Utah Geological Survey
a division of
Utah Department of Natural Resources

GEOLOGIC MAP OF THE MANTI 30' x 60' QUADRANGLE, CARBON, EMERY, JUAB, SANPETE, AND SEVIER COUNTIES, UTAH

by
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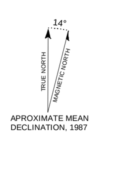
Utah Geological Survey 2006
Map 212DM
digitized from U.S. Geological Survey
Miscellaneous Investigations Series Map I-1631 (1987)
Plate 1 of 2

MANTI, UTAH

30X60 MINUTE SERIES (TOPOGRAPHIC)

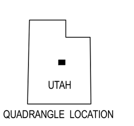
Base from U.S. Geological Survey, 1981
Projection: UTM Zone 12
Units: Meters
Datum: NAD 1927
Spheroid: Clarke 1866

This map is a cooperative project of the UGS and the U.S. Geological Survey (USGS) funded through the STATEMAP component of the National Cooperative Geologic Mapping Program, Agreement No. 02HQAG0055.



SCALE 1:100 000
CONTOUR INTERVAL 50 METERS
SUPPLEMENTARY CONTOUR INTERVAL 25 METERS

5 0 5 10 15 Kilometers
5 0 5 Miles

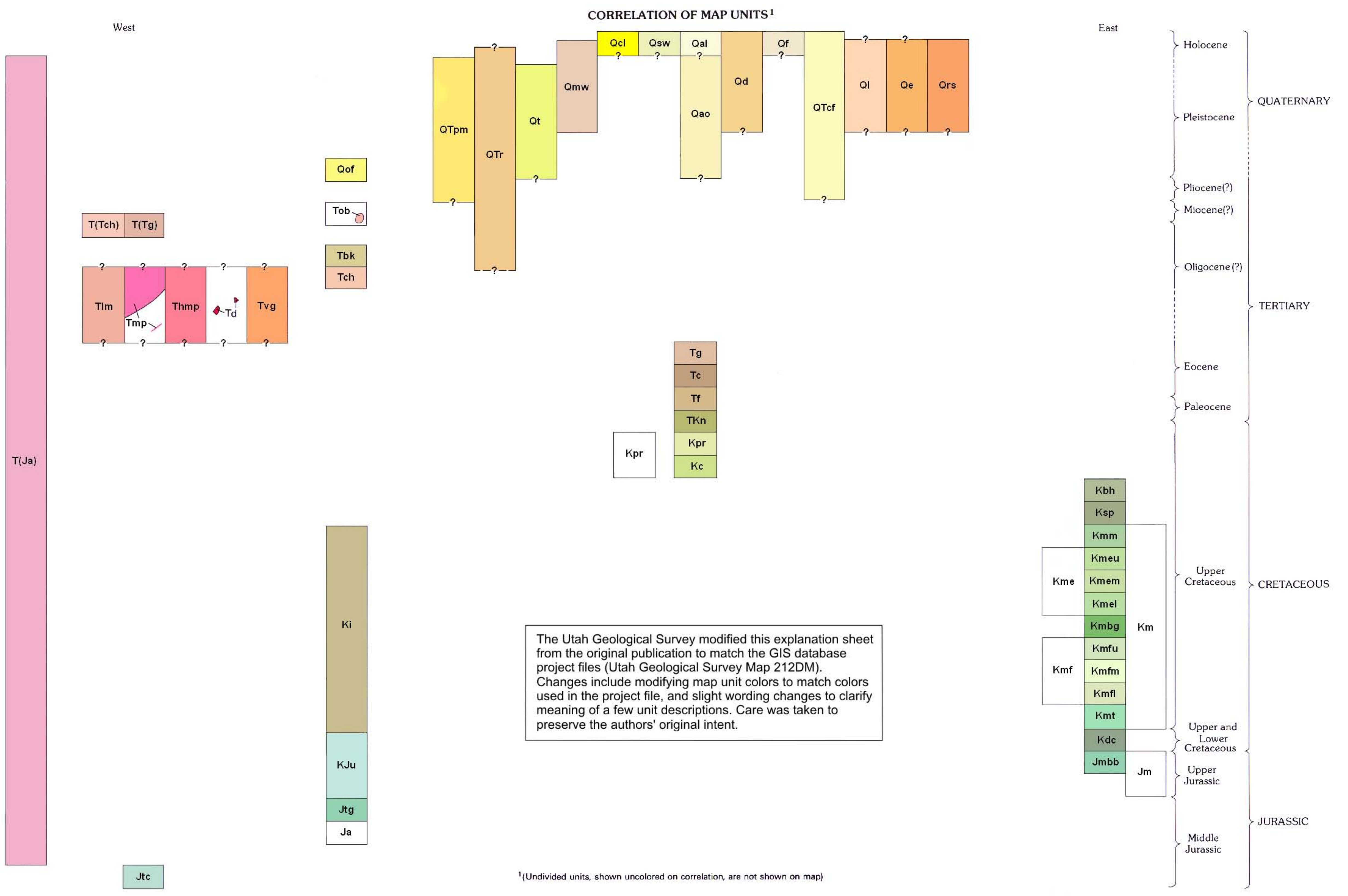


QUADRANGLE LOCATION

Caution to data user: The original published geologic map from which these GIS data files were prepared contains problems that affect the accuracy of this data. These include: 1- the topographic base map is not properly registered, as a result the geology does not properly fit the base topography; 2- color separates of the original topographic base map are not properly registered with each other; and 3- some graticules for 7.5' quadrangle tickmarks are not in the correct locations. While preparing this GIS database, the UGS made considerable effort to better fit the digital geologic map to the base map (using digital 7.5' topographic maps as guides), but the results were not entirely satisfactory and the eastern part of the digital 1:100,000-scale geologic and topographic maps do not match. Distortion varies across the map, but may locally exceed 100 meters on the ground. Therefore, we recommend that the digital geology be used only at a scale of 1:100,000, and with the digital topographic map included on this CD. These inaccuracies will be accentuated if this data is "draped" over other 1:100,000-scale topographic base maps or "blown up" to scales larger than 1:100,000.

Project Manager: Jon K. King
GIS Data Preparation: Basia Matyjasik

CORRELATION OF MAP UNITS[1]



The Utah Geological Survey modified this explanation sheet from the original publication to match the GIS database project files (Utah Geological Survey Map 212DM). Changes include modifying map unit colors to match colors used in the project file, and slight wording changes to clarify meaning of a few unit descriptions. Care was taken to preserve the authors' original intent.

[1](Undivided units, shown uncolored on correlation, are not shown on map)

CONTACT—Approximately located or inferred

GRADATIONAL

INTRUSIVE CONTACT—Approximately located or inferred. Boxes on intrusive unit

FAULT—Dashed where approximately located; dotted where concealed. Bar and ball on downthrown side

YOUNG FAULT SCARP—Reflects recent movement on active fault. Hachures represent modern fault scarp

DF DETACHMENT FAULT—Marks the boundary of a block of sedimentary rock that became detached and slid into its present position as a result of some earth disturbance, possibly one or more earthquakes

COAL MINE
Active
Inactive

SALT MINE
Sa Active
Sa Inactive

Zn ZINC MINE—Inactive

U PROSPECT—Marked by anomalously high radioactivity

DESCRIPTION OF MAP UNITS

QUATERNARY DEPOSITS

Qal ALLUVIUM (HOLOCENE)—Dark brown to gray, thin to thick bedded, locally massive, crossbedded in places. Unconsolidated. Consists of clay, silt, sand, granules, pebbles, and sparse cobbles. Fluvial sediments. Forms broad, even surfaces of low relief. Fresh-water lacustrine deposits. Thickness ranges widely; commonly less than 15 m (50 ft) thick

Qao OLDER ALLUVIUM (HOLOCENE AND PLEISTOCENE)—Much like alluvium in color, bedding and composition. Fluvial sediments. Forms small, discrete, rounded to irregular masses generally 15–45 m (50–150 ft) above adjacent valley floors. Thickness varies greatly, ranging from about 3–60 m (10–200 ft)

Qcl COLLUVIUM (HOLOCENE)—Brown to dark-brown heterogeneous mixture of fragments of many sizes and shapes which locally mantles lower valley walls and accumulates at the base of some steep cliffs. Unconsolidated to semiconsolidated debris. Thickness ranges from a few centimeters (one inch) to as much as 15 m (50 ft)

Qsw SLOPE WASH (HOLOCENE)—Light to dark gray; thin to thick bedded, laminated locally, faintly crossbedded. Unconsolidated to weakly cemented locally. Consists of clay, silt, sand, granules, and some pebbles. Fluvial sediments. Forms broad, gently sloping sheets. Thickness ranges from a thin film to as much as 8 m (25 ft)

Qd DUNE SAND (HOLOCENE AND PLEISTOCENE)—Light-brown to brown unconsolidated, well-sorted frosted grains of fine quartzose sand. Eolian sediments. Locally forms small active dune fields. Thickness ranges from a thin veneer to about 8 m (25 ft)

Qf ALLUVIAL FAN DEPOSITS (HOLOCENE)—Light brown to brown, locally gray; unconsolidated to semiconsolidated; moderately well sorted silt, sand, granules, pebbles, or cobbles at the mouths of streams. Fluvial sediments. Commonly lobate. Thickness uncertain, probably as much as 15 m (50 ft) locally

Ql LANDSLIDE DEPOSITS (HOLOCENE AND PLEISTOCENE)—Brown to dark-brown and gray heterogeneous mixture of fragments of diverse sizes and shapes. Debris. Irregular to lobate masses of bedrock that have slid downslope to form chaotic accumulation of rubble. Manti landslide, in Manti Canyon, is one of the larger landslides that has moved recently and threatened man-made features (Fleming and others, 1977). Hummocky topography; locally some concentric ridges. Thickness varies widely; may be as much as 45 m (150 ft) thick locally

Qe EARTHFLOW DEPOSITS (HOLOCENE AND PLEISTOCENE)—Brown to dark brown; sand, granules, pebbles, cobbles, and boulders in an unsorted matrix of clay and silt. Unconsolidated to semiconsolidated debris. Masses of detritus that have flowed downslope to form elongate, narrow, lobate land forms. Thickness varies widely; probably as much as 45 m (150 ft) thick locally

Qrs ROCK SLIDE DEPOSITS (HOLOCENE AND PLEISTOCENE)—Light-gray to brown unconsolidated and unsorted chaotic accumulation of angular boulders on steep slopes. Debris. Hummocky, locally lobate. Ranges in thickness from a few meters (about 10 ft) to as much as 45 m (150 ft)

Qmw MASS-WASTING DEPOSITS (HOLOCENE AND PLEISTOCENE)—Brown to dark-brown heterogeneous masses of mixed country rock, of diverse sizes and shapes that have slid downslope repeatedly as both small slumps and large debris flows. Debris. Locally includes small earthflows and rock falls. Thickness varies widely; probably does not exceed 61 m (200 ft)

Qt TILL (PLEISTOCENE)—Brown to dark-brown masses of unsorted, unconsolidated to semiconsolidated morainal rubble. Fragments range in size from clay to boulders. Glacial deposits. Characterized by lobate outlines and knob-and-kettle topography. Chiefly in Joes Valley although other deposits, here mapped as mass-wasting deposits, may have been deposits of till that have been saturated with water, mobilized, and then flowed downslope. Thickness as much as 61 m (200 ft)

Qof OLDER ALLUVIAL FAN DEPOSITS (PLEISTOCENE)—Gray to dark gray; thin to thick bedded; prominently crossbedded; unconsolidated. Consists of silt, sand, granules, pebbles, and small cobbles. Includes small thin interbedded lenses of crossbedded coarse sand. Fluvial sediments. As much as 60 m (200 ft) thick. Includes the "volcanic gravels" of Gilliland (1951, p. 53)

QUATERNARY AND TERTIARY DEPOSITS

QTr RUBBLE (HOLOCENE TO OLIGOCENE?)—Fragments, mostly of mudstone, light brown to grayish orange; unconsolidated to semiconsolidated; unbedded; well compacted debris. Composed chiefly of deposits of Quaternary age, but may include some material of Tertiary age. Thickness uncertain; may be as much as 91 m (300 ft) thick

QTcf COALESCED ALLUVIAL FAN DEPOSITS (HOLOCENE TO PLIOCENE?)—Brown to dark brown or gray; thin to thick bedded, commonly crossbedded; unconsolidated to semiconsolidated. Consist of silt, sand, granules, pebbles, cobbles, and sparse boulders. Fluvial sediments. Formed as a result of the overlap and interfingering of adjacent alluvial fans; form broad, low, sloping aprons at foot of adjacent highlands. Includes Sevier River Formation of late Pliocene and Miocene age (Young and Carpenter, 1965, p. 20). Thickness uncertain; possibly as much as 30 m (100 ft) locally

QTpm PEDIMENT MANTLE (HOLOCENE TO PLIOCENE?)—Light brown to brown, gray, or locally reddish brown; massive to crudely bedded; unconsolidated to well cemented. Consists of a poorly bedded mixture of silt, sand, granules, pebbles, cobbles, and boulders derived from adjacent uplands. Fluvial sediments. Surfaces are even and slope gently away from the uplands, but are somewhat deformed locally in the Sanpete and Sevier River valleys. Ranges in thickness from about 3 m (10 ft) to more than 45 m (150 ft). Includes units mapped by Spieker (1949, p. 38) as the Axtell Formation, which he suggests is "probably of late Tertiary" age

TERTIARY DETACHMENT BLOCKS

T(Tch) DISPLACED BLOCK OF THE OLIGOCENE(?) CRAZY HOLLOW FORMATION (TERTIARY)—Unbroken block of the Crazy Hollow Formation (Tch) carried "piggyback" to its present position, during either Oligocene(?) or Miocene time, on a block of the Green River Formation that slid valleyward

T(Tg) DISPLACED BLOCK OF THE EOCENE GREEN RIVER FORMATION (TERTIARY)—Unbroken block of the Green River Formation (Tgr) that slid into its present position, during either Oligocene(?) or Miocene time, along a westward-sloping glide plane. This block has rotated and tilted somewhat in its downward movement and now overlies the country rocks discordantly

TERTIARY SEDIMENTARY ROCKS

Tbk BALD KNOLL FORMATION OF GILLILAND (1951) (OLIGOCENE?)—Light-gray to tan mudstone, claystone, and interbedded siltstone, sandstone, and a few thin dense, finely crystalline limestone beds. Locally, limestone beds are soft. Fresh-water lacustrine deposits. Probably ranges in thickness from about 244 m (800 ft) to 305 m (1,000 ft)

Tch CRAZY HOLLOW FORMATION OF SPIEKER (1949) (OLIGOCENE?)—Red to reddish-brown, light yellow-brown, and locally white sandstone, shaly siltstone, and some conglomerate. In a few places includes gray, pink, and dark-gray to black, thin, dense limestone beds. Salt-and-pepper sandstone at base. Conglomerate lenses contain distinctive black, well-rounded chert pebbles. Fluvial deposits. Ranges in thickness from 0–50 m (160 ft) thick in this area, but as much as 305 m (1,000 ft) thick farther south

Tg GREEN RIVER FORMATION (EOCENE)—Consists of a limestone unit underlain by a shale unit. Fresh-water lacustrine deposits. Millen (1982) has discussed details of the stratigraphy and petrology as exposed on the Gunnison Plateau. Total thickness of formation varies widely, probably ranges from about 150–365 m (500–1,200 ft)

Limestone unit—Pale-yellowish-gray to yellow-brown to light-brown limestone; thin to thick bedded; even bedded. Contains thin sandstone and tuff layers. Limestones are dense, thinly laminated, and commonly oolitic. Includes thin stromatolitic limestone beds rich in ostracods. Forms resistant ledges and low cliffs

Shale unit—Light-green to grayish-green shale; thin bedded; fissile, somewhat calcareous. A few interbedded micritic limestones. Forms gentle slopes

Tc COLTON FORMATION (EOCENE)—Commonly claystone and mudstone variegated in shades of reddish brown, light gray, or light greenish gray. Locally includes beds of yellowish-gray to yellowish-brown siltstone and sandstone, and reddish-brown conglomerate. Sparse, interlayered thin beds of platy, light-gray, dense, finely crystalline limestone. Fluvial deposits. Volkert (1980) has discussed details of the stratigraphy and petrology as exposed on the Gunnison Plateau. Ranges in thickness from 100–260 m (325–850 ft)

Tf FLAGSTAFF LIMESTONE (EOCENE AND PALEOCENE)—Limestone, light gray to yellowish gray to light brown; locally dolomitic; red to pink near subjacent Jurassic red beds. Thin to thick bedded, locally massive; fine grained, dense, some algal nodules. Contains subordinate interbedded dark-gray, gray, and greenish-gray shale. Oncolite-rich limestone beds locally abundant (Weiss, 1969). Fresh-water lacustrine deposits. Forms resistant ledges and prominent hogbacks. Ranges in thickness from 0 in the central part of the Gunnison Plateau to about 305 m (1000 ft) near Ephraim

TERTIARY AND MESOZOIC SEDIMENTARY ROCKS

TKn NORTH HORN FORMATION (PALEOCENE AND UPPER CRETACEOUS)—Mudstone, claystone, sandstone, conglomeratic sandstone, conglomerate, and sparse limestone; units alternate irregularly. Mudstones are thick bedded to massive; sandstones range from thin to thick bedded; commonly crossbedded; fine to medium grained. Limestone beds are thin and dense, locally arenaceous. Contains minor coal beds along east flank of Gunnison Plateau near Wales. Fluvial and some fresh-water lacustrine deposits. Unstable, marked by many slumps, landslides, earthflows, and other mass-wasting deposits. Ranges in thickness from about 152–915 m (500–3,000 ft)

MESOZOIC SEDIMENTARY ROCKS

Kpr PRICE RIVER FORMATION (UPPER CRETACEOUS)—Gray to light-gray conglomerate, conglomeratic sandstone, and sandstone; minor shale. Thin to thick bedded; locally massive; commonly well cemented. Coarse conglomerates contain well-rounded clasts of light-brown and purple quartzite, light-gray quartz, light-gray and black chert, and sparse dark-blue limestone. Sandstones are fine to coarse grained. Fluvial deposits. Forms steep slopes and low cliffs. In western part of area consists chiefly of conglomerate beds that probably contain equivalents of Castlegate Sandstone. Ranges in thickness from a pinch out to about 366 m (1,200 ft)

Kc CASTLEGATE SANDSTONE (UPPER CRETACEOUS)—Sandstone, light brown to brownish gray; locally conglomeratic; irregularly bedded; massive; fine to coarse grained. Locally includes some thin, dark-gray, shaly siltstone units and some carbonaceous material. Fluvial deposits. Ranges in thickness from about 15 m (50 ft) to about 150 m (500 ft)

Ki INDIANOLA GROUP, UNDIVIDED (UPPER CRETACEOUS)

West of Sanpete Valley—Conglomerate, reddish brown and gray, thick bedded to massive, well cemented. Consists of sand, granules, pebbles and well-rounded cobbles of white, purple, green, grayish-green, and light-brown quartzite, light-brown to light-gray chert, white quartz, and some gray to dark-blue limestone. More carbonate clasts than in Price River Formation, and less than in North Horn Formation. Fluvial (synorogenic) deposits. Ranges in thickness from 2,440–4,570 m (8,000–15,000 ft) (Spieker, 1949, p. 13)

East of Sanpete Valley—Light-brown to yellowish-brown sandstone, shale, coal, and some conglomerate. Chiefly marine deposits. Includes four named units (in descending order) as follows: Sixmile Canyon Formation (sandstone, coal, and minor conglomerate), Funk Valley Formation (sandstone and shale), Allen Valley Shale (gray marine shale), and Sanpete Formation (sandstone). About 2,250 ft thick (Spieker, 1949, p. 13, 14)

Kbh BLACKHAWK FORMATION (UPPER CRETACEOUS)—Sandstone, shaly siltstone, shale, carbonaceous shale, and coal. Sandstones, light gray, light brown, and brownish gray; locally reddish brown; thin to medium bedded; crossbedded; fine to medium grained. Many thin to thick coal zones in lower part; major thick coal zone at base directly overlies Star Point Sandstone. Continental and deltaic deposits. Ranges in thickness from about 213 m (700 ft) to about 305 m (1,000 ft)

Ksp STAR POINT SANDSTONE (UPPER CRETACEOUS)—Light-brown to brown sandstone, shale, and shaly siltstone; thin to medium bedded; fine to medium grained. Consists of three sandstone units (in descending order) as follows: Spring Canyon, Storrs, and Panther Tongues. Sandstone units separated by beds of shale and shaly siltstone. Fluvial deposits. Formation ranges in thickness from about 61–305 m (200–1,000 ft); generally about 107 m (350 ft) thick

Km MANCOS SHALE (UPPER CRETACEOUS)—Consists of five members (in descending order) as follows: Masuk, Emery Sandstone, Blue Gate, Ferron Sandstone, and Tununk. Marine deposits. Formation ranges in thickness from 700 m (2,300 ft) to 1,860 m (6,100 ft)

Kmm Masuk Member—Shale and shaly siltstone, light gray, bluish gray, and dark gray; thin to medium bedded; few thin interlayered brown sandstone beds. Includes sparse discontinuous ledges of silicified shale. About 305 m (1,000 ft) thick

Kme Emery Sandstone Member—Consists of upper and lower sandstone units separated by a middle shale unit. Where exposed, member is about 87 m (285 ft) thick

Kmeu Upper unit—Sandstone, light brown, yellowish brown, and grayish brown; thin to medium bedded; locally crossbedded; very fine grained to fine grained. Quartzose. Weathers to angular thin plates. Stands as low cliffs. Where exposed about 11 m (35 ft) thick

Kmem Middle unit—Light-gray to gray shale, shaly siltstone, and sandstone; fissile, sandy locally; thin bedded, even bedded. Few thin interleaved sandstone beds that weather as steplike prominences. About 61 m (200 ft) thick

Kmel Lower unit—Sandstone, light brown, yellowish brown, and grayish brown; thin to medium bedded; very fine grained to fine grained. Quartzose. Stands as low cliff. About 15 m (50 ft) thick

Kmbg Blue Gate Member—Shale and shaly siltstone, light gray, bluish gray, and gray; fissile; thin to medium bedded; sparse interlayered thin sandstone beds. Forms low rounded hills. Resembles the Masuk and Tununk Members. As much as 610 m (2,000 ft) thick

Kmf Ferron Sandstone Member—Consists of upper and lower sandstone units separated by a middle shale unit. Where exposed, member is about 49 m (160 ft) thick

Kmfu Upper unit—Sandstone, buff, brown, and brownish gray; medium to thick bedded, locally massive; even bedded; very fine to fine grained. Forms cliffs. Thins northward. Zero to as much as 61 m (200 ft) thick in this area

Kmfm Middle unit—Shale, light gray to gray; fissile; locally somewhat silty and carbonaceous; thin bedded; even bedded. Interleaved thin lenticular sandstone beds. Contains important minable coal beds south of this quadrangle. Ranges in thickness from 0 –30 m (0 –100 ft)

Kmfl Lower unit—Sandstone and shale, light brown and grayish brown; thin bedded and even bedded; crossbedded; very fine to fine grained. Consists of two informally named sandstone units (in descending order) as follows: Washboard and Clauson units separated by a thin shale unit. Upper sandstone (Washboard unit) contains many very large, 1.5–2.4 m (5–8 ft), rounded, sandstone concretions. The lower unit ranges in thickness from about 3–13 m (10–40 ft)

Kmt Tununk Member—Shale and shaly siltstone, light gray to dark gray; fissile; thin to medium bedded; even bedded. Locally contains discontinuous ledges of silicified shale. Few sandstone concretions. Forms low rounded hills. Ranges in thickness from 122–198 m (400–650 ft)

Kdc DAKOTA SANDSTONE AND CEDAR MOUNTAIN FORMATION, UNDIVIDED

Dakota Sandstone (Upper Cretaceous)—Sandstone, tan to light brown; fine to medium grained; crossbedded. Contains thin discontinuous carbonaceous seams. Beach to marginal marine deposits. Thickness ranges from 0–9 m (0–30 ft)

Cedar Mountain Formation (Lower Cretaceous)—Consists of two units. Fluvial deposits. Thickness of Cedar Mountain Formation ranges from 49–100 m (160–230 ft)

Upper unit—Dominantly mudstone, variegated in shades of purple, red, gray, and green; massive to thick bedded. Few discontinuous sandstone lenses. Thickness ranges from 46–76 m (150–250 ft)

Lower unit—Conglomerate and conglomeratic sandstone, gray; massive to thick bedded; crossbedded. Consists of well-rounded clasts of white quartz, black, brown, and light-gray chert, and white quartzite. Forms resistant ledge. Thickness ranges from 3–24 m (10–80 ft)

KJu CRETACEOUS AND JURASSIC STRATA, UNDIVIDED.—Includes units assigned in the past to the qualified Morrison(?) Formation (Spieker, 1946, p. 125; 1949, p. 18). Includes conglomerate, sandstone, mudstone, and limestone, but all lithologies are not necessarily represented at any one exposure. Fluvial deposits

Conglomerate, reddish brown; medium bedded to massive; crossbedded. Clasts are well rounded; include light-brown quartzite, light-gray quartz, and dark-blue limestone

Sandstone, reddish brown to very light gray; thin- to medium bedded; crossbedded; fine- to coarse-grained; quartzose

Mudstone, variegated in shades of pale red, violet, and light gray; unbedded. Deposits weather to low rounded hills and knolls. Bentonitic. Locally contains small lenses of conglomerate and sandstone, and light-gray, dense, finely crystalline freshwater limestone. Contains gastroliths which suggest that this mudstone facies is correlative with the upper member of the Cedar Mountain Formation of Early Cretaceous age (W. L. Stokes, oral commun., 1981)

Jm MORRISON FORMATION (UPPER JURASSIC)—Consists of Brushy Basin Member (Jmbb) underlain by the Salt Wash Sandstone Member (not exposed in this area). Fluvial deposits. Formation ranges in thickness from 107–122 m (350–400 ft)

Jmbb Brushy Basin Member—Claystone and mudstone, variegated, dominantly bluish gray and gray with bands of yellow, green, maroon, brick red, and purple. Bentonitic. Contains few thin limestone and sandstone beds. Limestone beds locally gray and nodular. Ranges in thickness from 46–76 m (150–250 ft)

Jtg TWIST GULCH FORMATION (MIDDLE JURASSIC)—Reddish brown sandstone, shaly siltstone, and shale; locally some thin interbedded light-gray laminated or crossbedded sandstones. Thin to medium bedded, even bedded; fine grained. On Gunnison Plateau, from Chriss Canyon northward, thin orange-red conglomerate beds in upper part grade to red and gray massive conglomerates of Indianola Group. Marine deposits. Thickness estimated at about 914 m (3,000 ft) (Hardy, 1952, p. 23)

Ja ARAPIEN SHALE (MIDDLE JURASSIC)—Mudstone, calcareous, commonly light gray marked by pale-red blotches. In places wholly drab gray, elsewhere wholly reddish brown. Thin to medium bedded; even-bedded; locally amorphous. Intercalated thin, lenticular beds and seams of yellowish-gray to light-brown siltstone and sandstone. Sparse limestone beds. Contains thick beds of rock salt (halite), gypsum, and other evaporites. Selenite crystals abundant on many outcrops. Marine saline-basin deposits. Formation is complexly deformed, and shows signs of intense compression. Weathers to badland topography. Thickness uncertain because of intense deformation; estimates range from about 1,220 m (4,000 ft) to as much as 3,960 m (13,000 ft) (Spieker, 1949, p. 17; Gilliland, 1948, p. 30; Hardy, 1949, p. 16, 17)

Jtc TWIN CREEK LIMESTONE (MIDDLE JURASSIC)—Includes seven members (in descending order) as follows: Giraffe Creek, Leeds Creek, Watton Canyon, Boundary Ridge, Rich, Sliderock, and Gypsum Spring. Only Leeds Creek Member is believed to be exposed in this quadrangle, chiefly north of Little Salt Creek along the west flank of the Gunnison Plateau. Marine deposits. Light- to dark-gray; argillaceous limestone; dense; thin to medium bedded; even bedded. Locally complexly folded, and badly fractured. Complex relations between the Arapien Shale and the Twin Creek Limestone have been discussed by Sprinkel (1982). Thickness uncertain, possibly 150–305 m (500–1,000 ft)

QUATERNARY, TERTIARY, AND MESOZOIC SEDIMENTARY ROCKS

T(Ja) INTRUSIVE MASSES OF THE ARAPIEN SHALE (QUATERNARY(?) TO MIDDLE JURASSIC?)—Probably the salt component (and possibly other evaporites) in the Arapien Shale have been moving ever since they were deposited during the Middle Jurassic (Witkind, 1982). Some of this movement has been a slow, almost imperceptible upwelling. Every now and then, however, the salt seemingly has surged upward rapidly, and in so doing has forced the overlying mudstones of the Arapien Shale to bow up the country rock to form elongate, narrow diapiric folds. Subsequent removal of the salt resulted in collapse of the upwarps. Such major diapiric upwellings of the salt may have occurred during the Late Cretaceous, early Paleocene, and the late(?) Oligocene or Miocene. A localized upward surge of the salt likely deformed semiconsolidated sediments probably during the Pleistocene. The formation, thus, has several ages: its *depositional* age is Middle Jurassic. Its *emplacement* age (ages) has changed repeatedly. Symbol (T(Ja)) reflects both the depositional age (Ja), and the time of major emplacement (T), that is, Tertiary

EXTRUSIVE IGNEOUS ROCKS AND THEIR PRODUCTS

Tob OLDER BASALT FLOW(?) (MIOCENE?)—Basalt, dark gray to black, weathers reddish brown; fine grained. Only a small remnant preserved south of Willow Creek Reservoir, about 1.8 m (6 ft) thick

Tvg GOLDENS RANCH FORMATION OF MUESSIG (1951) (OLIGOCENE?)—Chiefly conglomerate and sandstone, and friable, light-pink and very light gray tuffs plus a lenticular, light-gray limestone. Conglomerate, brown to dark-brown; thin to thick bedded; locally massive; well-rounded cobbles of andesite and quartzite; includes a few sandstone beds. Interbedded volcanic flows in western part of area. Fluvial sediments rich in clasts of volcanic origin. Radiometric ages of about 32 m.y. determined on tuffs. Thickness uncertain; probably about 305 m (1,000 ft)

INTRUSIVE IGNEOUS ROCKS OF THE LEVAN AREA (JOHN, 1972)

Tlm MONZONITE (OLIGOCENE? TO UPPER EOCENE?)—Dike(?). Light gray to gray; fine grained, slightly porphyritic. Phenocrysts (10 percent of rock) consist of plagioclase (oligoclase-andesine) (about 8 percent), hornblende (about 1 percent), and biotite (about 1 percent). Groundmass includes plagioclase, orthoclase, and sparse quartz. Accessory minerals are apatite, sphene, and magnetite

Tmp MONZONITE PORPHYRY (OLIGOCENE? TO UPPER EOCENE?)—Dikes and two small stocks. Light gray to gray; aphanitic groundmass, porphyritic. Phenocrysts (32 percent of rock) consist of plagioclase (andesine) (about 20 percent), hornblende (about 10 percent), and biotite (about 2 percent). Groundmass consists of plagioclase, orthoclase, and sparse quartz. Accessory minerals consist of apatite, magnetite, sphene, and zircon

Thmp HORNBLENDE MONZONITE PORPHYRY (OLIGOCENE? TO UPPER EOCENE?)—Small irregular-shaped intrusions. Light gray to reddish gray; aphanitic groundmass, porphyritic. Phenocrysts (63 percent of rock) consist of plagioclase (andesine) (about 37 percent), hornblende (about 25 percent), and biotite (about 1 percent). Groundmass consists of a second generation of the same minerals plus orthoclase and quartz

Td PORPHYRITIC DIABASE (OLIGOCENE? TO UPPER EOCENE?)—Dikes(?). Greenish gray; porphyritic. Phenocrysts (70 percent of rock) consist of plagioclase (andesine-labradorite) (about 50 percent), augite (about 15 percent), hornblende (about 3 percent) and biotite (about 1 percent); locally some olivine. Groundmass consists of essentially the same minerals. Accessory minerals include apatite, sphene, and magnetite

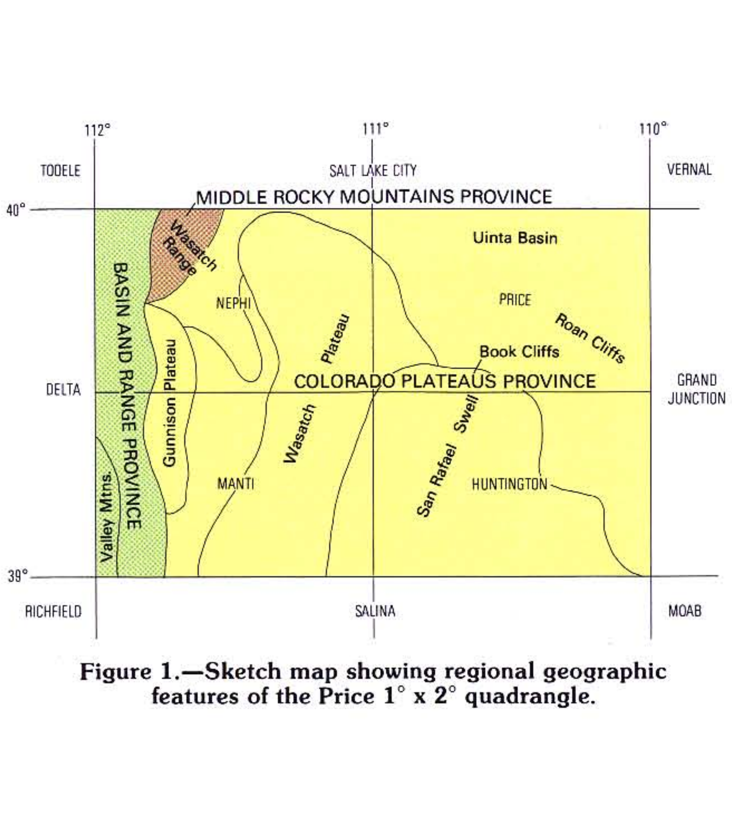


Figure 1.—Sketch map showing regional geographic features of the Price 1° x 2° quadrangle.

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(References, shown by colors or patterns, are keyed to the sources of geologic data)

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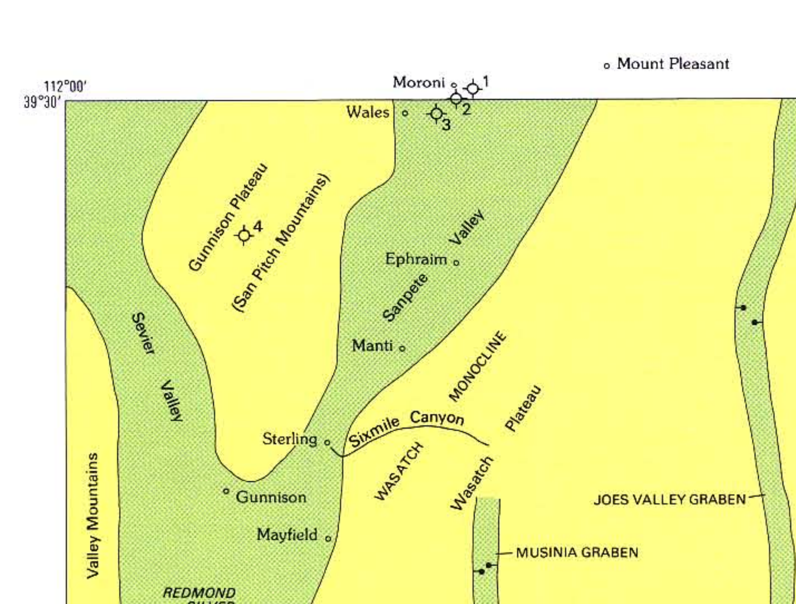
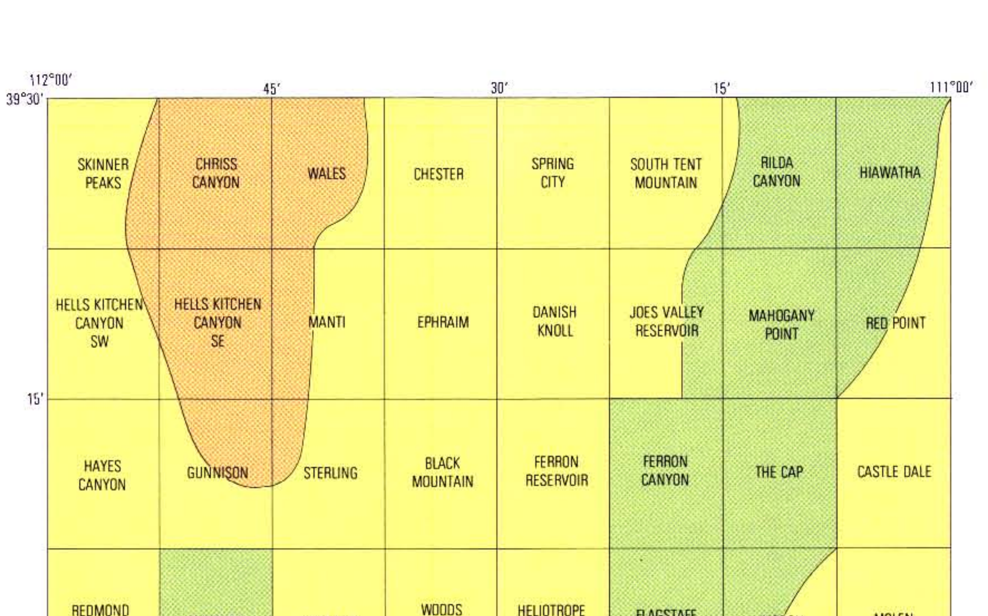


Figure 2.—Sketch map showing regional geographic features of the Manti 30' x 60' quadrangle.

EXPLANATION

TEST WELLS

1. Hanson Oil Corp. No. 1 A-X, Moroni
2. Tennessee Gas Trans. Co., J. W. Irons No. 1
3. Phillips Pet. Co. No. 1, Price-N
4. Chevron Oil Co. No. 1, Chriss Canyon Unit



EXPLANATION

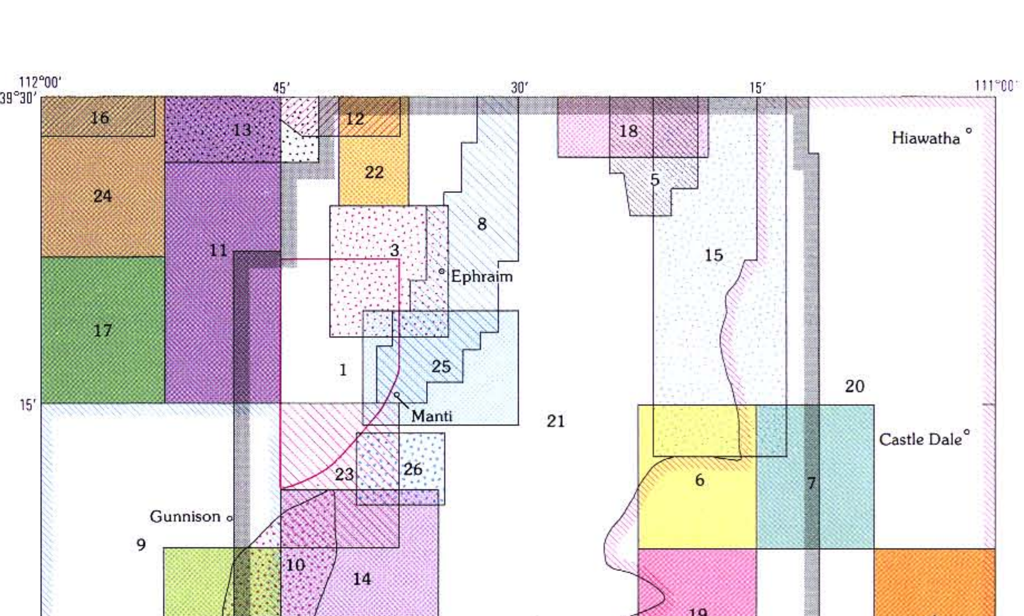
Original data unmodified or slightly modified

Original data modified by M. P. Weiss

Original data modified by I. J. Witkind

Note: Much of the existing geologic data was available only on planimetric base maps. Consequently all data were transferred, chiefly in the field, to modern 1:24,000 scale topographic maps (1965–1980) which were then reduced photographically to a scale of 1:100,000. The geologic data on these reduced maps were then drafted onto the 1:100,000-scale topographic map of the Manti 30' x 60' quadrangle (1981).

INDEX OF 7.5-MINUTE (1:24,000) QUADRANGLES USED IN COMPILATION



SOURCES OF GEOLOGIC DATA
(Colors and patterns correspond to numbered references)

INTRODUCTION

The U.S. Geological Survey is engaged in a broad program of field studies designed to present the geologic framework of the United States on easily read topographic maps. The maps selected as a base for these geologic data are part of the Army Map Service (AMS) series of 1° x 2° quadrangles at a scale of 1:250,000. The Price, Utah, AMS quadrangle is one of these maps (see fig. 1). For certain areas, however, chiefly those sectors of the country involved in the U.S. Geological Survey's Coal Exploratory Program, the geologic data are being compiled on newly developed base maps at a scale of 1:100,000. On these new maps the configuration of the land is shown by metric contours having a 50-meter contour interval. One of these new maps has been used as a base for this geologic map of the Manti 30′ x 60′ (1:100,000) quadrangle, the southwestern quadrangle of the four quadrangles that together make up the Price 1° x 2° quadrangle.

THE PRICE, UTAH, 1° x 2° AMS (1:250,000) QUADRANGLE

The geologic data compiled on the Manti quadrangle are but a part of a much larger geologic pattern best displayed on the Price, Utah, 1° x 2° quadrangle. The Price quadrangle includes within its borders parts of three major physiographic elements: the Colorado Plateaus, the Basin and Range, and the Middle Rocky Mountains Provinces. Most of the quadrangle, including the central and eastern parts, overlies the west margin of the Colorado Plateaus. Within this part of the plateaus are the southern edge of the Uinta Basin (expressed as the southward-facing, sinuous escarpments formed by the Book and Roan Cliffs), the northern part of the Canyonlands section (expressed by the northeast-trending San Rafael Swell), and the northernmost of the High Plateaus of Utah (the Wasatch Plateau). The western part of the sheet includes the east edge of the Basin and Range Province (the Great Basin). The join between the Colorado Plateaus and the Basin and Range Provinces trends northward through western Sanpete County and is a transition zone that is gradational in both geology and topography. A small wedge of the Middle Rocky Mountains Province—the southern Wasatch Mountains—dominates the northwest corner of the Price quadrangle.

THE MANTI, UTAH, 30′ x 60′ (1:100,000) QUADRANGLE

About half the Manti quadrangle (see fig. 2) is underlain by the Wasatch Plateau, a high, forested tableland composed of near-horizontal to gently warped Cretaceous and Tertiary strata. The east edge of the Wasatch Plateau overlooks Castle Valley, an arid, relatively barren, sage-covered lowland cut into poorly resistant strata on the west flank of the San Rafael Swell. By contrast, the west edge of the Wasatch Plateau looks across Sanpete Valley, a rich agricultural and ranching area, toward another tableland known to geologists as the Gunnison Plateau, to local inhabitants as the West Mountain, and to some Federal agencies as the San Pitch Mountains. The fact that the Gunnison Plateau, consists of the same stratigraphic units as are exposed in the Wasatch Plateau, and is essentially a gently warped upland much like the Wasatch Plateau, suggests that it is an integral part of the Colorado Plateaus. The Gunnison Plateau, however, is marked locally by structural complexities that seem to relate it to the Basin and Range structures so common farther west. We are uncertain, thus, just where the join between the two provinces should be in this part of central Utah. West of the Gunnison Plateau, and separated from it by the broad valley of the Sevier River, are the Valley Mountains, a low, elongate, north-trending tilted fault block that is much like the block-faulted ranges that make up the Basin and Range Province of western Utah and eastern Nevada. Because both the Wasatch and Gunnison Plateaus are plateaus, whereas the Valley Mountains are a tilted fault block, we tend, arbitrarily, to include the Wasatch and Gunnison Plateaus with the Colorado Plateaus Province.

We tentatively propose, thus, that the physiographic join between the Colorado Plateaus and the Basin and Range Provinces extends southward along the west flank of the Gunnison Plateau, flexes sharply to the southeast at the south end of the Gunnison Plateau, and continues southward along the west flank of the Wasatch Plateau.

In summary, the Manti quadrangle can best be visualized as consisting of parts of four physiographic elements. From east to west, these are: (1) the west flank of the San Rafael Swell, (2) the south half of the Wasatch Plateau, (3) the south half of the Gunnison Plateau (all three within the Colorado Plateaus Province), and (4) the east half of the Valley Mountains (essentially the easternmost range of the Basin and Range Province).

COLORADO PLATEAUS SEGMENT

San Rafael Swell

West-dipping shale and sandstone beds of Cretaceous age (Mancos Shale), exposed along the east edge of the Manti quadrangle, reflect the northwest flank of the San Rafael Swell. The swell is an elongate, oval, domelike structure, about 115 km (70 mi) long, and 50 km (30 mi) across (at its maximum width) that trends about N. 30° E. through Emery and Wayne Counties. The major axis of the San Rafael Swell is about 32 km (20 mi) east of the Manti quadrangle. The influence of the swell is strong: former near-horizontal Cretaceous and Tertiary strata were domed as the swell developed, and these units, now much eroded, express the general outline of the upwarp. The northern half of the San Rafael Swell (eastward beyond the Manti quadrangle) is bordered by a lowland underlain by Cretaceous shale beds, which are truncated in many places by pediment surfaces mantled by extensive deposits of sand and gravel. Rising abruptly above this sage-covered lowland are sandstone and shaly siltstone beds, younger but also of Cretaceous age, that crop out as steep, sinuous escarpments. On the east and north (beyond the Manti quadrangle) these cliffs are known as the Book Cliffs; on the west (and partly within the Manti quadrangle) they are unnamed but form the east flank of the Wasatch Plateau. Thick, well-developed coal beds (in the Blackhawk Formation of Late Cretaceous age) crop out along the cliffs and are mined extensively.

Wasatch Plateau

The Wasatch Plateau is a flat-topped mass about 130 km (80 mi) long and 40 km (25 mi) wide, and it appears as a huge upland that trends about N. 20° E. separating Sanpete Valley on the west from Castle Valley on the east. The top of the plateau is at an altitude of about 3,050 m (10,000 ft). In striking contrast to the clifflike aspect of the east flank of the Wasatch Plateau, the west flank of the plateau is a continuous westward-facing downwarp—the Wasatch monocline—that extends for almost the full length of the plateau. Westward-flowing consequent streams on the monocline have locally cut through the mantle of tilted beds to form deep, serpentine canyons that extend far back toward the crest of the plateau.

The Wasatch Plateau is underlain by flat-lying Cretaceous and Tertiary beds, most of which are well exposed either in the cliffs along its east flank or in the canyons cut into the Wasatch monocline. These rocks are broken by north and northeast-trending high-angle normal faults many of which are paired to form narrow, elongate grabens. Of these, one of the more spectacular is the Joes Valley graben, which traverses the full extent of the Manti quadrangle.

Gunnison Plateau

The Gunnison Plateau is a north-trending, oval upland composed of sedimentary rocks that have been warped into a southward-plunging syncline. Completely encircled by valleys, the plateau is about 61 km (38 mi) long, and about 23 km (14 mi) wide near its midpoint. The crest of the Gunnison Plateau reaches altitudes of about 2,450 m (8,000 ft), and thus is somewhat lower than the Wasatch Plateau. The southern end of the Gunnison Plateau merges with the lowlands of the Sanpete and Sevier Valleys, but the plateau gradually gains height northward, and its northern end, marked by steep, precipitous cliffs, towers above the adjacent valley floors.

The rocks that form the plateau are much faulted, although on the whole they are but gently warped. Only along the east edge of the plateau are these rocks intensely deformed, in a zone of complex structures that extends as a narrow welt, 1–2 km (1/2–1 mi) wide, from near Wales southward to the southern edge of the plateau (Spieker, 1949; Witkind, 1982). Comparable large-scale structures have not been found along the west flank of the plateau, although locally the rocks there are much deformed (Witkind, 1983).

BASIN AND RANGE SEGMENT

Valley Mountains

If the Gunnison Plateau is correctly assigned to the Colorado Plateaus Province, only a small part of the Basin and Range province is represented in the Manti quadrangle—essentially the east flank of the north-trending Valley Mountains. The Valley Mountains are an eastward-tilted fault block whose west flank (west of the quadrangle boundary) is bounded by a high-angle normal fault that trends north and dips steeply to the west. West of the Valley Mountains are other ranges, such as the Canyon and Pavant Ranges, which also trend north and which also are bounded along one or both margins by high-angle normal faults. From the Valley Mountains westward, therefore, the geologic pattern is one of alternating north-trending basins and parallel block-faulted ranges—typical Basin and Range topography.

THE TRANSITION ZONE

Structurally, the south-trending transition zone between the Colorado Plateaus and the Basin and Range Provinces dominates the Manti quadrangle. Structures transitional between the two provinces extend from the crest of the Wasatch Plateau westward to and possibly beyond the Valley Mountains.

The same sedimentary sequence that underlies the Wasatch Plateau is found in the Gunnison Plateau and in the Valley Mountains. Locally, in all three areas, the rocks are intensely deformed; complex structures abound. In the Wasatch Plateau these structures are best exposed at and near the mouth of Sixmile Canyon, near Sterling (Spieker, 1949, p. 49–51). The east flank of the Gunnison Plateau is marked by an extensive belt of complexly deformed rocks (Spieker, 1949, p. 72–74). Comparably deformed rocks are exposed along the northeast flank of the Valley Mountains. Beds are vertical to steeply overturned; locally, one or more angular unconformities break the sedimentary sequence. In several places two profound angular unconformities are exposed in a single outcrop, but surprisingly these unconformities are not extensive laterally. Strata that are separated by a striking angular unconformity, when traced laterally, rapidly approach parallelism and become conformable in distances as short as three-fourths of a kilometer (half a mile). Overturned beds become vertical, then upright, decrease in dip and in unusually short distances are near-horizontal and conform with both overlying and underlying units. The intense deformation is extremely localized.

Interpretations

This remarkable deformation has been interpreted in different ways. The late Professor E.M. Spieker and his many graduate students have attributed the deformation to multiple episodes of tectonic disturbance. In all, some 14 such episodes have been postulated (Spieker, 1949, p. 78). Subsequent work has suggested an additional two episodes to make a total, then, of 16 tectonic pulses (Gilliland, 1948, p. 74; 1951, p. 72; 1952, p. 1461). Of these, eight were orogenic (compressive) movements that have occurred since Jurassic time (Spieker, 1949, p. 40). The remainder were chiefly episodes of normal faulting, warping, or monoclinical flexing. Other workers in the area, however, chiefly Stokes (1952, 1956), Moulton (1975), Baer (1976), and Witkind (1982), have suggested that much of the deformation is more reasonably explained by multiple episodes of salt diapirism.

Regrettably, the field evidence is equivocal; strong arguments can be made for either interpretation. Weiss, one of the co-authors of this map, tends toward multiple tectonism as an explanation for most of the deformation. He sees much of the structural complexity as being thrust related and considers that salt diapirism played a minor role. Weiss believes the question is moot on the basis of surface geology, and that multiple tectonism cannot be fully discredited until diapirism can be demonstrated by subsurface data. Weiss attributes the intense deformation that marks the east flank of the Gunnison Plateau to an antiformal welt that lay just east of the Gunnison Plateau in latest Cretaceous and Paleocene time, and which subsequently bent the edge of the plateau block toward the west (Weiss, 1982). The welt may have been caused by compression from the east, diapirism, or both. Witkind, another co-author of this map, is a strong advocate of salt diapirism, and accordingly he attributes the bulk of the deformation, as well as the extreme localization of the deformed structures, to recurrent salt movement—in essence, the repeated growth and collapse of many linear salt diapirs. In his view, eastward-directed compressive impulses probably played a significant role in that, initially, they triggered the salt into upward movement. He sees this upwelling of the salt as responsible for most of the local deformation. Thus, he attributes the westward bend of the east edge of the Gunnison Plateau to the repeated upwelling of a salt diapir concealed beneath Sanpete Valley (Witkind, 1982, p. 26–27). As the diapir welled upward, vertical stresses were translated laterally into horizontal stresses, and it is the westward-directed component of these horizontal stresses that flexed the beds to the west.

FAULTS

A series of high-angle normal faults, of diverse orientation, cut and offset the rocks in the Manti quadrangle. In the Wasatch Plateau these faults form a simple pattern of breaks that trends generally north and northeast. By contrast, in the Gunnison Plateau, the pattern is much more complex. In addition to the north- and northeast-trending faults are a series of northwest- and westward-trending cross faults that break the rocks of the plateau into small, almost disjointed blocks. This same complex fault pattern persists in the Valley Mountains but is not as intense.

WASATCH PLATEAU

The crest and west flank of the Wasatch Plateau are broken by a system of high-angle normal faults that range in trend from about N. 10° W. to about N. 30° E. This fault system does not appear to extend eastward into the San Rafael Swell, for only a few northerly trending faults break the rocks of the swell; there, the fault pattern is dominated by west and northwest-trending faults.

The faults on the Wasatch Plateau are remarkably straight, and commonly persist as single breaks, or very narrow fault zones, traceable for very long distances. Some, such as those that bound the Joes Valley graben, are narrow fault zones that extend for the full length of the Manti quadrangle. The continuity of the faults is masked on the ground, however, by the fact that the faults are concealed in the valleys beneath mass-wasting deposits. In most places the faults are visible only along valley walls and on the interfluves between the valleys.

A few of the faults show opposite directions of displacement along their lengths. Thus, for example, at the northern end of such a fault, commonly known as a "scissors fault", the block west of the fault is downthrown. As the fault is traced southward the amount of displacement lessens, reaches a null point, and then changes, with the end result being that at the fault's southern end the block east of the fault is downthrown.

Many of the high-angle normal faults are paired to form grabens that exceed 65 km (40 mi) in length. In general, the grabens maintain a relatively constant width of about 3 km (2 mi) although locally they narrow to about half a kilometer (a quarter of a mile). Structural relief differs from graben to graben. In some grabens it is as low as 100 m (several hundred feet); elsewhere it is hundreds of meters. Spieker (1949, p. 43) suggested stratigraphic separation of 610–915 m (2,000–3,000 ft) in the Joes Valley graben, one of the major structural elements in the quadrangle, and of 1200 m (4,000 ft) in the nearby Musinia graben.

In many places the downthrown blocks are unbroken, but locally they are cut by a series of small internal faults that trend parallel to the major faults that bound the graben. In places, the many faults have so disrupted and broken the coal beds that underlie much of the Wasatch Plateau that these beds cannot be mined (Doelling, 1972a, p. 83).

The origin of the faults, and thus, of the grabens, is uncertain. The faults may reflect widespread crustal spreading stemming from an episode of extensional tectonics that has dominated the western interior of the United States since Miocene time. If so, the faults are tectonic in origin. By contrast, the faults may be related, in one way or another, to the salt that underlies much of the Sanpete-Sevier Valley area (Stokes, 1952; Stokes and Holmes, 1954, p. 40). Moulton (1975, fig. 19) implies that many of the faults that break the crest of the Wasatch Plateau do not extend below the base of the salt-bearing beds. This suggests that at least some of the faults and grabens may be genetically related to withdrawal of the salt. Not all faults, however, are so shallow; several appear to extend into the presalt rocks (Moulton, 1975, fig. 19).

If some of the grabens are indeed salt-induced structures, possibly they formed in response to an outward (valleyward) flowage of the salt, much as postulated by Baker (1933, p. 74) to explain the development of the grabens that are so common in the Paradox Basin of southeastern Utah and southwestern Colorado.

Differential flowage of salt may also explain the anomalous pattern of displacement that characterizes the scissors faults.

GUNNISON PLATEAU

As on the Wasatch Plateau, many of the north-trending faults that break the rocks on the Gunnison Plateau are paired to form grabens. The linear trends of the grabens, however, are masked by a maze of smaller faults that break and disrupt the downdropped blocks in the grabens. Two conspicuous examples of this are at the southern end of the plateau. Along the southwestern flank of the Gunnison Plateau, essentially between Mellor and Hells Kitchen Canyons, the downdropped block in a large north-trending graben consists of a chaotic jumble of blocks. A comparable graben, although one in which the downdropped block is not as badly broken, begins near the southeastern end of the plateau and extends northwesterly across the crest of the plateau. In sharp contrast to these north-trending grabens, however, is a transverse graben that trends west and breaks the rocks along the east flank of the Gunnison Plateau between Maple and Rock Canyons (directly west of Ephraim).

All these grabens and many of the other faults in the Gunnison Plateau may be salt related. Possibly the causative salt originally bowed up the rocks to form elongate, linear folds; subsequent removal of the salt caused the axial parts of folds to collapse along boundary faults and form the grabens.

The striking difference in intensity of faulting, when the Gunnison and Wasatch Plateaus are compared, may reflect the fact that the Gunnison Plateau appears to have been subjected to compressive forces from both the west and east, possibly by salt diapirs, which co-author Witkind believes abut its west, east, and north flanks. The synclinal aspect of Gunnison Plateau, and its southward plunge, may stem from the upward movement of these diapirs.

VALLEY MOUNTAINS

The crest of the Valley Mountains is broken by a north-trending graben known as Japanese Valley. Both east and west of the graben are other high-angle normal faults that also trend north. In general, those faults east of the graben are marked by downthrow to the west—toward the graben; those few faults west of the graben (beyond the confines of the Manti quadrangle) are marked by downthrow to the east—again toward the graben. The implication is strong that the graben is a collapse feature possibly related to withdrawal of salt. Test wells have indicated that the Valley Mountains are underlain by the Arapien Shale (the salt-bearing unit), but as yet none of the wells has penetrated salt. It may well be that whatever salt did underlie the Valley Mountains has been dissolved and removed.

MODERN FAULT SCARPS

A series of modern fault scarps are along both flanks of the Gunnison Plateau. In all localities, these scarps cut and offset surficial deposits, implying that the causative faults have moved in the recent past. The fault scarps trend northerly, dip valleyward, and range in height from 0.3–8 m (1–25 ft). Those scarps along the west flank of the Gunnison Plateau clearly reflect movement along the Wasatch fault zone, one of the many, young, active fault zones in the United States. The fault along the east flank of the Plateau, known as the Gunnison fault, cuts and offsets an old alluvial fan that heads in the mouth of Wales Canyon. The new scarp, in turn, is now partly concealed by a younger alluvial fan which also heads in Wales Canyon.

The origins of the faults are uncertain. The Wasatch fault has always been considered to be an extensional fault; hence, it may have formed in response to tectonic impulses. Movement along the fault would likely result in a major earthquake that would cause much damage to manmade features. By contrast, the close parallelism between the trace of the Gunnison fault and the suspected salt diapir believed to be concealed beneath Sanpete Valley, suggests that withdrawal of salt may have played some role in the development of that fault. If so, the Gunnison fault, although a geologic hazard, may not pose as much of a risk as the Wasatch fault.

WATER RESOURCES

Details about the surface-water resources of the Manti quadrangle are contained in a companion publication, U.S. Geological Survey Miscellaneous Investigations Series Map I–1482 (Price, 1983).

ECONOMIC DEPOSITS

Materials of economic interest in and near the Manti quadrangle include mineral fuels such as coal and hydrocarbon gas. Pools of oil and gas also may be in the area. Several fields producing carbon-dioxide (CO_2) gas are northeast of the quadrangle. Nonmetallic mineral deposits in the quadrangle include gypsum, salt and brines, sand and gravel, building stone, and limestone. Metallic mineral deposits are sparse; some zinc ore was mined near Redmond.

MINERAL FUELS

Coal

Vast amounts of coal underlie the Wasatch Plateau with some of it accessible along the Plateau's east flank (Spieker, 1931; Doelling, 1972a, 1972b). Of the six coal fields in and near the Price 1° x 2° quadrangle (the Wasatch Plateau, Book Cliffs, Salina Canyon, Mount Pleasant, Wales, and Sterling fields), only the Book Cliffs and Salina fields are beyond the boundaries of the Manti quadrangle. Of those fields, or parts of fields, within the quadrangle, apparently only the Wasatch field contains deposits of coal that are economically significant at present. Although seams and beds of coal crop out west of the Plateau, in Sanpete Valley near Wales, Mount Pleasant, and Sterling, these beds, for the most part, are thin (generally less than 0.3 m (1 ft) thick), discontinuous, and of poor quality. The early settlers mined these beds until the thicker, higher quality, and more continuous beds that are exposed along the east edge of the Wasatch Plateau were discovered. These latter beds are considered to contain some of the best coal in Utah (Doelling, 1972b, p. 554). Some test holes by the U.S. Bureau of Mines, however, indicated that at least three minable coal beds, ranging from 1–2 m (4–6 ft) in thickness, are in the subsurface in the Mount Pleasant area at depths between 290 m (955 ft) and 350 m (1150 ft) (Doelling, 1972b, p. 30).

Coal in the Manti quadrangle is contained chiefly within five units of Tertiary and Cretaceous age: the North Horn, Blackhawk, and South Flat (probably correlative with the Blackhawk) Formations, the Sixmile Canyon Formation of the Indianola Group, and the Ferron Sandstone Member of the Mancos Shale. Of these, only the Blackhawk Formation contains thick (as much as 8 m (25 ft) thick) coal beds that are either exposed or are buried beneath an overburden of 305 m (1,000 ft) or less. The Blackhawk Formation crops out all along the east flank of the Wasatch Plateau, and it is likely that its coal beds underlie much of the plateau. Comparable coal beds may be contained within the Ferron Sandstone Member, but if so these are so deeply buried they probably will be difficult to mine.

Surface investigations and drilling have determined that as many as 22 coal beds in the Blackhawk Formation are thick enough to be named (Doelling, 1972a, p. 85). Some of the thickest and most persistent coal beds are the Hiawatha, Castlegate A, Bear Canyon, Blind Canyon, Wattis, Upper Ivie, and Ivie beds (Doelling, 1972a, p. 85). Recent work by U.S. Geological Survey geologists, notably J. D. Sanchez, L. F. Blanchard, E. E. Ellis, and T. L. Brown, has suggested that these coal beds, rather than being laterally uniform masses, are best viewed as coal zones—groups of alternating discontinuous beds of coal separated by sandstone and mudstone splits. In general, each zone is separated from overlying and underlying coal zones by sandstone-rich strata, 2–6 m (5–20 ft) thick, that contain thin coal seams and carbonaceous material but are free of thick coal beds. Sanchez and his colleagues (Sanchez, Blanchard, and August, 1983) have grouped the various coal beds into a series of discrete, named coal zones. Within the Manti quadrangle, these workers recognize six such discontinuous coal zones in the lower part of the Blackhawk Formation; from oldest to youngest, these are (1) the Hiawatha, (2) Acord Lakes (which is correlative with the Muddy No. 1 and Muddy No. 2 coal zones), (3) Axel Anderson, (4) Cottonwood, (5) Blind Canyon, and (6) Bear Canyon coal zones. Within each coal zone the coal beds range in thickness from several centimeters (one inch) to as much as 8 m (25 ft).

The rank of most of the coal beds is high-volatile B bituminous as calculated from the Parr formulas of the American Society for Testing and Materials (1978) (J. D. Sanchez, oral. commun., 1983).

Details about these coal zones, including analyses of the moisture, fixed carbon, ash, and volatile contents of the contained coal beds, and the relations between the various coal zones are contained in a series of U.S. Geological Survey Coal Investigations maps (Sanchez and Brown, 1983; 1986; 1987; Brown and Sanchez, 1986).

Large, modern mines dug into those coal beds of the Blackhawk exposed along the east flank of the Wasatch Plateau have just begun to tap the large coal reserves that underlie the plateau. In the Manti quadrangle, most of the more productive mines are along the north and east flanks of East Mountain (northwest of Castle Dale). The bulk of the coal mined is transported via truck to coal-fired power plants constructed at Huntington (Huntington Plant) and Castle Dale (Hunter Plant); much of the electrical power produced by these two plants is transmitted out of state.

The presence of these rich coal beds has led to tentative plans for the construction of other coal-fired power plants in and near the Price quadrangle; five are planned for areas east of the Wasatch Plateau, and three for areas west of the Plateau (Witkind, 1979). The Intermountain Power Plant (IPP), now under construction near Lynndyl (west of the Wasatch Plateau), is one of these plants; when completed it will be the largest coal-fired power plant in the world.

Reserves

As a consequence of the increased interest in coal as a fuel, the east edge of the Wasatch Plateau has been drilled extensively in an attempt to determine reserves in the Wasatch Plateau coal field. On the basis of these data, coal reserves identified in that part of the Wasatch Plateau coal field within the Manti quadrangle total about 2 billion short tons (J.D. Sanchez, oral commun., 1983).

Principal coal reserves in the combined Salina Canyon, Mount Pleasant, Wales, and Sterling fields are about 350 million short tons (Doelling, 1972a, p. 88).

Hydrocarbon gas

Significant amounts of hydrocarbon gas have been produced from small structures that underlie the Wasatch Plateau (Walton, 1963). The most important is the Clear Creek structure, a fault segment, near Scofield Reservoir, north of the Manti quadrangle. Domelike structures, from which minor amounts of hydrocarbon gas have been produced, are in and near the northeast corner of the Manti quadrangle, but of these only the Flat Canyon structure (directly east of Upper Joes Valley) is within the quadrangle. Production is from both the Dakota Sandstone, and the Ferron Sandstone Member of the Mancos Shale (Walton, 1963, p. 345).

Carbon-dioxide gas

Pure carbon-dioxide gas has been produced from wells drilled into structures northeast of the Manti quadrangle. The Farnham dome, east of Wellington, contains CO_2 gas with major production from the Navajo Sandstone (Peterson, 1961). Somewhat closer to the Manti quadrangle is the Gordon Creek field southeast of Scofield Reservoir. The field is on the faulted Gordon Creek anticline, and production is from a series of beds that include the upper part of the Ferron Sandstone Member of the Mancos Shale (Upper Cretaceous), the Sinbad Limestone Member of the Moenkopi Formation (Triassic), and the "Coconino Sandstone" (probably the Cedar Mesa Sandstone of the Permian Cutler Formation). As most of these units are relatively impervious and have low porosity, the gas, seemingly, is contained within them because they are much fractured (Anonymous, 1961).

Oil and gas

In the past decade this sector of central Utah has been the scene of an intensive search for oil and gas. Seismic surveys have crisscrossed the area repeatedly; new surveys are launched even as previous ones end. Many wells have been drilled to test geologic concepts, favorable structures, and sedimentary units. As of late 1982, the search in the Sanpete-Sevier Valley area, on the whole, has been unsuccessful. Most test wells were either dry or had only small shows of oil or gas. Only those wells drilled on the crest of the Wasatch Plateau have had some success, chiefly in the discovery of sizable amounts of hydrocarbon and carbon-dioxide gases. Although some petroleum companies have lost interest in the area and have shifted their attention elsewhere, other companies are undeterred and apparently believe that the area has a strong potential for oil and gas.

Source rocks

Possible source rocks for oil and gas include the Mancos Shale of Late Cretaceous age, the Manning Canyon Shale of Late Mississippian and Pennsylvanian age, and the Arapien Shale of Middle Jurassic age.

Three exploratory wells drilled near Moroni in Sanpete Valley penetrated the entire thickness of the Mancos Shales, composed chiefly of black, marine, sedimentary rocks. The easternmost test well, Hanson Oil Corporation's well No. 1 A-X Moroni (SE, NW, sec. 14, T. 15 S., R. 3 E.) cut about 2,135 m (7,000 ft) of Mancos strata. About 2.4 km (1.5 mi) to the southwest the Tennessee Gas Transmission Company's J.W. Irons well No. 1 (C, SE, NE, sec. 16, T. 15 S., R. 3 E.) penetrated about 1,700 m (3,500 ft) of Mancos. And the westernmost well, the Phillips Petroleum Company's well No. 1 Price-N (SE, SE, sec. 29, T. 15 S., R. 3 E.) cut only about 610 m (2,000 ft) of Mancos Shale. Seemingly, the Mancos Shale thins markedly westward, implying a shoaling of the Mancos sea near the east edge of the Gunnison Plateau. How much of the Manti quadrangle is underlain by the Mancos is uncertain; we suspect that it underlies most of the Wasatch Plateau and Sanpete Valley, at the very least.

The Manning Canyon Shale is another black, marine sedimentary unit that may underlie the area at depth. This shale, like the Mancos, is rich in an oil-generative type of organic material, and so a most suitable source rock. Although not exposed in the Manti quadrangle, the Manning Canyon is a conspicuous unit farther to the north where it is part of the Charleston-Nebo thrust plate that forms the Mt. Nebo massif.

The Arapien Shale may be a source rock. Recently Kirkland and Evans (1981) suggested that calcareous mudstones deposited in highly saline, marine evaporitic basins may be rich source rocks. Considerable uncertainty exists, however, about the suitability of the Arapien Shale as a source rock for oil and gas because of its apparent low content of total organic carbon (TOC) (R. J. Coskey, Forest Oil Corporation, oral commun., 1982).

Reservoir rocks

Appropriate reservoir rocks are believed to be within the Mancos Shale, chiefly the Ferron Sandstone Member and sandstone units within the Emery Shale Member. Among the other beds in the stratigraphic section that have served as reservoir rocks for either hydrocarbon or carbon dioxide gas are the Dakota Sandstone, the Navajo Sandstone, the Sinbad Limestone Member of the Moenkopi Formation, and the "Coconino Sandstone" (probably the Cedar Mesa Sandstone of the Cutler Formation). Significantly, these beds have served as good reservoir rocks mainly because they are strongly fractured, and apparently not because of unusually high primary porosity. How severely a unit has been fractured may determine its suitability as a reservoir rock.

Structural traps

If the diapiric concept as proposed by Witkind (1982) is valid, structural traps may be adjacent either to the salt diapirs or to the mudstone sheaths (composed of Arapien Shale strata) that are integral parts of the diapiric folds. Presumably as the salt surged upward it raised the enveloping mudstones of the Arapien Shale, and these, in turn, bowed up the adjacent country rocks. The traps formed between the upturned country rocks and either the intrusive salt or the mudstones would seem suitable sites for the accumulation of oil and gas.

NONMETALLIC MINERAL DEPOSITS

Gypsum deposits

Extensive gypsum deposits are in the Arapien Shale; most of the commercial deposits are concentrated either south of the Manti quadrangle between Salina and Sigurd, or north of the quadrangle at or near the mouth of Salt Creek near Nephi. The mined gypsum is transported by truck to several gypsum plants at Sigurd where it is fabricated into plaster board. Small pods and lenses of gypsum are found, however, in most outcrops of the Arapien Shale; selenite crystals are common on outcrops.

In the Manti quadrangle the Arapien Shale crops out in three localities: along the west flank of the Gunnison Plateau, along the east side of Sevier Valley south of Sterling, and along the west side of Sevier Valley near and north of Redmond. Only farther north, however, near Nephi (beyond the Manti quadrangle) and in adjacent areas south of Nephi, is much gypsum seen in outcrop, where it occurs in disconnected pods and sheets. This scattered occurrence regionally may be misleading for extreme irregularity of thickness, width, and length is characteristic of many gypsum deposits. What may appear as a thin pod of gypsum on the outcrop may thicken and widen rapidly in the subsurface to become a significant deposit. In general, we estimate that the range in thickness of a gypsum lens is from about 15 m (50 ft) to as much as 105 m (350 ft). In like fashion the width and length are also highly irregular; we estimate that some lenses are as much as 305 m (1,000 ft) wide, and about 210 m (700 ft) long.

Salt and brines

Very little rock salt (halite) is exposed at the surface, although much salt probably underlies the Sanpete-Sevier Valley area. So, for example, the Phillips Price-N well, near Moroni in Sanpete Valley, penetrated about 610 m (2,000 ft) of salt. Farther west (beyond the Manti quadrangle), near Yuba Dam in Sevier Valley, Placid Oil Company's Monroe 13–7 well (SW, NE, sec. 13, T. 16 S., R. 2 W.) cut about 215 m (700 ft) of salt. Chevron Oil Company's Chriss Canyon well (NE, SW, sec. 33, T. 16 N., R. 1 E.), near the southern end of the Gunnison Plateau, cut through about 245 m (800 ft) of salt (L. A. Standlee, Chevron Oil Co., oral commun., 1982). The salt is contained within the Arapien Shale, and where exposed and mined near Redmond, appears as near-vertical, much-contorted beds interleaved with reddish-brown calcareous mudstone. It is likely that several salt beds are in the Redmond area, but the Arapien Shale strata have been so contorted that correlation of beds from one salt mine to the next is uncertain. At Redmond the main salt bed being mined is about 60 m (200 ft) thick (Picard, 1980, p. 145). Pratt, Heylmun, and Cohenour (1966, p. 54) estimate that the salt may range from 180 to 300 m (590 to 980 ft) in thickness. About 9,000 metric tons of salt are mined per year (Pratt and Callaghan, 1970, p. 48), with most of it being used chiefly for livestock and de-icing roads.

Considerable brine is formed in the salt mines near Redmond as a result of ground-water seepage, and drillers have used this brine to drill through the salt beds in the Arapien Shale. The drillers add the brine to their drilling mud, gradually increasing the salinity until the mud becomes supersaturated. At that stage they can drill through a bed of salt without the salt either caving in or dissolving.

The salt is extremely mobile and plastic. Chevron Oil Company was forced to abandon their Chriss Canyon well before reaching potential reservoir rocks because the mobile salt repeatedly crushed the casing of the well (L. A. Standlee, Chevron Oil Co., oral commun., 1982).

Sand and gravel

Vast amounts of sand and gravel are exposed in the Manti quadrangle, chiefly along the base of such major topographic highs as the Wasatch and Gunnison Plateaus and the Valley Mountains. Most of the material was deposited as broad, low alluvial fans that have since coalesced to form extensive aprons. Locally these aprons have been dissected to form sand and gravel-capped mesas and buttes of many sizes, of which the largest are the pediments so well displayed at the base of both the Book Cliffs and on the east flank of the Wasatch Plateau.

West of the Wasatch Plateau, and along the flanks of both the Gunnison Plateau and the Valley Mountains, where the streams have not cut as deeply, the large coalesced alluvial fans partly fill the valleys. Extensive gravel pits have been opened in the various deposits with most of the sand and gravel produced used extensively for both highway and building construction.

The deposits are crudely sorted and commonly contain many impurities, chiefly shale or mudstone fragments; consequently much of the material extracted must be crushed, sized, and purified before it is suitable for use.

Building stone

Although several formations within the quadrangle contain sedimentary units suitable for use as building stone, the lithologic unit most favored by the local inhabitants is the light-tan to ivory, oolitic limestone contained within the upper limestone unit of the Green River Formation. The limestone is an excellent dimension stone for it has a pleasing color, is easily quarried and worked, and is generally free of closely spaced fractures. An outstanding example of the suitability of this limestone as a dimension stone is the magnificent Mormon Temple in Manti. Much of the stone used in the construction of the temple came from small quarries between Ephraim and Mount Pleasant, but some of it was quarried locally from the large slide block of Green River Limestone on which the Temple now stands. Many of the older homes and storage houses in the area, built by the earlier pioneers, are also constructed of this attractive limestone. The rock has also been used for monuments, curbstone, and flagstones for it stands up well in the dry climate of central Utah.

Limestone

Several small quarries have been opened in Flagstaff Limestone beds that crop out along the east side of Sevier Valley. At one time a sugar refining plant, south of Gunnison, used high-calcium limestone extracted from Flagstaff beds exposed east of Axtell, about 3–6 km (2–4 mi) east of Redmond. The quarries, on both sides of the Willow Creek road, have been operated intermittently during the past half century, but none ever produced much limestone. In the past most of the crushed limestone was heated in nearby kilns and converted to lime that was used locally, chiefly as a base for mortar or plaster. During recent years the limestone has been crushed to a powder and then sold to various of the coal mine operators, mainly for use as a coal-dust suppressant. A slurry of powdered limestone mixed with water, when sprayed on the walls and roofs of the mines, not only suppresses the coal dust but also keeps the coal from flaking, and, in addition, reflects more light.

METALLIC MINERAL DEPOSITS

Zinc

Small amounts of oxidized zinc and zinc-lead ore have been produced from a small mine, known as the "Redmond silver mine". The mine, about 5 km (3 mi) northeast of Redmond (Heyl, 1963, 1978), is in a small cuesta that occupies parts of secs. 4 and 5, T. 21 S., R. 1 E. The mine produced zinc ore intermittently from about the time of World War I to about 1950 when it was closed due to depletion of the ore body. The bulk of the zinc ore (chiefly hydrozincite and smithsonite) was concentrated in shattered Green River rocks next to the contact between Arapien strata on the east and Green River beds on the west (Heyl, 1963, 1978).

The geologic relations near the mine (Witkind, 1981) can be interpreted either as a fault zone in which the crustal block west of the fault has been downthrown, or as an intrusive (diapiric) contact between the Arapien Shale and the bowed-up Green River Formation. Although Heyl (1963, 1978), who examined the mine when it was open, favors the fault interpretation, Witkind, a co-author of this map, favors the second alternative; Witkind proposes that the Arapien Shale, forced upward by the intrusive action of the salt, tilted up, deformed, and broke the overlying Green River beds. Witkind believes that the base-metal deposits stem from saline solutions that picked up their metal content when they percolated through the Arapien Shale. Zinc from these mineral-rich solutions was then deposited in the fractured limestones of the Green River Formation.