UTAH GEOLOGICAL SURVEY
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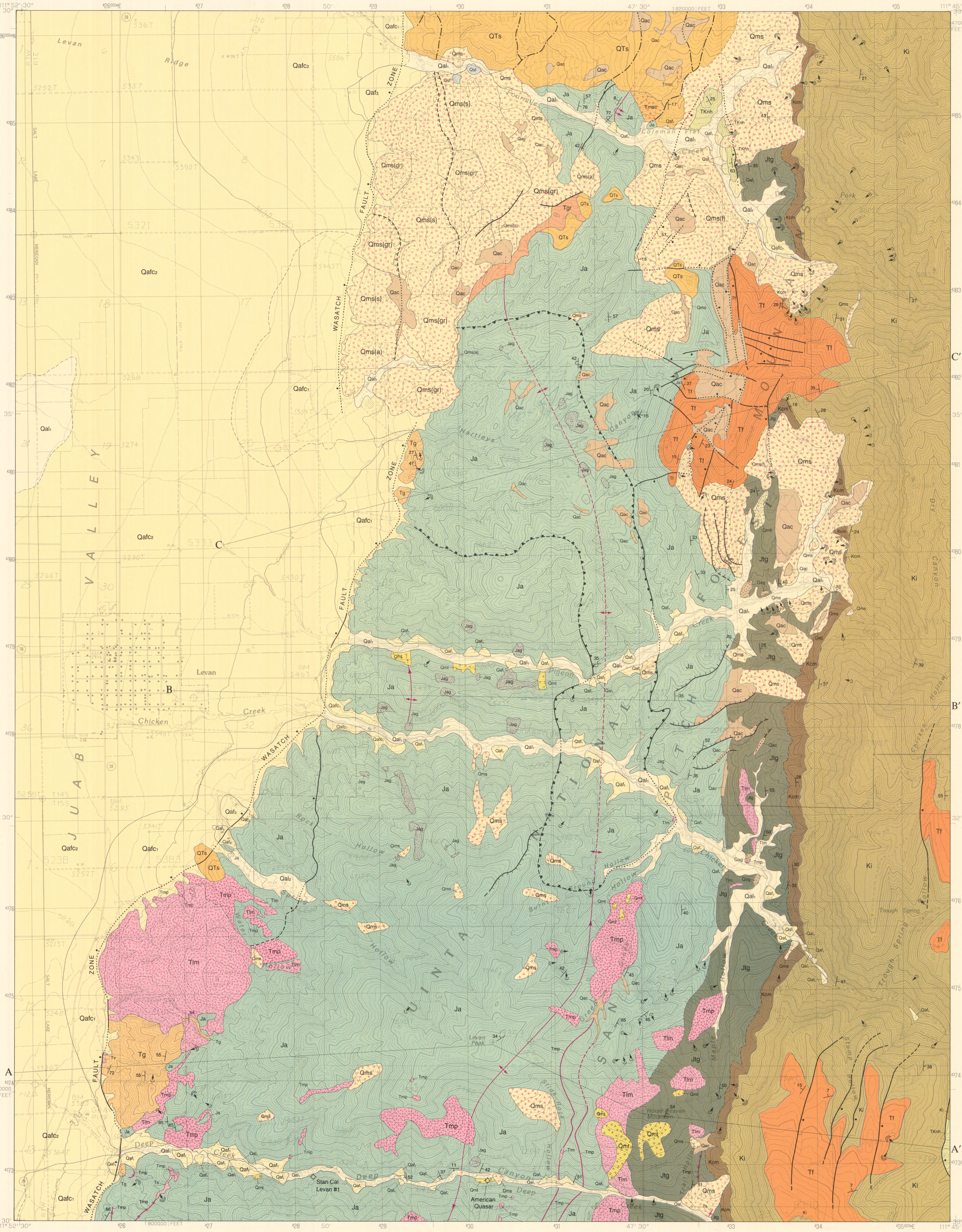
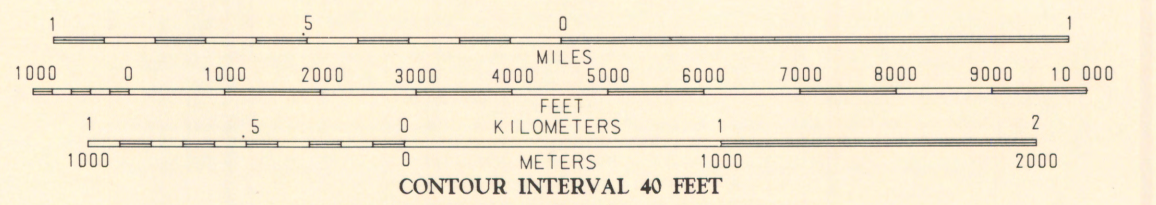
Plate 1
Utah Geological Survey Map 135
Provisional Geologic Map of the Levan Quadrangle



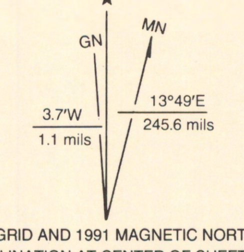
Base from U.S. Geological Survey Levan 7.5' Quadrangle, 1983

Thesis advisor: Dr. Malcolm P. Weiss
Cartography by K. Brown and J. Parker

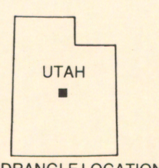
SCALE 1:24 000



CONTOUR INTERVAL 40 FEET
SUPPLEMENTAL CONTOUR INTERVAL 20 FEET



UTM GRID AND 1991 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET



QUADRANGLE LOCATION

PROVISIONAL GEOLOGIC MAP OF THE LEVAN QUADRANGLE, JUAB COUNTY, UTAH

by

William L. Auby

1991

DESCRIPTION OF MAP UNITS

Qst Spring tufa — *Pink to pinkish-gray, coarsely crystalline limestone. Forms a thin coating on older deposits.*

Qal1 Younger alluvial deposits — *Reddish-brown or very light-gray, stratified, poorly sorted clay- to cobble-sized sediment. Found in major canyons, currently being dissected.*

Qag Alluvial gravel deposits — *Pebble- to cobble-sized quartzite and limestone clasts mixed with sand and silt. Occur in small patches elevated 80-100 feet (24-30 m) above stream level.*

Qafc (1, 2) Qaf (1, 3) Alluvial fan deposits — *Poorly sorted clay, silt, sand, gravel, and boulders that reflect local sources. Coalesced alluvial fans along the main mountain front are denoted by "Qacf"; single fans at mouths of tributary canyons are denoted by "Qaf." The numbers differentiate three ages of alluvial fans. The oldest (Qaf3) occur as elevated erosional remnants at the edge of Juab Valley about 40 feet (12 m) above the current stream elevation. All mapped intermediate-age fans are coalesced (Qafc2) and extend far out into Juab Valley. The youngest alluvial fans occur as coalesced fans along the edges of Juab Valley (Qafc1) and as single fans in the major canyons (Qaf1).*

Qac Alluvium and colluvium — *Sand, silt, and clay washed from adjacent slopes, with a large colluvial component. Covered with brownish-black or grayish-brown soil. Found in small depressions or on gentle slopes.*

Qal2 Older alluvial deposits — *Poorly sorted clay- to cobble-sized sediment more elevated than Qal1.*

Qmt Talus deposits — *Angular, blocky fragments deposited on or at the base of steep slopes; commonly cobble to boulder sized, but ranging up to very large blocks.*

Qms (s, gr, a) Fourmile Creek landslide complex — *Extremely poorly sorted clay- to boulder-sized material deposited as slumps, landslides, and debris flows. Characteristically have a hummocky topography, are heavily vegetated and soil covered. Derived from the Salt Creek Fanglomerate (Qms(s)), the Golden's Ranch Formation (Qms(gr)), and the Arapien Shale (Qms(a)). Similar to other landslide deposits.*

Qms Landslide deposits — *Extremely poorly sorted clay- to boulder-sized material deposited as slumps, landslides, and debris flows. Characteristically have a hummocky topography, are heavily vegetated and soil covered.*

Qmfr Remnant debris-flow deposit — *Silt to cobble-sized detritus from the Flagstaff Limestone.*

QTs Salt Creek Fanglomerate — *Light red with associated reddish soil cover. Gravel consisting of well-rounded quartzite and limestone clasts, locally cemented and interbedded with sandstone. Quartzite clasts are white, light brown, reddish and purplish. Limestone clasts are dark gray and commonly contain Paleozoic fossils.*

Tmsc Slide block consisting of Cedar Mountain Formation.

Ts / Tlm / Tmp Levan monzonite suite — *Shallow intrusive rock consisting of monzonite porphyry (Tmp), white leucomonzonite (Tlm) and dark gray syenite (Ts) that forms stocks, dikes and sills. Monzonite porphyry contains 30-35% phenocrysts consisting of hornblende, orthoclase, plagioclase, biotite and magnetite. Leucomonzonite contains 5-7% phenocrysts consisting of plagioclase, orthoclase, biotite and magnetite. Syenite consists of 50% orthoclase, 25% biotite, 13% plagioclase, 7% magnetite and 2% quartz.*

Tgr Goldens Ranch Formation — *Light gray with medium- to dark-gray clasts. Gravel consisting of volcanic clasts and minor quartzite and limestone clasts. Locally cemented and bedded with volcanic sandstone.*

Tv Volcaniclastic rocks of unknown affinity — *Greenish-gray volcanic sandstone and volcanic conglomerate. Weathers to grayish-purple. Conglomerate contains clasts of quartzite, chert, sandstone and volcanic rocks. Sandstone has a chlorite matrix.*

Tg Green River Formation — *Medium-gray limestone and light-gray mudstone with interbedded, "tawny" limestone, sandstone, siltstone and conglomerate. Limestone is commonly sandy, micritic, fossiliferous and oolitic. Sandstone commonly found as channel fill and exhibits cross-bedding and scour and fill structures.*

Tf Flagstaff Limestone — *Yellowish-gray, interbedded, sandy limestone and calcareous mudstone. Limestone is micritic and commonly contains stromatolites, oncolites, root casts and chert nodules. Mudstone is commonly silty.*

TKnh North Horn Formation — *Light gray and yellowish-gray, interbedded mudstone, sandstone, and minor amounts of conglomerate.*

Ki Indianola Group — *Reddish-brown and light gray, massive, cliff-forming conglomerate consisting of cobble- to boulder-sized clasts of quartzite and limestone. Yellowish-brown and light gray sandstone, fine to coarse grained and locally ferruginous. Minor amounts of reddish-orange siltstone and red mudstone. Very rare limestone.*

Kcm Cedar Mountain Formation — *Interbedded reddish-orange siltstone and reddish-brown, fine- to coarse-grained sandstone. Minor amounts of conglomeratic sandstone and limestone. Contains limestone nodules and polished chert pebbles.*

Jtg Twist Gulch Formation — *Interbedded pale reddish-brown siltstone and sandstone with minor amounts of conglomerate and mudstone. Sandstone is thin to medium bedded and fine grained.*

Ja Arapien Shale — *Light olive gray and light gray, argillaceous micrite and calcareous mudstone, platy and laminated bedding. Forms weathered slopes. Contains lenses of gypsum and red mudstone. Interbedded yellowish-gray sandstone and siltstone in upper 1/4 of unit, ledge-forming limestone in lower 3/4.*

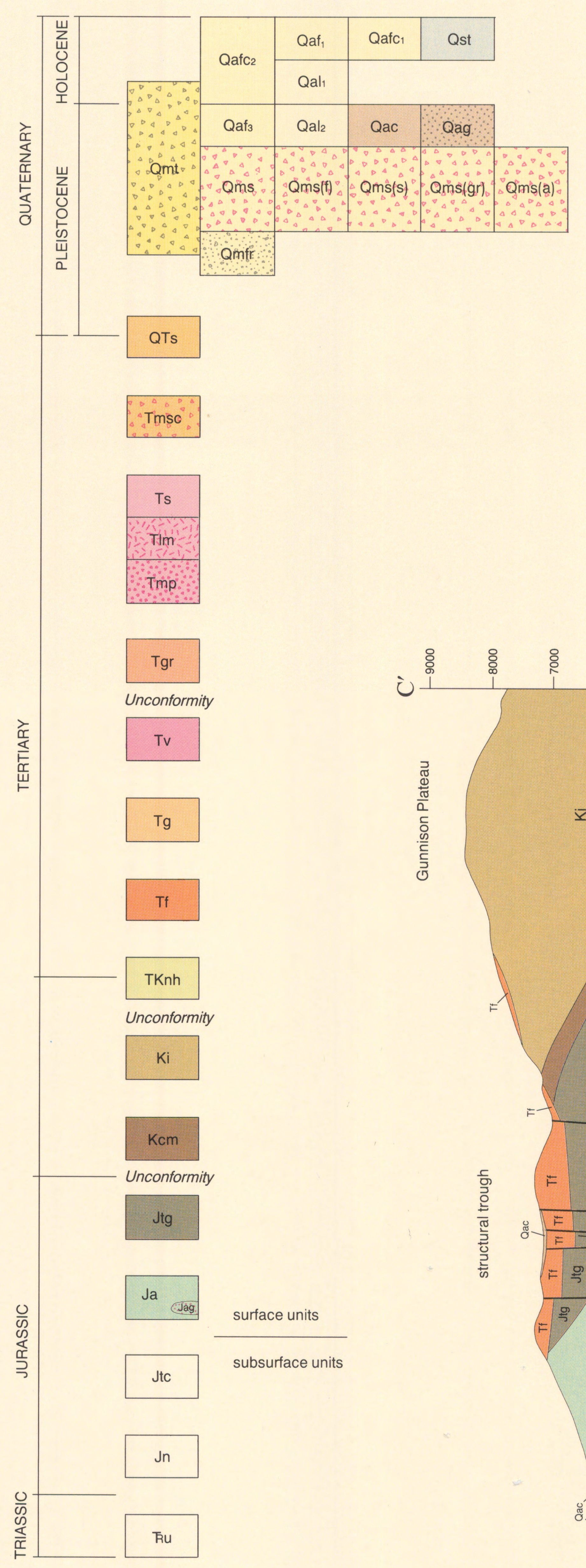
Jag Gypsum deposits in the Arapien Shale — *Lenses and beds of pale gray to white massive gypsum. Predominantly rock gypsum, but selenite and satin spar occur.*

Jtc Twin Creek Limestone — *Shown only on the cross section.*

Jn Navajo Sandstone — *Shown only on the cross section.*

TRu Triassic rocks, undifferentiated — *Shown only on the cross section.*

CORRELATION OF MAP UNITS



MAP SYMBOLS

Contact: *dashed where approximate.*

Normal fault: *bar and ball on downthrown side; dashed where inferred; dotted where covered.*

Reverse fault: *teeth on hanging wall; dotted where covered.*

Diapiric contact: *rectangle on diapiric mass; dashed where approximate; dotted where covered.*

Slump scarp: *hachured on downthrown side; dashed where inferred; dotted where covered.*

Fault inferred from air photos; may be slump scarp.

Anticline: *showing trace of axial plane and plunge of axis; dotted where projected beneath geologic units; dashed where modified by diapirism.*

Overturned anticline: *showing trace of axial plane.*

Landslide and debris flow scarp and path.

Rotational slump scarp and path.

35 Strike and dip of bedding.

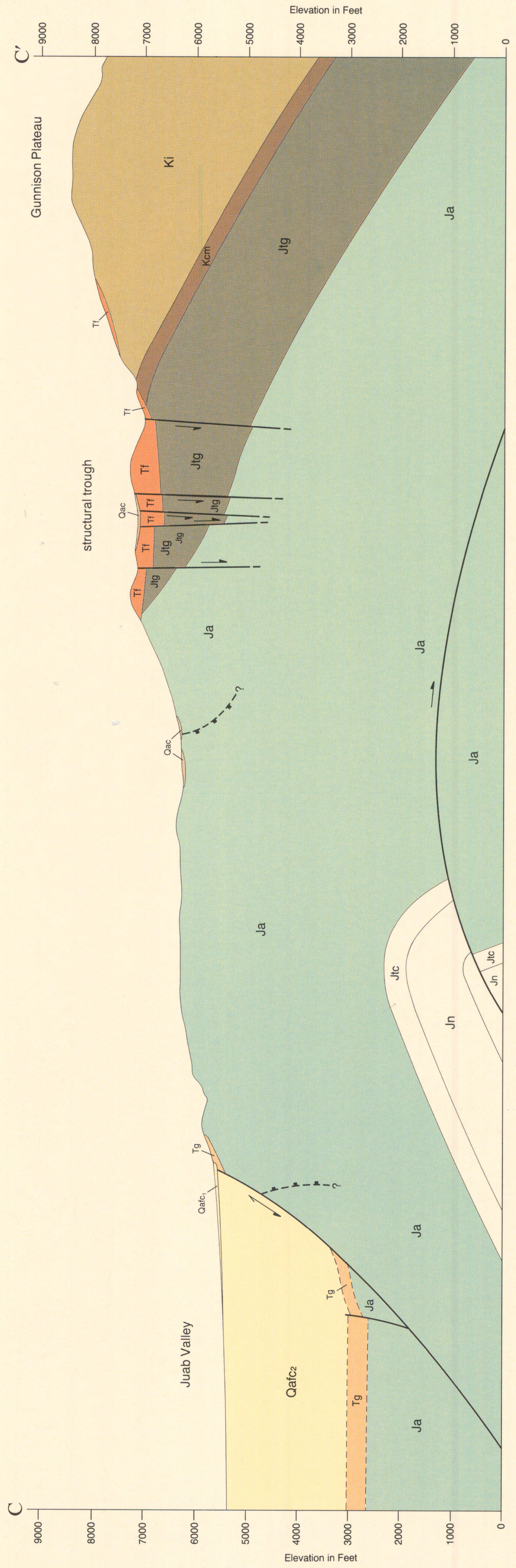
77 Strike and dip of overturned bedding.

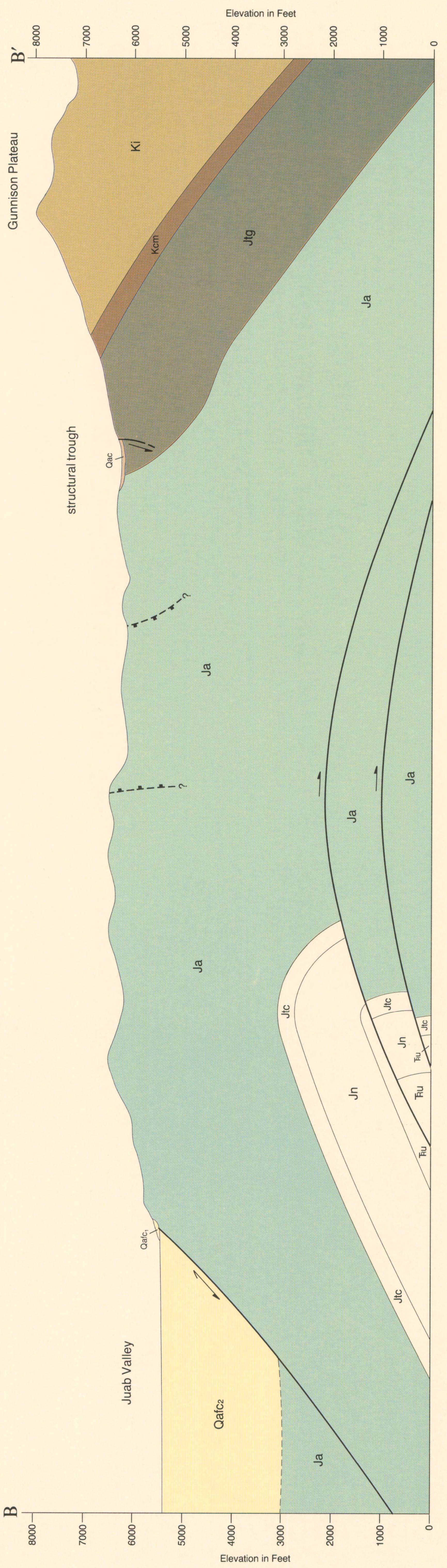
Dike

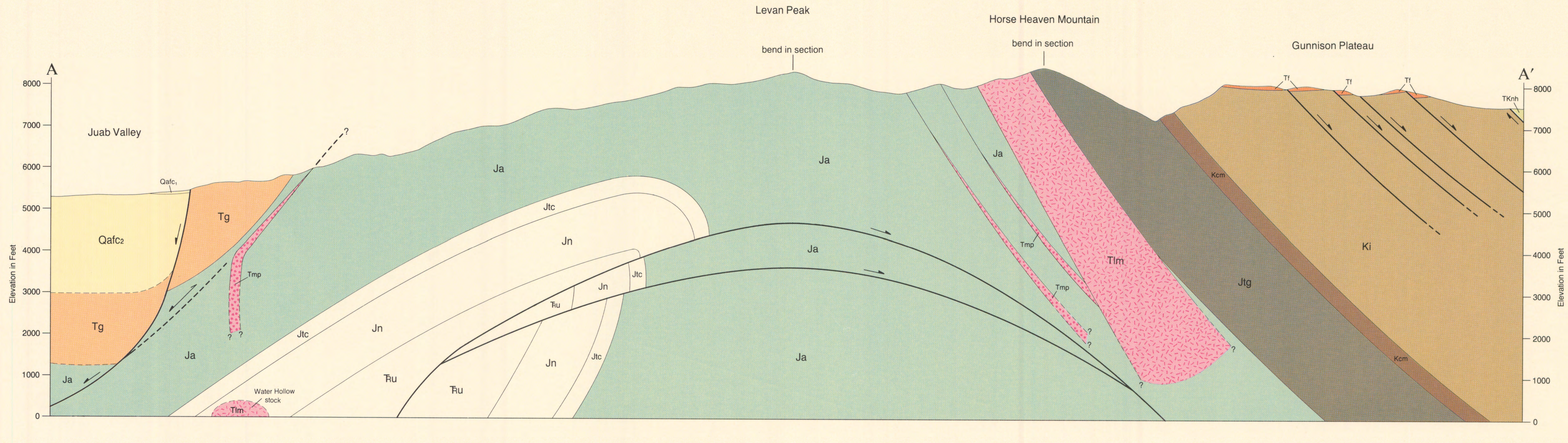
Sill: *dashed where approximate.*

Abandoned well: *oil or gas.*

Compound movement: *primary direction shown by open arrow; secondary movement shown by solid arrow; only on cross section.*





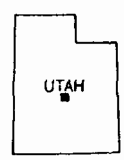


W.L. Auby PROVISIONAL GEOLOGIC MAP OF THE LEVAN QUADRANGLE, JUAB COUNTY, UTAH UGS MAP 135

PROVISIONAL GEOLOGIC MAP OF THE LEVAN QUADRANGLE, JUAB COUNTY, UTAH

by

William L. Auby
Northern Illinois University



MAP 135 **1991**

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PROVISIONAL GEOLOGIC MAP OF THE LEVAN QUADRANGLE, JUAB COUNTY, UTAH

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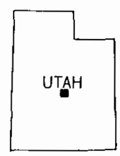

MAP 135 **1991**
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PROVISIONAL GEOLOGIC MAP OF THE LEVAN QUADRANGLE, JUAB COUNTY, UTAH

by William L. Auby
Northern Illinois University

ABSTRACT

The Levan quadrangle is located along the northwestern part of the Gunnison Plateau. Rocks mapped range from Jurassic marine sediments to Quaternary surficial deposits. The Jurassic Arapien Shale is the most extensive unit mapped and, despite its name, is composed largely of thin-bedded to laminated micrite. Terrestrial Cretaceous strata were deposited in a thick, coarse clastic wedge adjacent to the Sevier orogen. Latest Cretaceous and early Tertiary strata were deposited in a foreland basin between the Sevier orogenic belt and the Laramide uplifts farther east. Depositional settings at that time progressed from alluvial to lacustrine. Volcanism occurred in the Oligocene and Miocene and is represented by volcaniclastic sediments and igneous intrusives. Monzonite intrusives yield a radiometric age of approximately 23.4 Ma. The Pleistocene is represented by large mass-movement deposits.

The structure of the area is dominated by the broad Levan anticline, which was formed by the stacking and bending of thrust sheets during the Sevier orogeny in Late Cretaceous time. The anticline is cored by the Arapien Shale, which is disharmonically folded above a tightly folded Navajo Sandstone.

The anticline remained an upland throughout the latest Cretaceous-early Tertiary time. North Horn beds are mostly absent from the Levan quadrangle but lap unconformably onto the anticline farther east. Both the Flagstaff Limestone and the Green River Formation unconformably overlie the anticline in the quadrangle.

Cenozoic tectonism included the intrusion of a diapir into the crest of the anticline, collapse of the east limb into a structural trough adjacent to the diapir, folding of the Gunnison monocline, and formation of the Gunnison Plateau and Juab Valley, which are separated by the Wasatch fault. Landsliding, earthquakes, and flash floods are the major geologic hazards. Sand and gravel, gypsum, limestone, and petroleum represent potential resources of the Levan quadrangle.

INTRODUCTION

Edmund Spieker (1946 and 1949) defined much of the stratigraphy of central Utah and worked out the regional structure. Faculty and students of Ohio State University and, more recently, Northern Illinois University, have continued mapping in the area and have carried out many detailed investigations on the individual formations of the Gunnison Plateau.

Preliminary mapping, which included the Levan quadrangle, was first conducted by Hunt (1950) as part of his study of the northern Gunnison Plateau. The tectonic development of the plateau was first addressed by Spieker (1949). The idea of salt tectonics as a mechanism for the tectonic development of the region was first hypothesized by Stokes (1952, 1956), and more recently by Witkind (1982). Gilliland (1963) recognized the possibility of shale diapirism in Sanpete Valley. Standlee (1982) and others proposed that eastward-directed overthrusting and later basin and range normal faulting are the main mechanisms of tectonic development in central Utah.

STRATIGRAPHY

The exposed bedrock of the Levan quadrangle ranges in age from Jurassic to Tertiary and surficial deposits range in age from Pleistocene to Holocene. The strata reflect the major tectonic settings which existed in central Utah from the Jurassic to the present. The oldest exposed formation is the Middle Jurassic Arapien Shale, a muddy marine carbonate unit deposited on a stable platform directly east of the Cordilleran miogeocline (Burchfiel and Hickcox, 1972; Standlee, 1982).

A change from carbonate marine to clastic nonmarine deposition took place in the Late Jurassic. The Upper Jurassic Twist Gulch Formation was deposited in a marginal marine environment. Strata of the Cretaceous System were deposited on a foreland as compressional deformation and mountain building were taking place to the west. Cretaceous beds are represented by a thick, coarse, clastic wedge deposited in the foredeep directly eastward of the Sevier orogenic belt. The Lower Cretaceous Cedar Mountain Formation is thought to be the first synorogenic unit (Stokes, 1972), although deformation may have begun in the Late Jurassic in Nevada and western Utah (Armstrong, 1968). The bulk of the clastic wedge in the Levan quadrangle consists of the Upper Cretaceous Indianola Group.

The entire sequence was deformed by a late stage of Sevier thrusting in the late Cretaceous, and strata of latest Cretaceous and Tertiary age overlie the older rocks with angular discordance. After deformation, the Sevier orogenic belt continued to be a major source of clastics, through the early Tertiary, shed into a series of basins developed between it and Laramide uplifts to the east. Sediments deposited in the Levan area from latest Cretaceous time through the Eocene were alluvial (North Horn Formation) and lacustrine (Flagstaff Limestone and Green River Formation).

Mid-Tertiary volcanism is represented in the Levan area by volcaniclastic sediments and igneous intrusives. The volcanics may be related to the onset of extensional tectonics which created the present basin and range physiography. Quaternary surficial deposits include mass-movement deposits, several ages of alluvial fans, alluvium, and colluvium.

JURASSIC ROCKS

Arapien Shale (Ja) and gypsum beds (Jag) — The Arapien Shale is well exposed in the Levan quadrangle and forms rugged foothills between Juab Valley and the Gunnison Plateau. The highly deformed nature of this unit makes it difficult for stratigraphic study and has resulted in various tectonic interpretations. It is usually intricately folded and faulted except for the easternmost part which dips eastward. Lower Arapien strata are exposed in the middle and on the western side of the outcrop belt; upper Arapien rocks crop out only to the east. The north-central part of the belt has been deformed by diapirism.

The Arapien Shale is not completely exposed on the quadrangle, but the exposed section consists of light-gray micrite (80%), gray sparite (13%), and sandstone and siltstone (5%). Lenses of rock gypsum and grayish-red mudstone make up less than 2 percent. Hardy (1952) divided the Arapien in its type area into 5 subunits, A through E. In the Levan quadrangle two of his units are recognized. The lower 4000 feet (1219 m) of the exposed section is equivalent to Hardy's unit A and the upper 1500 feet (457 m) are equivalent to his unit C.

The lower Arapien contains beds of light-gray sparite (coarse-crystalline limestone) and lenses of gypsum interbedded with micrite (micro-crystalline carbonate mudstone). The micrite is the most abundant rock type and is composed of microcrystalline calcite. Its colors include light gray, medium gray, olive gray, light olive gray, and pinkish gray. Ripple marks and flaser bedding are common and interference ripple marks are rare. The sparite beds are commonly massive, range in thickness from 1 to 10 feet (0.3 to 3 m), and form resistant ledges in contrast to the slope-forming micrite. Gypsum lenses are well exposed in Chicken Creek Canyon, Pigeon Creek Canyon and in the upper Hartleys Canyon area. A lens is typically 200 feet (61 m) thick and several hundred feet long. Rock gypsum dominates, but large selenite crystals and satin spar are also present.

The upper Arapien contains sandstone and siltstone beds interlayered with micrite. The sandstone is fine to medium grained, friable and commonly ripple marked. Bedding is thin to thick and forms ledges 1 to 15 feet (0.3 to 4 m) thick. The siltstone is thickly laminated to thinly bedded and commonly contains cross-laminae. Beds are calcareous and ripple marked and coal fragments were found in one outcrop. The sandstone and siltstone are commonly grayish yellow green, yellowish gray , grayish yellow, and light greenish gray.

Thin-section analysis of sandstone samples produced the following data: the sandstone is weakly cemented with calcium carbonate, and quartz and minor amounts of chert make up 80 to 95 percent of the grains. Rock fragments, consisting of limestone, ooliths, and claystone, make up most of the remainder. Feldspar and glauconite occur in trace amounts. The grains are subangular to subrounded.

The Arapien Shale was deposited in a large, restricted marine embayment that developed during a major regression of an epeiric sea that covered the western edge of the North American craton (Sprinkel and Waanders, 1984). Shallow marine to intertidal and estuarine environments of deposition were periodically hypersaline (Picard, 1980).

In the Levan quadrangle the thickness of the Arapien Shale has been greatly increased by folding and duplexing related to thrust faulting. The maximum orderly thickness that can be observed is the uppermost 1600 feet (183 m) in Chicken Creek and Pigeon Creek Canyons. The total thickness of the Arapien Shale is 5472 feet (1667 m) in the Dixel Resources #1 Gunnison State well (section 15, T. 16 S., R. 1 E.) and 5690 feet (1734 m) in the Chevron U.S.A. #1 Chriss Canyon well (section 33, T. 16 S., R. 1 E.) (Standlee, 1982).

The lower contact of the Arapien Shale is not exposed in the quadrangle, as throughout most of central Utah. The nearest exposure is on the ridge between Quaking Asp Canyon and Red Canyon northeast of Nephi (Biek, 1987),where it rests conformably on the Twin Creek Limestone. The Arapien Shale is conformably overlain by the Twist Gulch Formation, and a sharp contrast between the light grey of the Arapien Shale and pale reddish-brown of the Twist Gulch easily distinguishes the contact. Locally, in the Levan quadrangle the Arapien Shale is unconformably overlain by the Tertiary Flagstaff Limestone, Green River Formation and by volcaniclastics and fanglomerate.

Fossils are rare in the Arapien Shale, but Sprinkel and Waanders (1984) have recognized a dinoflagellate assemblage of Bathonian age in the lower Arapien and a Callovian assemblage in the upper Arapien Shale. In contrast, Villien (1984) reported on a microfossil assemblage from samples obtained in the Chicken Creek area. Villien found the lower Arapien to be of Bathonian to late Callovian age and the upper Arapien to be of Oxfordian to Kimmeridgian age. He concluded that the Arapien is temporally equivalent to the Curtis and Morrison Formations in eastern Utah and the Stump Formation of northern Utah.

Twist Gulch Formation (Jtg) — In the Levan quadrangle, the Twist Gulch Formation is exposed as a narrow north-south-trending belt in the east-central part of the quadrangle, between the plateau escarpment and the rugged Arapien hills. Between Pigeon Creek and Fourmile Creek it is covered by Tertiary strata while north of Fourmile Creek it is obscured by large Quarternary landslide complexes. Generally, the Twist Gulch is poorly exposed and weathers easily. Much of it is covered with a thin layer of colluvium and good exposures exist only in the walls of canyons.

The Twist Gulch Formation is mostly pale reddish brown and consists of interbedded sandstone (54%), siltstone (30%), mudstone (15%), and conglomerate (1%). Generally, the siltstone and mudstone are slope formers and the sandstone and conglomerate are ledge formers. Sandstone is typically thin to medium bedded, but thick to massively bedded ledges occur. Sandstone ledges range in thickness from 4 to 7 feet (1.2 to 2 m). The sandstone is friable and ranges from very fine grained to coarse grained but is typically fine-grained. Sandstone beds show planar cross-stratification, with alternating fine- and medium-grained cross laminae. Pebbly and gritty lenses are common at the bases of thicker sandstone beds.

The sandstone ranges from quartz arenite to subarkose and is weakly cemented with calcium carbonate and hematite. Composition consists of 87 to 97 percent quartz, 3 to 9 percent feldspar, and less than 5 percent rock fragments. Heavy minerals include 1 to 2% magnetite and a trace amount of tourmaline; the rock fragments consist of volcanic fragments, limestone and mudstone. The grain shapes are subrounded to rounded.

Siltstone is thin bedded, friable and is typically found interlayered with very fine-grained sandstone. Together, they occur in intervals of 20 to 60 feet (6 to 18 m) and form moderate slopes.

The conglomerate is crudely bedded to massive and forms ledges up to 15 feet (4.5 m) in thickness but typically 6 feet (1.8 m) thick or less. It is lighter in color and contains lenses of coarser conglomerate and graded sandstone lenses. The conglomerate is composed of granule- to pebble-sized clasts consisting mostly of variegated chert and lesser amounts of limestone, mudstone, quartz, and feldspar.

Thin beds of mudstone occur throughout the Twist Gulch section. These layers are of a dark-red color and are compacted into wavy, irregular beds 3 to 4 inches (8 to 10 cm) thick. The upper 150 feet (46 m) of the formation is dominantly red mudstone with irregular lenses of pale red purple-weathering mudstone.

The Twist Gulch Formation was deposited in a marginal marine (Hunt, 1950), probably deltaic, setting which prograded into the Arapien marine embayment. Possible sourcelands were the Uncompahgre Uplift to the east and the rising Sevier highlands to the west.

The thickness of the Twist Gulch Formation in Chicken Creek Canyon is 1667 feet (508 m). It is overlain by the Cedar Mountain Formation and the upper contact is almost everywhere covered; the exposed contact in Chicken Creek Canyon appears to be erosional. In the Nephi area the contact may be gradational (Biek, 1987).

Like the Arapien Shale, the Twist Gulch is difficult to correlate because of the inability to trace the formation laterally and the lack of fossils. Most workers believe the Twist Gulch is equivalent to the upper Jurassic San Rafael Group of eastern Utah. Imlay (1964) reported the presence of at least one species *(Melagrinella curta)* in the upper Twist Gulch that is unknown except in the Curtis Formation or its equivalents. Similar lithology led Stokes (1972) and Standlee (1982) to believe the Twist Gulch is correlative with the Curtis and Summerville Formations of eastern Utah and the Stump Formation of northern Utah. Villien (1984), however, reported that non-marine palynomorphs of Early Cretaceous (Aptian to Albian) age have been found in Chicken Creek Canyon in the Twist Gulch Formation and suggests it to be equivalent to the Kelvin Formation of northern Utah.

CRETACEOUS ROCKS

Cedar Mountain Formation (Kcm) — The Cedar Mountain Formation does not crop out well in the Levan quadrangle because it is largely obscured by landslides and colluvium. The Cedar Mountain Formation consists of siltstone (30%), sandstone (30%, conglomeratic sandstone (20%), mudstone (20%) and locally, fresh-water limestone. The sandstone is moderate reddish orange, pale reddish brown, and moderate reddish brown; the siltstone is moderate reddish orange and the mudstone is dark reddish brown. The moderate reddish orange color helps to distinguish this formation from the underlying Twist Gulch Formation.

Limestone nodules and polished chert pebbles are distinguishing features of the Cedar Mountain Formation. These are most commonly found as float in covered areas. The nodules are mostly 2 to 3 inches (5 to 7 cm) in diameter and the polished chert pebbles are commonly ½ to 1 inch (1.2 to 2.5 cm) in diameter.

The base of the formation is marked by an 18-foot-thick (5 m) ledge of cross-stratified sandstone that rests disconformably on the Twist Gulch mudstone. It is thick bedded and contains pebbly lenses which locally fine upward into mudstone. This bed is exposed intermittently from the south side of Chicken Creek Canyon to a major tributary canyon on the north side of Pigeon Creek Canyon. The remainder of the section consists of the lithologies listed above. The sandstone is thin to thick bedded and typically forms ledges 2 to 5 feet (0.6 to 1.5 m) thick. It is friable and fine to very coarse grained. The sandstone is quartz arenite weakly cemented with calcium carbonate and hematite. Quartz and minor amounts of chert comprise 98 to 100 percent of the grains, feldspar 0 to 2 percent, and limestone fragments occur in trace amounts. Trace quantities of magnetite and zircon grains are also present. Grain shapes range from angular to rounded.

Conglomeratic sandstone forms ledges 5 to 15 feet (1.5 to 4.5 m) thick and contains pebble- to cobble-sized clasts which float in a sandstone matrix of various grain sizes. Beds are somewhat massive but contain conglomerate lenses. Siltstone and mudstone are typically interbedded, forming covered slopes of 20 to 40 feet (6 to 12 m) in thickness.

The Cedar Mountain Formation was deposited in alluvial fans, braided floodplain and lacustrine settings (Stuecheli, 1984). The sediments were shed eastward from the rising Sevier highland to the west. In Chicken Creek Canyon the thickness of the Cedar Mountain Formation is 305 feet (92 m). It thickens northward and Biek (1987) reported the unit to be 680 feet (207 m) thick in an exposure east of Nephi and north of Salt Creek Canyon.

The upper contact of the Cedar Mountain Formation is easily discernible throughout the area. It is placed beneath a massive, clast-supported boulder conglomerate in the Indianola Group which forms an easily traceable ledge. Below the contact, the Cedar Mountain is not well exposed and is usually covered. In Chicken Creek Canyon the contact is somewhat gradational and sandstone grades to conglomeratic sandstone and into the clast-supported Indianola conglomerate over an interval of less than 5 feet (1.5 m). Elsewhere, Indianola conglomerate appears to overlie covered Cedar Mountain mudstone.

Formerly, this unit was termed the Morrison (?) Formation by Spieker (1946, 1949), who thought it might correlate with the Morrison Formation of eastern Utah. Later it was suggested that these beds are correlative to the Lower Cretaceous Cedar Mountain Formation of eastern Utah, based on lithology and stratigraphic position (Stokes, 1972). Stuecheli (1984) found bivalves belonging to the freshwater genus *Protelliptio* (Barremian to early Cenomanian) and leaf impressions of primitive Early Cretaceous angiosperms. Therefore, the author has mapped the unit as the Cedar Mountain Formation and it is correlative to the Kelvin Formation of northern Utah (Standlee, 1982).

Indianola Group (Ki) — The Indianola Group is exposed along the eastern edge of the Levan quadrangle. It forms a prominent escarpment extending the length of the quadrangle and consists of a thick sequence of boulder conglomerate (51%) with interbedded sandstone (26%), mudrock (23%), and a minor amount of freshwater limestone. The conglomerate is gray or reddish gray, clast-supported, polymodal, and polymictic. Clasts are generally well rounded and range in size from pebbles to boulders. Clast percentages vary but average 80 percent of the rock. The clasts consist of variegated quartzite (60%), dark-gray, fossiliferous limestone (35%), and sandstone (5%). Typically, conglomerate beds form massive ledges 60 to 100 feet (18 to 30 m) thick. In places they weather to steep cliffs or pinnacles and form the escarpment on the northwestern edge of the plateau.

The sandstone is typically orange-red in the lower part and yellow-brown or very light-gray and ferruginous up-section. It occurs as lenses or covered intervals a few feet thick in the lower 3400 feet (1036 m), but forms ledges 40 to 180 feet (12 to 54 m) thick in the upper half of the section. The sandstone is medium to thick bedded and locally massive. It is typically friable and contains trough and planar cross stratification. Mudstone is interlayered with the sandstone and conglomerate and occurs as covered intervals averaging 5 feet (1.5 m) in thickness. It generally consists of reddish siltstone.

A 20-foot (6 m) interval of micrite and sandy micrite occurs in Chicken Creek Canyon near the middle of the formation. The fresh micrite is pale red but moderate reddish orange weathered. The sandy parts show well-developed cross stratification. It is medium to thick bedded, contains plant fragments, and is intercalated with sandstone and pebbly lenses.

The Indianola Group is a synorogenic unit that was deposited in the early Late Cretaceous foreland basin in front of the eastward-thrusted terrain of western Utah. Indianola strata were deposited proximal to the Sevier highland source. In Chicken Creek Canyon the Indianola Group is 6841 feet (2085 m) thick. Regionally, the Indianola thins and becomes finer to the east.

In the Levan quadrangle the Indianola is angularly overlain by patches of the Tertiary Flagstaff Formation. Based on the nonmarine palynomorphs found 120 feet (36 m) above the base in Chicken Creek Canyon (Standlee, 1982), the lowermost Indianola, perhaps the lower few hundred feet, is thought to be Early Cretaceous (Albion?) in age. The uppermost part of the Indianola is believed to be of Campanian age (Jefferson, 1982). The Indianola correlates with the Mancos Shale and Mesaverde Group of eastern Utah and the Frontier Formation and Echo Canyon Formation of northern Utah (Villien and Kligfield, 1986, p. 285).

CRETACEOUS—TERTIARY ROCKS

North Horn Formation (TKnh) — Exposures of the North Horn Formation are limited to Coleman Flat and to section 13, T. 15 S., R. 1 E., and both are incomplete. It consists of light gray mudstone, sandstone and minor amounts of conglomerate. The fresh rock is very light gray but weathers yellowish gray to grayish yellow. The sandstone is lithic and generally fine grained. Lenses of conglomeratic sandstone are common. Conglomerate beds with pebble- to cobble-sized clasts were observed on hill 6572 on the north side of Coleman Flat.

The North Horn Formation is of Maastrichtian to Paleocene age (Spieker, 1946). It was deposited in alluvial fans grading to fluvial and lacustrine environments and its source was the inactive Sevier orogenic belt (Birsa, 1973).

TERTIARY ROCKS

Flagstaff Limestone (Paleocene-Eocene) (Tf) — The Flagstaff Limestone of the Levan quadrangle forms an abutment of the escarpment between Pigeon Creek and Fourmile Creek, and it forms a thin caprock on top of the plateau along the southeastern quadrangle margin. The lithology differs in the two areas, but the limestones of both sections have been dolomitized to some extent. The section between Pigeon and Fourmile Creeks consists of interbedded sandy limestone and limy mudrock in about equal proportions. The limestone is micritic, is typically sandy or silty, and commonly contains allochems. Thin-bedded to platy micrites are interbedded with calcareous mudstone and together they form slope intervals 20 to 150 feet (6 to 45 m) thick. Medium- to thick-bedded micrites form ledges 2 to 15 feet (0.6 to 45 m) thick which make up about 30 percent of the section and locally contain conglomerate lenses of limestone and quartzite pebbles. The fresh limestone is light greenish gray near the base of the section, and yellowish gray, pinkish gray, very pale orange, grayish orange, and very light gray elsewhere. Typically, it weathers yellowish gray.

The limestone contains 0 to 40 percent sand grains which are subangular to subrounded, poorly to moderately sorted and which float in a micrite matrix. They are mostly quartz but include a few percent chert and quartzite and a trace amount of feldspar. Common sedimentary structures in the limestone include stromatolites, oncolites, root casts and, rarely, chert nodules.

Mudstone makes up about half of the section and consists of calcareous siltstone and calcareous mudstone. Typically, mudstone is yellowish gray and forms covered slopes. Siltstone is thin bedded to thickly laminated. A single tuff bed, 1 foot thick (0.3 m) and pale yellowish orange, occurs 620 feet (189 m) above the base.

The Flagstaff on top of the plateau is dominantly limestone and has a basal conglomerate. The basal conglomerate is a massive, cliff-forming bed, about 7 feet (2 m) thick consisting of clasts reworked from the underlying Indianola Group. The rest of the section consists of micritic limestone and a minor amount of mudstone. The fresh limestone is medium to light gray and yellowish gray on weathered surfaces. It is thin to thick bedded and typically a ledge former. Fossils are quite common in the limestones and generally increase up-section from a few percent just above the conglomerate to about 65 percent half-way up. Sand content generally decreases up-section, from 20 percent to none. Mudstone makes up less than 5 percent of the section and locally is a highly organic paper shale.

The Flagstaff Limestone was deposited in a lake or series of lakes developed in the early Tertiary foreland basin when drainage was blocked to the east by Laramide uplifting of the San Rafael Swell, Douglas Creek Arch, Monument Uplift, and Circle Cliffs. Clastic sources were the Sevier orogenic belt and the Levan and Sanpete Valley anticlines (Stanley and Collinson, 1979).

In the Levan quadrangle, the Flagstaff Limestone has an erosional top and it caps the folded Mesozoic strata. It is about 900 feet (270 m) thick in its thickest section between Pigeon Creek and Fourmile Creek where an incomplete section of 841 feet (256.3 m) was measured. The Flagstaff on the plateau, in the southeastern part of the quadrangle, is about 50 feet (15 m) thick but thickens rapidly southeastward in the adjacent quadrangle (Fountain Green South). Throughout most of central Utah, the Flagstaff is gradationally underlain by the North Horn Formation and it grades upward into the Colton Formation or the Green River Formation where Colton beds are absent.

In the Levan quadrangle between Pigeon Creek and Fourmile Creek, the Flagstaff rests above an angular unconformity on folded Arapien, Twist Gulch, Cedar Mountain, and Indianola strata. On the plateau, the Flagstaff rests unconformably on Indianola strata. The absence of Price River and North Horn strata suggests that the area was a paleohigh during the time that they were being deposited elsewhere. La Rocque (1960) collected several species of freshwater and land mollusks from the Flagstaff Limestone in the Wasatch and Gunnison Plateaus and determined a Paleocene to Eocene age for the unit.

Green River Formation (Eocene) (Tg) — In the Levan quadrangle, the Green River Formation crops out into three small exposures along the western edge of the mountain front. The largest exposure is just north of the mouth of Deep Canyon, where it is 1420 feet (430 m) thick. The Green River is dominantly limestone and dolomitic limestone (45%) interbedded with mudstone (40%) and lesser amounts of sandstone and siltstone (15%). The carbonate is medium dark gray, grayish orange, very pale orange, and yellowish gray and the bedding is platy to medium bedded. It is mostly micritic and commonly contains fossils, intraclasts, ooliths, and quartz grains. Mudstone is light gray, yellowish gray, and light olive gray and commonly forms slopes. Sandstone typically occurs as channels and lenses and some is conglomeratic. Sandstone exhibits scour and fill structures and trough cross stratification. The sedimentary structures, associated conglomerate, and geometry of the sand bodies indicate deposition in a fluvial environment, while the carbonate and mudstone were deposited in a shallow lacustrine setting. The unit was deposited in a marginal lake environment (Lake Uinta) with a prograding shoreline. Lake Uinta formed on a slowly subsiding basin between the Sevier highlands and the Laramide uplifts, including the then newly rising Uinta Uplift. It occupied much of the former Flagstaff basin but extended much farther east (Stanley and Collinson, 1979).

The Green River is overlain disconformably by the Crazy Hollow Formation in most places outside the quadrangle. In the Levan quadrangle, the Green River has an erosional top, rests in angular unconformity on the Arapien Shale, and it is intruded by igneous rock. Apparently, a portion of the quadrangle was still a paleohigh after Flagstaff deposition and was eventually overlapped by Green River strata.

Volcaniclastic rocks of unknown affinity (Tv) — Two small outcrops of greenish volcaniclastic rock occur at the top of the Green River section in the southwestern part of the quadrangle, just south of the first deep gulch north of the mouth of Deep Canyon (SESW section 7, T. 15 S., R. 1 E.). They are deeply weathered and poorly exposed, making it impossible to determine the bedding. It is not clear whether these rocks are lenses within the Green River or lie on top of it. The outcrops weather to grayish purple and are composed of greenish-gray volcanic sandstone and volcanic conglomerate. The sandstone is composed of about 25 percent quartz grains, 20 percent feldspar crystals, 5 percent rock fragments, 50 percent clay matrix, and a trace of magnetite. The quartz grains are subrounded and the feldspars are subhedral to euhedral. Feldspars are altered and appear as white specks in the sandstone. Rock fragments are angular and volcanic, and the clay matrix is secondary chlorite.

The conglomerate is composed of pebble-sized clasts of quartzite, chert, sandstone, and volcanic rock mixed with quartz grains and feldspar crystals. It is cemented with secondary chlorite, and locally with calcite. The volcanic clasts are medium gray and porphyritic, with phenocrysts of feldspar. The rocks represent a reworking of volcanic rock with sedimentary particles. These rocks may be correlative with the Goldens Ranch Formation, known to overlie the Green River farther south and on Long Ridge (Muessig, 1951), or the Moroni Formation. However, the lithology is unlike the Goldens Ranch or the Moroni Formations.

Goldens Ranch Formation (late Eocene to early Oligocene?) (Tgr) — Volcaniclastic rocks are exposed in the area between Fourmile Creek and the drainage area just north of Hartleys Canyon in slump masses and landslides. Schoff (1937) informally named them the Moroni Formation, but others have assigned them to the Goldens Ranch Formation (Muessig, 1951; Jefferson, 1982). The volcaniclastics of the Levan quadrangle are lithologically similar to both the Goldens Ranch and Moroni Formations and in this report they are labeled the former.

The Goldens Ranch Formation consists of waterlain volcanic conglomerate and volcanic sandstone. Both are weakly cemented and in most places have weathered to gravel-covered slopes. Locally, they are consolidated and crudely bedded. In such exposures, bedding is thick to very thick and cross stratification is common.

Volcanic conglomerate dominates the unit. Its color is light gray, but clasts are usually darker, ranging from medium gray to grayish black. Quartzite clasts are much lighter and their colors are variable. All clasts are pebble to boulder sized and are subangular to rounded. Most clasts are volcanic, with andesitic to rhyolitic types being the most common. They are commonly vesicular and porphyritic. Quartzite and limestone clasts are fairly common; some quartzite clasts are boulder sized. The clasts float in a volcanic sandstone matrix and make up about 45 percent of the rock. The matrix is a light-gray tuffaceous sandstone and ranges from fine sand to granules.

Light-gray tuffaceous sandstone is interbedded with the conglomerate. It is fine to medium grained and cemented with fine vitreous material which makes up about 25 percent of the rock. Sand fraction analysis is as follows: 55 to 70 percent feldspar crystals, 25 to 40 percent volcanic rock fragments, 3 percent quartz grains, 2 percent clinopyroxene grains, and a trace of magnetite grains. Grains are angular to subangular.

The Goldens Ranch Formation represents a reworking of ash with detritus, eroded from older volcanic flows and other rocks, deposited in an alluvial setting. Sources of the volcanic clasts probably include flows of latite and andesite from the Tintic mining district (Muessig, 1951). Other nearby vents may also have contributed material.

A complete section of this unit is not exposed in the Levan quadrangle, but it appears to range in thickness up to a few hundred feet. The Goldens Ranch Formation rests with angular unconformity on the Arapien Shale and is overlain by the Salt Creek Fanglomerate. The nature of the upper contact is uncertain but is probably disconformable because of the great age difference.

Lithologically, these volcaniclastic rocks are similar to both the Hall Canyon Member of the Goldens Ranch Formation (Clark, 1987) and the Moroni Formation in the Cedar Hills (Banks, 1986). Similar thickness and a closer proximity to the distribution of the Goldens Ranch favor correlation with the Hall Canyon Member. Radiometric ages obtained from apparent ash-flow tuffs within the Moroni Formation range from 35 to 39 Ma, and dates from the Goldens Ranch Formation range from 32 to 34 Ma (I.J. Witkind, personal communication, 1985). These dates are uncertain because of possible older xenocrystic or detrital minerals within the tuffs. If these volcaniclastics correlate with either one of these formations, then they were deposited in the late Eocene or early Oligocene.

Levan monzonite suite (early Miocene) — The intrusive igneous rocks that crop out along the western margin of the Gunnison Plateau were first described by Zeller (1949) who identified them as monzonite. John (1972) identified six rock types which are listed in chronological order: (1) porphyritic diabase, (2) biotite-augite monzonite, (3) hornblende monzonite porphyry, (4) monzonite porphyry, (5) porphyritic leucomonzonite, and (6) syenodiorite. Three of these occur in the Levan quadrangle: monzonite porphyry, leucomonzonite, and syenite. It is herein proposed that the name Levan monzonite suite be given to all the intrusives along the western margin of the plateau, as monzonite is the dominant rock type and syenite and diabase occur only in minor amounts.

Several stocks, sills, dikes, and small irregular masses of plutonic rock intruded the Arapien, Twist Gulch, and Green River Formations in the area west of the plateau escarpment between Chicken Creek and Little Salt Creek (Chriss Canyon quadrangle), a distance of 7 miles (11 km). The largest pluton is the Water Hollow stock, located a mile (1.6 km) south of Levan. It is about a mile (1.6 km) in diameter and has several satellite masses on its northeast and south sides. Extensive sills are found in Green Grove Hollow and in Horse Heaven Mountain. Another stock is located in the south flank of Levan Peak. Several dikes occur in Deep Canyon, Green Grove Hollow and Maple Hollow; and of three small sills, two occur in Deep Canyon and one is well exposed in Chicken Creek Canyon.

Monzonite porphyry (Tmp) — The monzonite occurs as a porphyry and as a slightly porphyritic, mafic-poor aphanite (leucomonzonite). The monzonite porphyry is older and more abundant and is found in the Green Grove Hollow sill, the Levan Peak stock, in several of the sills, dikes, and plugs around the Water Hollow stock, and in most of the smaller dikes and sills. The fresh color is medium light gray to light gray and light brownish gray weathered. The porphyry has an aphanitic groundmass and phenocrysts comprise 30 to 35 percent of the rock. The phenocrysts are rarely clustered. Hornblende and orthoclase phenocrysts are the most abundant; other phenocrysts are of plagioclase, biotite, magnetite, and quartz. The orthoclase crystals are commonly zoned and the plagioclase altered to calcite. The groundmass consists of cryptocrystalline feldspar.

Cognate inclusions of biotite-hornblende melamonzonite are fairly common in the monzonite porphyry. The inclusions are dark gray to black and range in size from 1 to 10 inches (2.5 to 25 cm) long. They have a phaneritic texture and are composed of hornblende (40%), biotite (30%), plagioclase (15%), orthoclase (10%), and magnetite (5%).

Leucomonzonite (Tlm) — At two localities leucomonzonite has intruded monzonite porphyry and is, therefore, younger. One location is along the westernmost of the two sills occurring in Deep Canyon (SW section 15, T. 15 S., R. 1 E.), the other is at the monzonite porphyry dike which is intruded by the Water Hollow stock (SW section 8, T. 15 S., R. 1 E.). Leucomonzonite comprises the Water Hollow stock, the Horse Heaven Mountain sill, two small dikes in Chicken Creek Canyon, and the Chicken Creek sill. Typically its outcrops are deeply weathered. Fresh surfaces are very light gray to white and weathered surfaces show a variety of colors, commonly pale yellowish brown, very pale orange, or grayish pink. The texture is aphanitic and slightly porphyritic. Phenocrysts make up 5 to 7 percent of the rock and include plagioclase (2-4%), orthoclase (2%), and magnetite (1%). Sphene and apatite are present in trace amounts. The orthoclase is commonly zoned and magnetite is commonly altered to hematite or limonite and much of the feldspar has been replaced by limonite. The groundmass consists of cryptocrystalline feldspar. Biotite comprises 1 percent of the Chicken Creek sill.

Syenite (Ts) — Two outcrops of syenite occur in the Levan quadrangle. One, a dark-gray biotite syenite located near the mouth of Deep Canyon has intruded into a monzonite porphyry dike. It has a fine-grained phaneritic texture and is slightly porphyritic. It contains 50 percent orthoclase, 13 percent plagioclase, 25 percent biotite, 7 percent magnetite, 2 percent quartz, 2 percent apatite, and 1 percent zircon. Replacement minerals include calcite and microcrystalline and chalcedonic quartz. The chert is found in the centers of calcite amygdules.

The other outcrop is a medium-bluish-gray porphyritic dike with an aphanitic groundmass located on the north side of Deep Canyon, and partly buried by a landslide deposit near the base of Horse Heaven Mountain (NW section 23, T. 15 S., R. 1 E.). It is composed of 8 percent phenocrysts: 3 percent orthoclase, 1 percent biotite, 3 percent apatite, and 2 percent magnetite. The groundmass is composed of cryptocrystalline feldspar and magnetite. The dike is extremely altered; much of the feldspar has altered to calcite, chlorite, and kaolinite.

Country rock alteration — Generally, the monzonite intruded the country rock without significant contact metamorphism. Slight alteration occurs in the Twist Gulch Formation on Horse Heaven Mountain and at the base of the Chicken Creek sill, where reddish-brown siltstones have been altered to light-olive-gray or pale-brown hornfels. The thickness of these zones is unknown.

Metasomatic alteration exists within the Green River limestones along the contact with the Water Hollow stock. Pyrite, sulfur, gypsum, and iron oxide minerals occur in shallow prospect pits. Iron minerals and gypsum are concentrated along bedding planes. Iron oxide minerals, pyrite, calcite veins, gypsum, and minute amounts of malachite were observed in a mine near the contact. Elsewhere, limestone shows recrytallization of calcite.

Two samples of igneous rock were submitted for radiometric dates using the potassium-argon method. A sample of leucomonzonite from the Chicken Creek sill yielded a date of 23.5 ± 1 Ma and a monzonite porphyry from Maple Hollow yielded a date of 23.3 ± 1.2 Ma. The time of intrusion is, therefore, early Miocene (Aquitanian).

Slide block of Cedar Mountain Formation (late Tertiary) (Tmsc) — A displaced mass of rock belonging to the Cedar Mountain Formation occurs on the north side of Fourmile Canyon in section 11, T. 14 S., R. 1 E., and rests against Arapien Shale. It is covered by the Salt Creek Fanglomerate and is, therefore, older than the Quaternary landslides.

Salt Creek Fanglomerate (late Tertiary - early Quaternary) (QTs) — The Salt Creek Fanglomerate is exposed along the northwestern margin of the Gunnison Plateau and throughout the Salt Creek area. In the Levan quadrangle, it forms a thin sheet covering the foothills on both sides of Fourmile Canyon. The southernmost exposure is in the southwestern part of the map area where a small gravel patch, consisting of quartzite and limestone cobbles, occurs on the south side of Spring Hollow. The most elevated exposure is on hill 7128 which is south of Coleman Flat.

Over most of its outcrop area, the Salt Creek is a thin, unconsolidated covering of cobble and pebble gravel. Most of the sand and mud has washed away leaving behind the gravel. Locally, it is well cemented and bedded, but only in small outcrops. The largest of these occurs in a small gulch on the north side of Coleman Flat where thick beds of conglomerate are interbedded with sandstone. Slopes covered with Salt Creek have a reddish soil cover and the underlying bedrock is commonly stained red from pigments washed down from it.

The clasts consist of well-rounded pebbles and cobbles of quartzite and limestone with rare boulders of quartzite. Quartzite predominates over limestone. The quartzite clasts are white, light brown, reddish, and purplish and the limestone clasts are bluish gray and commonly contain Paleozoic fossils. The clasts are reworked from the Mesozoic strata of the Salt Creek headwaters and nearby uplands, mainly from the Indianola Group.

The Salt Creek Fanglomerate was deposited in alluvial fan settings which seem to have worked their way down the Salt Creek area to spread over the northwest margin of the Gunnison Plateau and the southernmost Wasatch Mountains and probably well into the Juab Valley area. Its thickness ranges from 0 to about 150 feet (0 to 45 m) in the Levan quadrangle. It overlies the Arapien Shale in angular unconformity and the Tertiary volcaniclastic rocks disconformably.

The age of the Salt Creek has not been well established. Eardley (1933) suggested it may be late Tertiary or Pleistocene because of its unconformable relation with early Tertiary strata. The elevation at which this unit now resides (up to 1000 feet or 304 meters above the valley floor) and its disconformable nature support a late Tertiary age. Possible correlatives are the Axtell Formation of eastern Sevier Valley (Spieker, 1949) and the Sevier River Formation in the Pavant Range (Callaghan, 1938).

QUATERNARY DEPOSITS

Remnant debris flow deposit (Qmfr) — An erosional remnant of a debris-flow deposit of Pleistocene age occurs high up in the east wall of a canyon on the north side of Pigeon Creek (NW ¼, section 25, T. 14 S., R. 1 E.). The deposit is cut by the canyon and debris of the same flow occurs on the west wall, but there it is involved in a younger landslide (Qms). The deposit consists of silt to cobble-sized detritus from the Flagstaff Limestone.

Landslide deposits (Qms-Qms(f)) — Landslide deposits are most common within the Arapien foothills and along the base of the escarpment. They characteristically have a hummocky topography, are heavily vegetated, soil covered, and dissected by streams. Their weathered nature makes type of movement determination difficult. The larger deposits appear to be complex and were probably formed by several episodes of movement. Landslides composed entirely of debris from the Flagstaff Limestone are differentiated (Qms[f]), others are not (Qms). The deposits consist of clay to boulder-sized detritus and in some cases are crudely stratified.

The formations in which landslides mainly occur are the Arapien Shale, Twist Gulch and Cedar Mountain Formations. The former because it is composed chiefly of soft micrite and the latter two because they contain much mudstone.

The age of these deposits is apparently Pleistocene and, until recently, they have been stable. Many have been reactivated in very recent times, as evidenced by small slumps and slides that occur on them.

Fourmile Creek landslide complex (Qms(s)-Qms(gr)-Qms(a)) — The largest landslide complex occurs south of Fourmile Creek in sections 9, 10, 16, 15 and 21, T. 14 S., R. 1 E., and has been mapped separately as the Fourmile Creek landslide complex. It is made up of several large slumps, slides and flows covering an area of about 2.5 mi^2 (6.5 km^2), and involves debris from the Salt Creek Fanglomerate (Qms[s]), Goldens Ranch Formation (Qms[gr]), and Arapien Shale (Qms[a]). The underlying Arapien rocks experienced shear failure and carried rock from the other two units. The main body of the complex has a westward-directed displacement and moved out from the mountain front, creating a slight salient into Juab Valley.

The complex consists of clay to boulder-sized detritus and, rarely, large blocks of cemented Salt Creek Fanglomerate. The surface is hummocky and broken by many slump scarps.

The age of the complex is probably Pleistocene and has been stable since then. The slump scarps are deeply eroded and, in places, buried under alluvium and slopewash (Qas). In addition, the complex is heavily vegetated and stream dissected.

Talus (Qmt) — Talus, produced by rock fall, occurs in several patches on the southern flank of Horse Heaven Mountain and as talus cones in Pigeon Creek. The deposits on Horse Heaven Mountain form slopes, averaging about 30 degrees, of blocky material derived from two sources, the monzonite intrusives and hornfels of the Twist Gulch Formation. These blocks average about 15 inches (38 cm) in diameter. Much larger blocks occur at the base of the monzonite porphyry outcrop in Green Grove Hollow. Many blocks are commonly tens of feet across.

The talus cones in Pigeon Creek consist of blocky fragments of micrite weathered from the Arapien Shale. The talus forms slopes averaging about 35 degrees and the average block size is 6 inches (15 cm) in diameter.

Alluvium and colluvium (Qac) — Deposits of alluvium with a strong slopewash component occur at several elevations throughout the foothills. These deposits consist of sand, silt, and clay washed from nearby hills and deposited during seasonal floods by slopewash processes and streams. All are associated with low-order ephemeral streams and are found in small depressions or on gentle slopes. They are easily spotted from a high vantage point or on air photos as grass-covered, relatively flat areas, in contrast to brush-covered steep slopes. They are usually covered by a well-developed soil, commonly a brownish-black or grayish-brown color.

These deposits have collected in a variety of geomorphic settings. They are found at the heads of slump masses, along slump scars, in sag hollows and in the grabens on top of the Flagstaff buttress. In the area around Pigeon Creek Canyon they form terrace-like features near the base of the escarpment, which may be elevated proximal fans or stream terraces.

Alluvial fans (Qaf_1-$Qafc_1$-$Qafc_2$-Qaf_3) — Three ages of alluvial fans are mapped in the Levan quadrangle. The oldest fans (Qaf_3) occur as elevated erosional remnants at the edge of Juab Valley. They are deeply eroded and of indeterminate thicknesses. They rise about 40 feet (12 m) above the current stream elevation. The fan near Fourmile Creek abuts against the Fourmile Creek landslide complex, which suggests that the fans are younger than the landslide deposits and may be of latest Pleistocene age.

The large coalescing fans that spread far into Juab Valley ($Qafc_2$) are of early Holocene age. These fans emanate from the mouths of major canyons in characteristic fan shape and merge. Their thicknesses are unknown and their fanheads are incised by channels indicating a downfan migration of the point source (Ritter, 1978, p. 278). The fans consist of poorly sorted clay, silt, sand, and gravel. Large boulders from the Indianola Group are common.

The youngest alluvial fans occur as coalesced fans along the edges of Juab Valley ($Qafc_1$) and as single fans in the major canyons (Qaf_1). The coalesced fans are deposited on top of older coalesced fans ($Qafc_2$) and have a slightly steeper slope. The toes of the younger fans can be identified along this change in slope. Their thicknesses are indeterminate but are calculated from profiles to range from 40 to 100 feet (12 to 30 m) at the fan apices. Their age may be middle or late Holocene.

Single fans (Qaf_1) occur at the mouths of tributary canyons emptying into the major canyons. Single fans have much steeper profiles than the fans in Juab Valley but are of similar thickness. The toes of these fans are usually truncated by stream erosion and the fans are commonly tree covered.

The sediments in the younger fans reflect the source rock that is adjacent to them. Most occur where the major canyons transect the Arapien Shale and are dominantly composed of Arapien micrite, locally a few contain detritus eroded from the monzonite intrusives. The coalesced fans in Juab Valley ($Qafc_1$) are mostly of Arapien detritus but locally include Green River, monzonite, Salt Creek, and volcaniclastic debris. Both types are crudely stratified and consist of poorly sorted clay to boulder-sized sediment.

Alluvial gravel (Qag) — Stream-deposited gravels (Qag) occur in tiny patches at elevated levels in Chicken Creek and Pigeon Creek Canyons. The gravels include clasts of quartzite and limestone mixed with sand and silt. They superficially resemble the Salt Creek Fanglomerate but are not cemented, do not have a red coloration, and occur at a much lower elevation than the Salt Creek. The gravels may correlate with the older alluvial fans (Qaf_3) and would therefore be latest Pleistocene in age.

Alluvium (Qal_1-Qal_2) — Two ages of alluvial deposits were mapped in the Levan quadrangle. The older deposits (Qal_2) occur in the lower reaches of Spring Hollow. Although their relationship to the younger alluvium (Qal_1) is not clear, they are thought to be older because of their steeper slope and association with the remnant fans (Qaf_3) which occur at the mouth. They are probably late Pleistocene in age and are currently being dissected by stream erosion.

The younger alluvial deposits occur in the bottoms of the major canyons and in the central part of Juab Valley. They consist of stratified and poorly sorted clay to cobble-sized sediment. Alluvium in tributary canyons, such as Maple Hollow, consists of poorly stratified sand, silt, and clay with rare pebbles. Alluvium is reddish brown where it is near the Twist Gulch bedrock and very light gray where it transects the Arapien foothills. The thickness is highly variable but does not exceed 40 feet (12 m). This alluvium is currently being dissected by stream erosion and is correlative to the large coalesced fans ($Qafc_2$) of early Holocene age.

Spring tufa (Qst) — Two small deposits of spring tufa occur on the south bank of Fourmile Creek near its mouth (SW ¼, section 3, T. 14 S., R. 1 E.). The pink to pinkish-gray limestone is coarsely crystalline, much like a marble, and forms a hard crust over the Salt Creek landslide rubble (Qms[s]). Smaller deposits can be found on the north bank. The springs were dry when I observed them in 1985.

STRUCTURE

The Levan quadrangle is located along the west side of the Gunnison Plateau. The plateau is a structural highland surrounded on three sides by structural valleys and connected to the autochthonous block of the Nebo thrust system to the north. Its principal structure is a north-south-trending syncline plunging gently southward. Tertiary strata form a westward-dipping monocline along the southwestern margin of the plateau (Hardy and Zeller, 1953), known as the Gunnison monocline. It is continuous for nearly 18 miles (29 km) from the southern end of the plateau to Little Salt Creek Canyon, all to the south of the Levan quadrangle. In the quadrangle it is recognizable between Deep Canyon and Hartleys Canyon by outcrops of westward-dipping Green River strata.

LEVAN ANTICLINE

The principal structure of the Levan quadrangle is a north-trending, doubly plunging anticline with its apex on the ridge connecting Levan Peak to Horse Heaven Mountain. The east limb is composed of Arapien to Indianola strata and is the same as the west limb of the Gunnison Plateau north-south-trending syncline. The west limb is complexly structured, consisting of many small folds which parallel the anticlinal axis, and of the westward-dipping Green River beds. It is cut by the Wasatch fault and the down-faulted part is buried beneath Juab Valley.

The anticline formed as a result of late Cretaceous folding and thrust faulting, as shown by two wells drilled in Deep Canyon and illustrated in cross-section A-A'. In the subsurface, the Navajo Sandstone and Twin Creek Limestone are folded into a series of overturned folds that are offset by thrust faults. Above the Twin Creek Limestone, the Arapien Shale is disharmonically folded and tectonically thickened. The intense folding and stacking of thrust sheets within and below the Arapien folded the overlying section into an anticline. The deformation was the result of a late Cretaceous (post-Indianola, pre-North Horn) episode of compressional tectonism occurring towards the end of the Sevier orogeny.

GUNNISON MONOCLINE

A west-dipping homocline consisting of Green River strata is superimposed on the west limb of the Levan anticline. The fold appears to be an erosional outlier of the northern end of the Gunnison monocline, which consists of Flagstaff, Colton and Green River beds farther south outside of the map area. Within the quadrangle, the fold is preserved in two separate outcrop areas, one between Deep Canyon and the Water Hollow stock and the other near the mouth of Hartleys Canyon.

The fold is interpreted to be an extensional fold because, at the time of folding, regional compressional tectonism had ended (Armstrong, 1968) and extensional tectonism may have begun. Possible mechanisms for formation of the fold include drag folding along the Wasatch fault or folding of the hanging wall over a thrust fault with a ramp/flat style of geometry as the thrust was reactivated with a reverse sense of movement. The latter model has been proposed for the development of the Wasatch monocline which occurs east of the quadrangle (Royse, 1983). The model involves a late Cretaceous thrust fault with a ramp/flat geometry (figure 1a) that was reactivated in the Tertiary as a normal fault. As the hanging wall moved relatively westward, the overlying Green River beds were bent over the fault (figure 1b). The Green River beds then became part of the footwall during subsequent formation of the Wasatch Fault (figure 1c).

Formation of the fold near Deep Canyon occurred sometime between the intrusion of the Water Hollow stock 23.5 Ma (early Miocene) and deposition of the Green River Formation (Eocene). The beds there dip 55° W. The Green River beds near Hartleys Canyon dip 37° W. and rest on a collapsed diapir. These beds were again deformed during formation and subsequent collapse of the Hartleys Canyon diapir, which is described below.

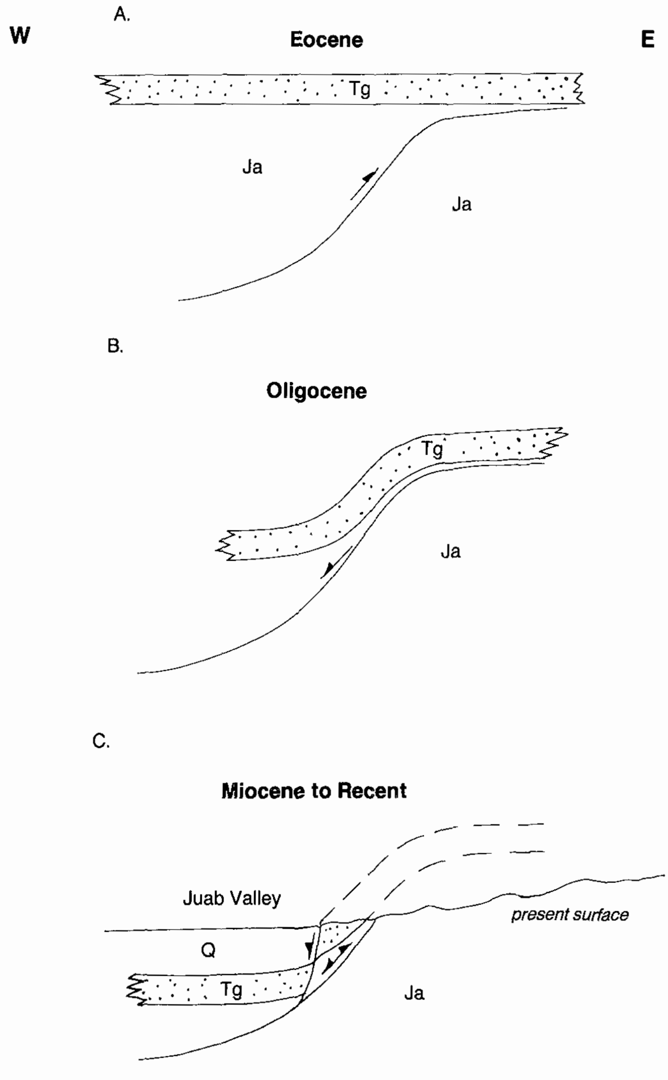

Figure 1. *Diagram showing evolution of the Gunnison monocline. a. Green River beds are deposited over thrust fault. b. The former thrust is reactivated with a reverse sense of direction, as a normal fault. Green River beds are bent over thrust ramp as the hanging wall moves relatively westward and downward. c. Formation of the present Wasatch fault produces a segment west of the old thrust and exposes a remnant of the monocline in the new footwall.*

HARTLEYS CANYON DIAPIR

Field evidence suggests that a local diapir, formed from the upward flowage of argillaceous micrites, calcareous mudstones, and evaporites (salt and gypsum) of the Arapien Shale, intruded into the crest of the Levan anticline. The main mass of the diapir occurs in the Hartleys Canyon area and is, therefore, termed the Hartleys Canyon diapir.

The diapir is confined to within the Arapien Shale and is identified by a contrast in regional strike. Throughout most of the quadrangle, the Arapien Shale has a north-south-oriented regional strike. But within the area around Hartleys Canyon and within a narrow arm extending south across Chicken Creek the structure is chaotic. The deformation within this area may be best explained as resulting from the intrusion and subsequent collapse of a diapir originating from within the Arapien Shale.

The western diapiric contact is visible about 2 miles (3.2 km) up from the canyon mouths of Pigeon Creek and Chicken Creek, where tightly folded sparite beds suddenly disappear against chaotically bedded micrite of the diapiric mass. The eastern diapiric contact is exposed about ½ mile (0.8 km) farther up the canyons where the chaotically bedded micrite is juxtaposed against eastward dipping sandstone, siltstone and micrite of the upper Arapien. Several outcrops of the brecciated micrite occur along the diapiric contact in Burnt Ground Hollow (NE ¼, NE ¼, section 3, T. 15 S., R. 1 E.). The brecciation may have been the result of the intrusive action of the diapiric mass. Diapirism occurred sometime in the middle to late Tertiary between deposition of the Green River beds and Pleistocene landsliding, which covers the northwest corner of the diapiric mass.

STRUCTURAL TROUGH

A structural trough occurs in the east-central part of the quadrangle between the plateau escarpment and the Arapien foothills. It trends north-south and extends from Fourmile Creek Canyon to Chicken Creek Canyon, affecting an area 6 miles long and 1 mile wide (9.6 km by 1.6 km). It involves mainly the Arapien, Twist Gulch, and Flagstaff formations and locally includes the Cedar Mountain, Indianola, and North Horn beds.

The northern half (Fourmile Creek to Chicken Creek canyons) is heavily faulted and is capped by brittle Flagstaff Limestone, which is downwarped into a synclinal structure. The edges of the structure dip inward and the center is downfaulted along a series of normal faults, forming a trough. Four small graben structures occur within the trough, two oriented east-west and two north-south, and were probably formed by differential subsidence. The northernmost extent of the subsidence is in the Coleman Flat area in Fourmile Creek Canyon where a block of North Horn is down-dropped between two normal faults.

The southern half of the trough is characterized by sagging of the less brittle Twist Gulch Formation and lacks the faulting that characterizes the north half. Between Pigeon Creek and Chicken Creek canyons the sagging has created a shallow depression, where several large slump scarps occur between the plateau escarpment and the Arapien foothills.

The close proximity of the Hartleys Canyon diapir to the structural trough suggests a causal relationship between the two: the trough formed in response to the flowage of Arapien Shale into the crest of the Levan anticline during formation of the diapir. As a result, the east limb of the anticline sagged, forming the structural trough.

WASATCH FAULT

The Wasatch fault is a major extensional fault zone composed of numerous and discontinuous normal faults that extend 230 miles 370 km) from the Utah-Idaho border to Gunnison, Utah (Smith and Bruhn, 1984). It is composed of several Quaternary segments, the southernmost of which extends through the Levan quadrangle and bounds the western edge of the Gunnison Plateau. Schwartz and Coppersmith (1984) reported that this segment has a lower slip rate than most other segments and that only one surface-faulting event is known to have occurred along the segment since early to middle Holocene.

In the area covered by the Levan quadrangle, the main fault is located along the mountain front, where several scarps occur in alluvial deposits at the mouths of Deep Canyon and Pigeon Creek Canyon, across the remnant alluvial fans near Spring Hollow, and in bedrock at scattered locations. Schwartz and Coppersmith (1984) dated a displaced alluvial deposit in Pigeon Creek Canyon by carbon 14 and determined the scarp to have formed about 1750 ± 350 years ago.

North of Hartleys Canyon, the main fault is covered by the Fourmile Creek landslide complex. The slide complex is offset by several slump scarps, the longest of which nearly transects the complex and may be controlled by the main fault. To the west, the complex is truncated by a branch of the Wasatch fault.

A seismic reflection profile shot across Juab Valley near Levan shows the Wasatch fault to have an average dip of 34° W, and it appears to flatten into an older thrust ramp (Smith and Bruhn, 1984). The Levan segment of the Wasatch fault may have originated as a thrust fault which was then reactivated in the Tertiary with an opposite sense of direction, i.e., a normal fault (see section on Gunnison monocline).

NORMAL FAULTS

Normal faults other than the Wasatch fault occur in two groups. The first group occurs in the plateau abutment between Pigeon and Fourmile Creeks and cuts the Flagstaff and Arapien Formations along a series of grabens. Their origin is related to the subsidence of the structural trough, as discussed previously. The displacements along these faults range from tens of feet to about 200 feet (61 m).

The second group occurs on the plateau in the southeastern part of the quadrangle. These faults trend north-south and can be traced for no more than a mile (1.6 km). Their displacements are measured in tens of feet. The faults break parallel to the bedding of the Indianola, which dips about 45 degrees to the east, and offset Flagstaff beds which unconformably cap the upturned Indianola beds.

ECONOMIC GEOLOGY

SAND AND GRAVEL

Abundant and easily accessible deposits of sand and gravel, suitable for road fill, are found in the alluvial fans of the Levan quadrangle. One fan, emanating from Deep Canyon, has been quarried. The alluvial sediment is suitable for road fill. Other potential sources of gravel are the talus deposits in Pigeon Creek Canyon. The gravel from one talus deposit was used to surface a new road in that canyon. The micrite of the Arapien Shale could be used as a source of crushed gravel for surfacing roads.

GYPSUM

Large deposits of gypsum are common in the Levan quadrangle, several of which have been mined. The deposits occur as tectonically thickened beds or lenses in the complexly folded belt of the Arapien Shale. The deposits in Pigeon Creek and Chicken Creek canyons occur in the canyon walls and access is difficult. Access to the deposits in Hartleys Canyon is much easier. The deposits range in size from 200 feet (61 m) in length and 100 feet (30 m) in height to 2000 feet (609 m) in length and 600 feet (183 m) in height. They consist of dense, massive rock gypsum and are commonly associated with a reddish mudstone.

LIMESTONE

The strongly dolomitic Flagstaff Limestone has too much $MgC0_3$ to be used for cement (greater than 3 percent), but it may be suitable for other uses, including building or crushed stone. Rock similar to the Arapien Shale micritic limestone has been used as cement rock elsewhere in Utah (Twin Creek Limestone).

METALLIC OCCURRENCES

Several prospect pits have been dug into areas of hydrothermal alteration around the contact between the Water Hollow stock and the Green River Formation. A small amount of iron ore was removed from a shallow quarry and traces of malachite have been found.

PETROLEUM

The Navajo Sandstone and Twin Creek Limestone are potential reservoir rocks for petroleum in the region. Two exploratory wells drilled in Deep Canyon tested this formation but were dry. However, the regional structure contains ideal petroleum traps for future exploration.

GEOLOGIC HAZARDS

LANDSLIDING

Landslides are common in the Levan quadrangle. Two ages of landslides were mapped: large Pleistocene deposits and historical landslide scars. The latter show that slope failure persists in the area. Shroder (1971) reported that the second highest number of landslides in Utah occurs in the High Plateaus region in which the Gunnison Plateau is included. Furthermore, large concentrations of landslides occur along the Wasatch fault because the fault is siesmically active and has great relief, and because the range experiences relatively high precipitation.

Landslide-prone units commonly have mudstone overlain by well-indurated rock. The weaker mudstone gives way to shear stresses allowing stronger overlying rock to slide. The weathered micrite of the Arapien Shale is also prone to landsliding and slumping. Landsliding is more common during the spring wet season, especially in years of higher than normal precipitation such as occurred from 1982 to 1984, when most of the younger landslide deposits were formed. Other factors which might cause landsliding include earthquakes and canyon-cutting, which oversteepens slopes. Landsliding may cause significant damage to engineered structures such as roads, irrigation pipelines, water systems, fences and block streams.

EARTHQUAKES

Central Utah and the Levan quadrangle lie within the Intermountain seismic belt which broadly follows the transition zone between the Basin and Range and Colorado Plateau physiographic provinces. The largest shock recorded in central Utah since instrumental monitoring began in 1962 at the University of Utah (McKee and Arabasz, 1982) occurred near Levan on July 7, 1963, and had a magnitude of 4.4. Apparently, no larger earthquakes have occurred in historical times. Nevertheless, earthquakes clearly pose a threat to the Levan and surrounding area.

FLASH FLOODING

Flash floods are a common hazard in arid mountainous regions. When rainfall reaches the surface faster than the ground can absorb it or when the ground is already saturated, it drains as surface runoff. Canyons with extensive drainage areas can quickly collect large volumes of water, resulting in a flood. Floods, sweeping down the canyon, do much erosional damage to the stream banks and are capable of moving large boulders as well as much mud, silt and sand. When the flood waters reach the mouths of the canyons, they deposit the eroded materials upon the alluvial fans.

One such flood, which occurred in the spring of 1983, destroyed half of the Chicken Creek Campground by eroding and undermining the bank of the creek. The town of Levan is located on the alluvial fans of the two major canyons, Chicken Creek and Pigeon Creek, and is therefore endangered. The areas of greatest flash-flood hazard occur along the major drainages, which are Fourmile Creek, Pigeon Creek, Chicken Creek and Deep Creek.

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System	Series	Geologic Unit	Symbol	Thickness feet (meters)	Lithology
QUAT.	H. / Plei.	Surficial deposits	Q	0-100 (0-30)	
	Plio.	Salt Creek Fanglomerate	QTs	0-150 (0-45)	
TERTIARY	Miocene	Levan monzonite suite	Ts Tlm Tmp	—	
	Olig.	Goldens Ranch Formation	Tgr	300 (90)	
	Eocene	Green River Formation	Tg	1420 (430)	
	Paleo.	Flagstaff Limestone	Tf	50-900 (15-270)	
		North Horn Formation	TKnh	500 (165)	
CRETACEOUS	Upper	Indianola Group Undifferentiated	Ki	6841 (2085)	
	Lower	Cedar Mountain Fm.	Kcm	305 (92)	
JURASSIC	Upper	Twist Gulch Formation	Jtg	1667 (508)	
	Middle	Arapien Shale (incomplete)	Ja	5500 (1680)