Member of the Sego Sandstone—*Medium to dark gray, slope-forming, thin-bedded mudstone in the lower part which coarsens upward to yellowish-orange, thin- to massive-bedded, cliff-forming sandstone in the upper part. Cross bedding is common. Intensely bioturbated in some horizons; channel sandstone beds near the top. The upper of three repeated coarsening upward sequences in which the sandstone beds (near-shore deposits) increase westward while the mudstone beds (marine deposits) increase eastward.*

Ksem Middle Member of the Sego Sandstone—*Coarsening upward sequence similar to the upper member but with fewer channel sandstone beds near the top and with more mudstone in the lower part.*

Ksel Lower Member of the Sego Sandstone—*Coarsening upward sequence similar to the middle member but with more mudstone in the lower parts.*

Kmbt Buck Tongue of the Mancos Shale—*Medium to dark gray, slope-forming, bentonitic, gypsiferous marine mudstone. Contains zone with mudstone concretions up to 3 feet (1 m) in diameter. Forms a broad bench and sparsely vegetated "badland" slopes.*

Kc Castlegate Sandstone—*Pale yellowish-orange, thin to massive bedded sandstone with minor mudstone, carbonaceous shale and coal. Often with cross, convolute or channeled bedding. Forms a prominent massive cliff. Locally bioturbated. Contains channel sandstone deposits near top on west side of area. Becomes more marine eastward.*

Kb Blackhawk Formation—*Pale yellowish-orange, cliff-forming, thin to massive-bedded sandstone and minor dark gray mudstone, carbonaceous shale and coal. Often with convolute bedding or cross bedding. Locally intensely bioturbated. Often difficult to distinguish from the overlying Castlegate Sandstone. Forms lower part of "Book Cliffs" cuesta.*

Kmu Upper member of the Mancos Shale—*Medium to dark gray, slope-forming, gypsiferous, bentonitic mudstone. Coarsens upward to thin interbedded sandstone and mudstone. Forms sparsely vegetated "badlands" topography.*

