UTAH GEOLOGICAL SURVEY
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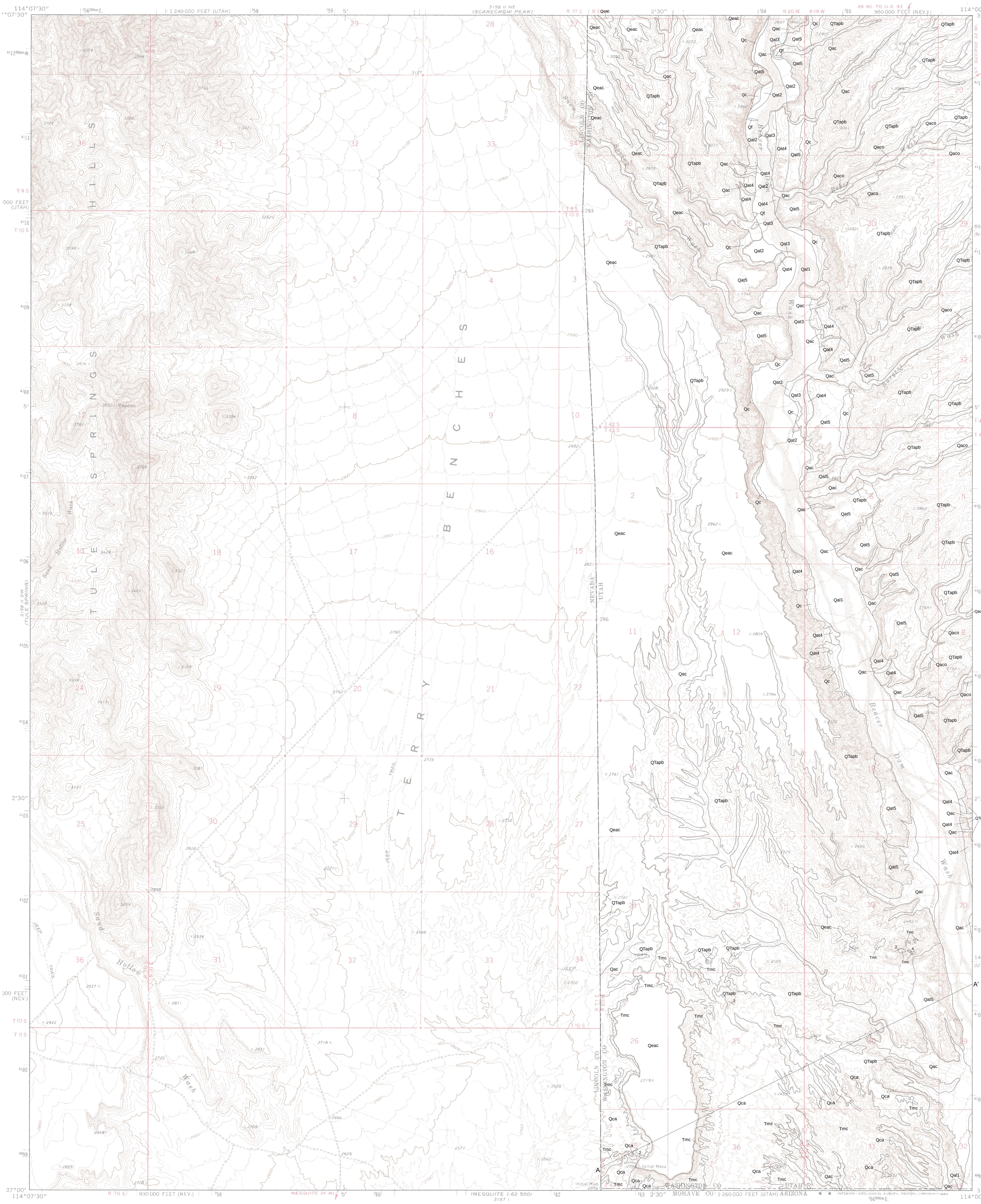

SCALE 1:24,000

Contour Interval 20 feet

1 0.5 0 1 2 Miles

APPROXIMATE MEAN DECLINATION, 1999

Research supported by the Utah Geological Survey and the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS STATEMAP award number 04HQAG0040. The views and conclusions contained in this document are those of the authors, and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

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Interim Geologic Map of the East Half of the Terry Benches Quadrangle, Washington County, Utah

by

Janice M. Hayden, Lehi F. Hintze, and J. Buck Ehler

2005

Geologic data in NAD 1927; base map in NAD 1927.
Field mapping by authors, 2005.
Cartographic assistance by Paul Kuehne and Darryl Greer.

Interim Geologic Maps of the Castle Cliff Quadrangle and the east half of Terry Benches Quadrangle, Washington County, Utah and Mohave County, Arizona

by
Janice M. Hayden, Lehi F. Hintze, and J. Buck Ehler

November 2005

Utah Geological Survey Open-File Reports 457 and 464

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Description of Map Units

QUATERNARY

Qf **Artificial-fill deposits** (Historical) – Artificial fill used to create small dams; consists of engineered fill and general borrow material; although only a few deposits have been mapped, fill should be anticipated in all built-up areas, many of which are shown on the topographic base map; 0 to 20 feet (0-6 m) thick.

Alluvial deposits

Qal_1 **Alluvial-stream deposits** (Holocene) – Moderately to well-sorted clay to boulder deposits along Beaver Dam Wash; includes terraces up to 5 feet (1.5 m) above modern channels; 0 to 30 feet (0-9 m) thick.

Qa **Alluvial deposits, undivided** (Holocene to Pleistocene) – Shown on cross-section only as a combination of alluvial and mixed alluvial and colluvial deposits along Beaver Dam Wash.

Qat_2-Qat_6

Alluvial-terrace deposits (Holocene to Pleistocene) – Moderately to well-sorted sand, silt, and pebble to boulder gravel that forms level to gently sloping surfaces above modern drainages; subscript denotes height above drainages; level-2 deposits are about 5 to 30 feet (1.5-9 m), level-3 deposits are 30 to 60 feet (9-18 m), level-4 deposits are 60 to 120 feet (18-37 m), level-5 deposits are 120 to 180 feet (37-55 m), and level-6 deposits are more than 180 feet (55 m) above modern drainages; deposited primarily in stream-channel and flood-plain environments; mapped along Beaver Dam Wash; map unit includes underlying Quaternary-Tertiary alluvial-pediment and basin-fill deposits (QTapb) that cannot be differentiated along the steep margins of Beaver Dam Wash due to similar lithologies; 0 to 30 feet (0-9 m) thick.

Qapb **Alluvial-pediment and basin-fill deposits** (Pleistocene) – Silt, sand, gravel, and boulder conglomeratic deposits derived mostly from Precambrian metamorphic and Paleozoic sedimentary rocks of the Beaver Dam Mountains, but also includes a variety of volcanic rocks derived from the Bull Valley Mountains to the north; forms surfaces that slope toward Beaver Dam Wash that have an intermediate level of incision, indicating that they are younger than Quaternary-Tertiary alluvial-pediment and basin-fill deposits (QTapb) but older than older alluvial-colluvial deposits (Qaco); conglomerate is matrix or clast supported with poorly cemented, light-brownish-gray matrix of poorly sorted silt to angular, coarse sand; clast size ranges from pebbles to large boulders and clasts are subangular to subrounded; typically forms slopes, which are steeper and more resistant where clast supported; commonly includes pedogenic carbonate surfaces; 100 feet (30 m) thick.

Colluvial deposits

Qc **Colluvial deposits** (Holocene to Pleistocene) – Poorly to moderately sorted, angular to subrounded, clay- to boulder-size, locally derived sediment deposited principally by slope wash and soil creep on moderate to steep slopes; locally includes talus and alluvial deposits too small to map separately; 0 to 20 feet (0-6 m) thick.

Mass-movement deposits

Qms **Landslide deposit** (Holocene) – Historically active; very poorly sorted, clay- to boulder-size, subangular to subrounded debris in chaotic, hummocky mounds with fissures 1 to 6 feet (0.3-2 m) wide; locally derived from Quaternary-Tertiary alluvial-pediment and basin-fill deposits (QTapb); basal slip surface developed in alluvial clay; mapped in the NW¼NE¼ section 36, T. 42 S., R. 19 W. in the Castle Cliff quadrangle; landslide deposit is approximately 400 feet (120 m) wide and 230 feet (70 m) long; 0 to 65 feet (0-20 m) thick (Willis and Willis, 1986).

Mixed-environment deposits

Qac, Qaco

Mixed alluvial and colluvial deposits (Holocene to Pleistocene) – Poorly to moderately sorted, clay- to boulder-size, locally derived sediment; gradational with alluvial, colluvial, and mixed eolian and alluvial deposits; younger deposits (Qac) are deposited in swales and minor active drainages whereas older deposits (Qaco) are younger than and commonly derived from alluvial-pediment and basin-fill deposits (Qapb and QTapb); older deposits form incised, inactive, gently sloping surfaces along minor active drainages that are similar to terraces along a major drainage; 0 to 30 feet (0-9 m) thick.

Qca **Mixed colluvial and alluvial deposits** (Pleistocene) – Gypsiferous, clay- to cobble-size sediment eroded from mixed eolian and alluvial caliche deposits (Qeac) and Quaternary-Tertiary alluvial-pediment and basin-fill deposits (QTapb); deposited by slope-wash and alluvial processes on the Muddy Creek Formation around Initial Mesa eastward to Beaver Dam Wash along the south edge of Terry Benches quadrangle; forms erosional remnants incised up to 120 feet (37 m) that cap the Muddy Creek Formation; 20 to 30 feet (6-9 m) thick.

Qeac **Mixed eolian and alluvial deposits with pedogenic carbonate soil** (Holocene to Pleistocene) – Windblown sand, silt, clay and local alluvial gravels; bluish-white, stage V (Birkeland and others, 1991), laminated pedogenic carbonate (caliche) deposits with crinkle bedding and well-developed pisolithes, derived from reworked alluvial-pediment and basin-fill deposits, alluvial gravels and Muddy Creek formation; eolian deposition is ongoing; map unit locally includes 0 to 5 foot (0-1.5 m) thick, yellowish-gray to light-olive-gray conglomerate at the base of the pedogenic carbonate; clasts are gravel- to cobble-size and are subrounded to rounded; conglomerate coarsens upward; map unit typically overlies Quaternary-Tertiary alluvial-pediment and basin-fill deposits, but also caps Initial Mesa where it overlies the Muddy Creek Formation in the Terry Benches quadrangle; 6 to 30 feet (2-9 m) thick.

QUATERNARY-TERTIARY

Alluvial deposits

QTapb **Alluvial-pediment and basin-fill deposits** (Pleistocene to Pliocene) – Silt, sand, gravel and boulder conglomeratic deposits derived mostly from Precambrian metamorphic and Paleozoic sedimentary rocks of the Beaver Dam Mountains, but also includes a variety of volcanic rocks derived from the Bull Valley Mountains to the north; forms extensive surfaces, which slope toward Beaver Dam Wash; deeply incised, in some areas up to 300 feet (90 m); conglomerate is matrix or clast supported with poorly cemented, light-brownish-gray matrix of poorly sorted silt to angular, coarse sand; clast size ranges from pebbles to large boulders and clasts are subangular to rounded; usually forms a slope, which is steeper and more resistant where clast supported; commonly includes caliche surfaces, not mapped separately, that are not part of the broad, elevated surface mapped as mixed eolian and alluvial caliche deposits (Qeac); maximum exposed thickness is 300 feet (90 m).

Mass-movement deposits

QTms(Mr)
QTms(Dm?)
QTms(Cbk)

Landslide deposits (Pleistocene to Pliocene) – Detached gravity slide blocks of highly brecciated lower Paleozoic rocks that have moved down slope and have come to rest at the foot of the mountain (Cook, 1960); identity of source formation is indicated on the map in parentheses, but queried where brecciation makes identification questionable; where the base is exposed, a landslide detachment fault symbol is used to show the contact between these slide blocks and their underlying unit; a simple contact line is used locally where the basal parts of the slide blocks are buried by alluvial-pediment and basin-fill deposits or mixed alluvial and colluvial deposits; timing of emplacement is poorly constrained, but seems to coincide with deposition of QTapb; slide masses are 10 to 200 feet (3-60 m) thick.

TERTIARY

Tmc **Muddy Creek Formation** (Pliocene to Miocene) – Very fine to very coarse grained, grayish-orange to light-reddish-orange, calcareous sandstone; sand grains are poorly sorted and subangular; sandstone is interbedded with medium-reddish-brown siltstone and mudstone layers; lenses of matrix-supported conglomerate are common, with beds ranging from 1 inch to 2 feet (2.5-60 cm) thick; pebble- to cobble-sized clasts are poorly sorted and subrounded; formation is poorly cemented and forms slopes; deposited as basin-fill sediment (Kowallis and Everett, 1986); Bohannon (1984) noted that the Muddy Creek Formation is overlain by a 5.9 million-year-old basalt and overlies a 10.6 million-year-old sandstone near Lake Mead, whereas Carpenter and Carpenter (1990) interpreted a Miocene to Quaternary age for a Muddy Creek sequence just southwest of the quadrangle based on the fanning-upward geometry of seismic reflectors and numerical ages for the Horse Spring-Cottonwood Wash sequence below; Metcalf (1982) reported a regional thickness of over 2000 feet (600 m) in some of the deeper basins in southern Nevada; partial exposed thickness in the Terry Benches quadrangle south of Initial Mesa is 300 feet (90 m); 150 feet (45 m) is the thickest exposure in the Castle Cliff quadrangle.

unconformity

PERMIAN

Pq **Queantoweap Sandstone** (Lower Permian) – Very pale orange to grayish-orange-pink, fine-to medium-grained, thin- to thick-bedded, cross-bedded, calcareous sandstone; forms ledges to low cliffs; Hammond (1991) reported a thickness of 1200 to 1500 feet (350-450 m) in the Jarvis Peak quadrangle to the east; only basal 500 feet (150 m) is exposed in the southeast corner of Castle Cliff quadrangle.

Pp **Pakoon Dolomite** (Lower Permian) – Light-gray, medium- to thick-bedded, fine-grained dolomite with some chert nodules, which weathers to light-brownish-gray ledges and low cliffs; mostly unfossiliferous, but bryozoans and fusilinids occur in thin limestone beds interbedded with rare, ledge-forming sandstone in the upper part (Hintze, 1986); top 50 feet (15 m) is mostly gypsum with minor limestone and sandstone intervals; upper contact is drawn at the base of the more massive sandstone above the gypsum/limestone intervals; mapped in the southeast corner of the Castle Cliff quadrangle in a structurally complex area where thickness is estimated at 400 feet (120 m).

PENNSYLVANIAN

IPc **Callville Limestone** (Upper to Lower Pennsylvanian) – Medium-gray, fine- to medium-grained, medium- to thick-bedded limestone with cyclic interbeds of moderate-orange-pink sandstone and light-gray dolomite increasing in the upper third; commonly cherty and fossiliferous; *Lithostrotionella* coral is common in upper part whereas brachiopods and bryozoans are common in limestone beds throughout (Hintze, 1985a); forms ledge-slope topography similar to the overlying Pakoon Dolomite; upper contact is placed at the base of the lighter-colored dolomite beds; upper portion mapped in the southeast corner of the Castle Cliff quadrangle whereas the lower portion is mapped along the east edge, south of Castle Cliff, where a large sheet of Callville strata rests on an attenuated and brecciated sequence of Mississippian Redwall Limestone and Cambrian Bonanza King Formation/Tapeats Quartzite; complete thickness in the Jarvis Peak quadrangle to the east is 1500 feet (450 m) (Hammond, 1991); exposed thickness estimated at 1200 feet (360 m).

unconformity

MISSISSIPPIAN

Mr **Redwall Limestone** (Lower Mississippian) – Medium- to dark-gray, very thick bedded, cherty, fossiliferous, cliff-forming limestone; in the Beaver Dam Mountains, the basal 60 feet (18 m) is coarse grained and dolomitic, above which is an 80-foot-thick (25 m) cherty, bioclastic limestone that weathers to a dark yellowish brown and probably correlates to the Thunder Springs Member of McGee and Gutschick (1969) as mapped by Steed (1980) in the Virgin River Gorge south of the map area; upper 460 feet (140 m) is bioclastic and fossiliferous, containing horn corals, colonial corals and brachiopods (Hintze, 1985a); in the map area, the Redwall Limestone is highly attenuated beneath the Callville Limestone at Castle Cliff and is found only as gravity slide blocks [QTms(Mr)] in the northeast quarter of that quadrangle; the largest of these blocks, which rests on highly attenuated and brecciated Cambrian Bonanza King Formation, forms Sheep Horn Knoll just east of Welcome Spring (Cook, 1960); many slide blocks lie along the edge of the Precambrian unit, where slickensides of 13 to 17 degrees, trending to the south and southwest, indicate the inclination and direction of the slide plane; maximum thickness preserved is 400 feet (120 m).

DEVONIAN

Dm? **Muddy Peak Dolomite** (Upper Devonian) – To the north in the West Mountain Peak quadrangle, the lower portion is silty, fine-grained, light-olive-gray to pale-yellowish-gray, thin- to medium-bedded dolomite and forms a ledgy slope, whereas the upper portion is medium-gray, medium crystalline, very thick bedded dolomite with scattered chert nodules and sandy laminae that weathers to form light-gray hoodoos or pinnacles below the massive Redwall Limestone cliffs (Hayden, 2005); Hammond (1991) reported a thickness of 500 to 700 feet (150-200 m) in the Jarvis Peak quadrangle to the east; in the Castle Cliff quadrangle, however, the Muddy Peak is questionably present as part of three dolomite slide blocks [QTms(Dm?)], one just west of Welcome Spring and two others along the north-central edge of the quadrangle; blocks reach 50 feet (15 m) thick and are highly brecciated.

unconformity

Section missing due to attenuation faulting (Upper Cambrian – Nopah Dolomite)

CAMBRIAN

Cbk **Bonanza King Formation** (Upper and Middle Cambrian) – Medium- to light-brownish-gray, fine- to medium-grained, medium- to thick-bedded dolomite with some bluish-gray silty limestone beds in the lowest 300 feet (90 m) (Hintze, 1986); Hintze (1985b) measured 2623 feet (800 m) just to the north along the north side of Horse Canyon in the West Mountain Peak quadrangle; however, in the Castle Cliff quadrangle, the Bonanza King Formation is only present as highly brecciated and attenuated outcrops at Castle Cliff and Welcome Spring; at Castle Cliff, it is smeared to a thickness of less than 100 feet (30 m) between Cambrian Tapeats Quartzite below and Redwall Limestone above; at Welcome Spring, approximately 200 feet (60 m) is present as a slide block [(QTms(Cbk)] between Precambrian rocks below and Redwall Limestone above.

Section missing due to attenuation faulting (Middle to Lower Cambrian – Bright Angel Shale)

Ct **Tapeats Quartzite** (Lower Cambrian) – Dark-reddish-orange to pale-reddish-brown quartzite with a few thin layers of quartz pebble conglomerate and sandstone; thin to very thick bedded; generally forms ledges and dip slopes; Hammond (1991) reported a complete thickness of 1300 feet (400 m) near the north edge of the Jarvis Peak quadrangle to the east; however, only the basal 700 feet (210 m) of the Tapeats Quartzite is present in the northeast corner of the Castle Cliff quadrangle; at Castle Cliff, a highly attenuated and brecciated section 50 feet (15 m) thick rests unconformably on the Precambrian rocks below.

unconformity

PRECAMBRIAN

pC **Precambrian gneiss, schist, and pegmatite, undivided** (Middle to Early Proterozoic) – Dark-gray dioritic gneiss consisting mostly of amphibole with about 10 percent each of feldspar, quartz, and pyroxene, interrelated with schist and pegmatite (Hintze, 1985a); dioritic gneiss is the most resistant and most extensively exposed rock type; schist contains principally either mica or amphibole with some plagioclase feldspar, quartz, garnet, and sillimanite (Reber, 1952); granitic pegmatites are common and intrude both gneiss and schist; less common, white pegmatites are composed of 60 percent orthoclase and 25 percent quartz with some mica, plagioclase, and garnet (Hintze, 1986). Numerous mining prospects and three adits are mapped; one, reclaimed in 2004, has secondary copper/gold mineralization concentrated along the contact with slide blocks near Welcome Spring (Doug Jensen, Utah Division of Oil, Gas, and Mining, verbal communication, July 26, 2005). Exposed in a continuous belt about 8 miles (13 km) long and 4 miles (6 km) wide with at least 3000 feet (900 m) of relief. Although the age of Precambrian rocks in the Beaver Dam Mountains has not been determined, King (1976) compared them to the Vishnu and Brahma schists of the Grand Canyon area, which are Middle Proterozoic age. Olmore (1971) reported a 1.7-billion-year K-Ar age (mineral not specified) on a pegmatite in similar Precambrian rocks in the East Mormon Mountains, Nevada, 15 miles (24 km) to the southwest, which would make those rocks Early Proterozoic. A nonconformity of approximately 1.2 billion years, referred to in the Grand Canyon area as the "Great Unconformity," separates the Precambrian rocks from the overlying Cambrian strata.

Structure

The complex structure of the area is discussed in detail by Reber (1952), Hintze (1986), Anderson and Barnhard (1993), Carpenter and Carpenter (1994), and O'Sullivan and others (1994). Only a short summary is given here. The study area lies along the truncated west flank of the Precambrian-cored Virgin-Beaver Dam Mountains anticline, interpreted by Reber (1952) to be a Late Cretaceous Laramide-type compressional structure. However, the Beaver Dam Mountains anticline formed prior to being overridden by the Muddy Mountain-Tule-Square Top Mountain thrust, exposed to the north and west of the study area, during Late Cretaceous time, between 97 and 70 million years ago (Carpenter and Carpenter, 1994). This suggests two separate phases of southeast-directed compression (Hintze, 1986).

Crustal extension in the area began in late Oligocene to early Miocene time (Carpenter and Carpenter 1994). In some cases, normal faults reactivated old zones of structural weakness inherited from both Precambrian rifting and Cretaceous compression, whereas other normal faults initiated as new zones of brittle failure (Anderson and Barnhard, 1993). Movement along these normal faults created the modern basin-range physiography and resulted in significant extension of the crust. In addition, the Virgin-Beaver Dam Mountains normal fault system, which is listric in nature, has attained greater than 26,000 feet (8000 m) of vertical separation just south of the study area at the latitude of the Virgin Valley depocenter, which contains that thickness of Oligocene to Quaternary syntectonic clastic deposits shed from adjacent tilted horsts (Carpenter and Carpenter, 1994). Also associated with this vertical component of extension are rootless gravity slide blocks ranging from 10 to 200 feet (3-60 m) thick exposed along the western margin of the Beaver Dam Mountains and along the eastern Virgin Valley basin margin.

Acknowledgments

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Map Symbols

Contact – dashed where approximated

Syncline – dashed where approximated

Anticline – dashed where approximated

Normal fault – dashed where approximated, dotted where concealed, bar and ball on down-thrown side

High-angle fault (probably normal) – identified using geophysical data; **G** denotes where fault position was determined using seismic reflection data

Attenuation fault – dotted where concealed, triangles on hanging-wall block

Landslide detachment fault bounding slide block – hachures on displaced block

45 Strike and dip of bedding

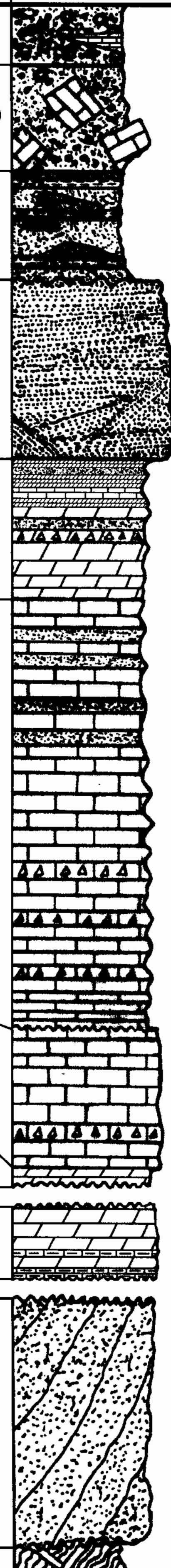
30 Strike and dip of foliation

Spring

Gravel pit

Prospect

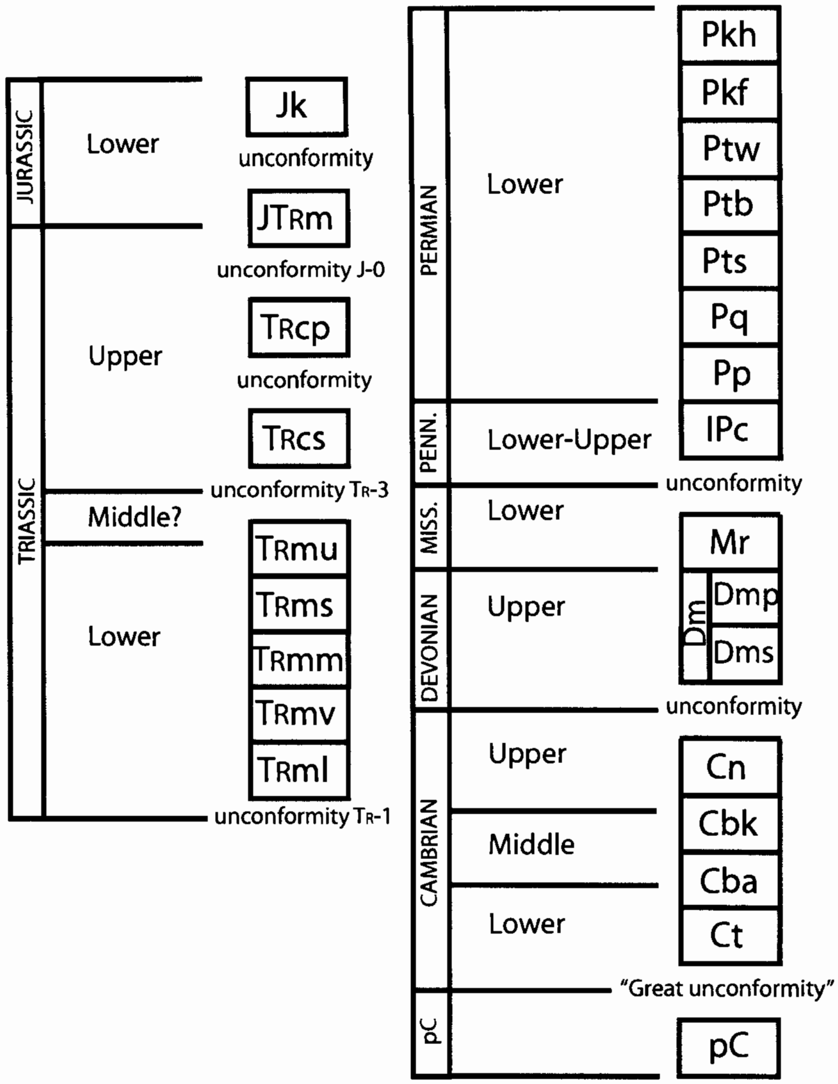
Adit



SYSTEM	SERIES	FORMATION	SYMBOL	THICKNESS Feet (Meters)	LITHOLOGY
QUATERNARY	Holocene	Surficial Deposits	Q_	0-100 (0-30)	
QUATERNARY	Pleistocene	Alluvial and Basin Fill Deposits	QTapb	10-300+ (3-90+)	
TERTIARY	Pliocene	Landslide Deposits	QTms(_)		parent bedrock of gravity slide blocks indicated in parentheses
TERTIARY	Miocene	Muddy Creek Formation	Tmc	300+ (90+)	only patches exposed
PERMIAN	Lower	Queantoweap Sandstone	Pq	500+ (150+)	medium to small-scale cross-bedding inclined in many directions in lower part
PERMIAN	Lower	Pakoon Dolomite	Pp	400 (120)	
PENNSYLVANIAN	Lower - Upper	Callville Limestone	IPc	1200 (360)	cyclic *Lithostrotionella* (hair coral) beds in upper part cherty
MISSISSIPPIAN	Lower	Redwall Limestone	Mr	400 (120)	structurally attenuated Thunder Springs Member
DEVONIAN	Upper	Muddy Peak Dolomite?	Dm?	50 (15)	structurally attenuated
CAMBRIAN	Section missing due to attenuation faulting (Nopah Dolomite)				
CAMBRIAN	Upper & Middle	Bonanza King Formation	Cbk	200 (60)	laminated white boundstone in upper part structurally attenuated thin-bedded shaly limestone at base
CAMBRIAN	Section missing due to attenuation faulting (Bright Angel Shale)				
CAMBRIAN	Lower	Tapeats Quartzite	Ct	700 (210)	locally attenuated "Great Unconformity" ~ 1.2 billion years
PreCambrian		Gneiss, Schist, Pegmatite	pC		probably Vishnu Schist

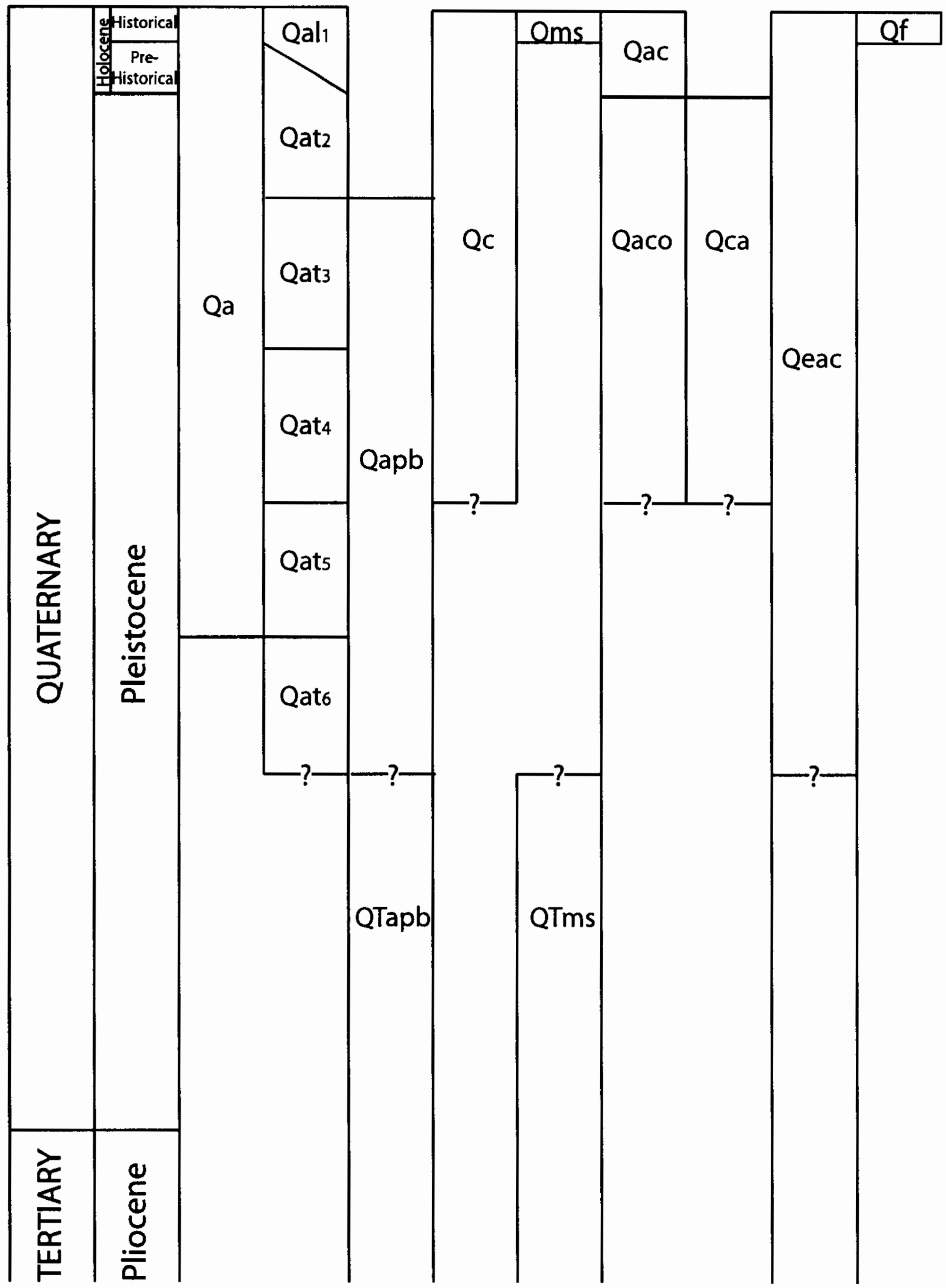
Castle Cliff and Terry Benches 11/21/05 J. Buck Ehler

CORRELATION OF BEDROCK UNITS

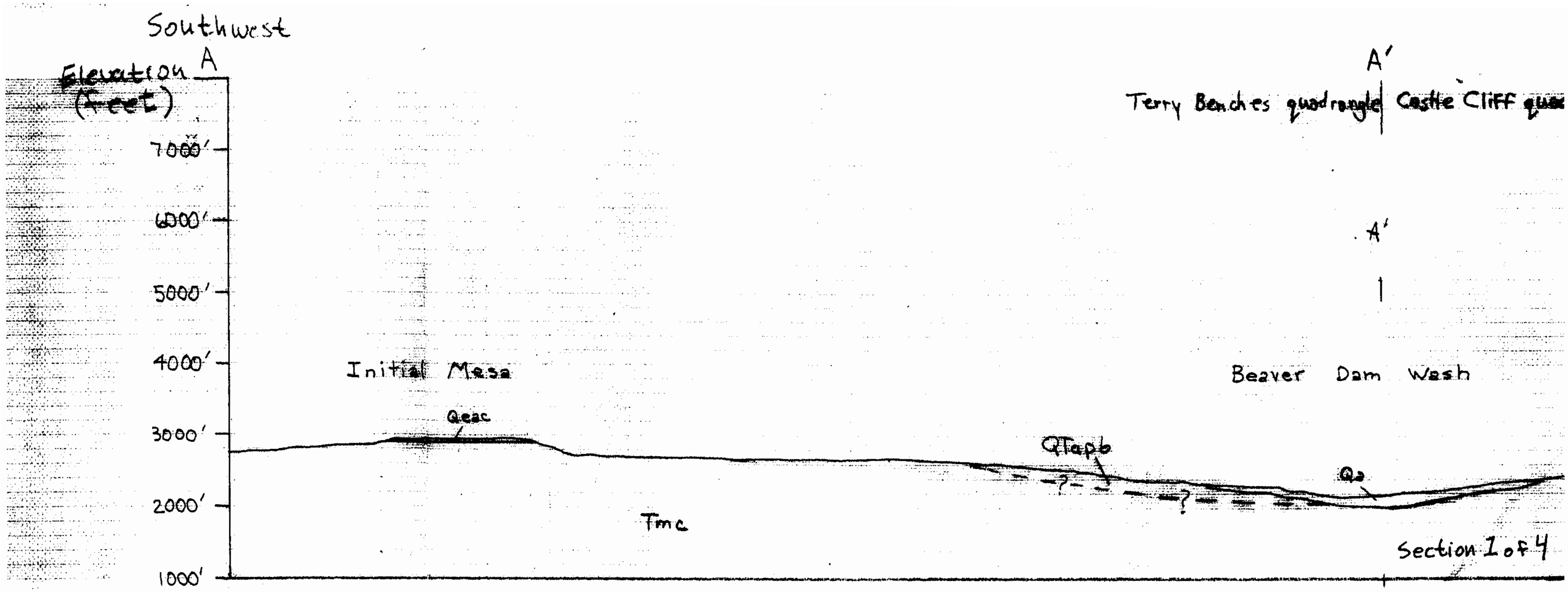


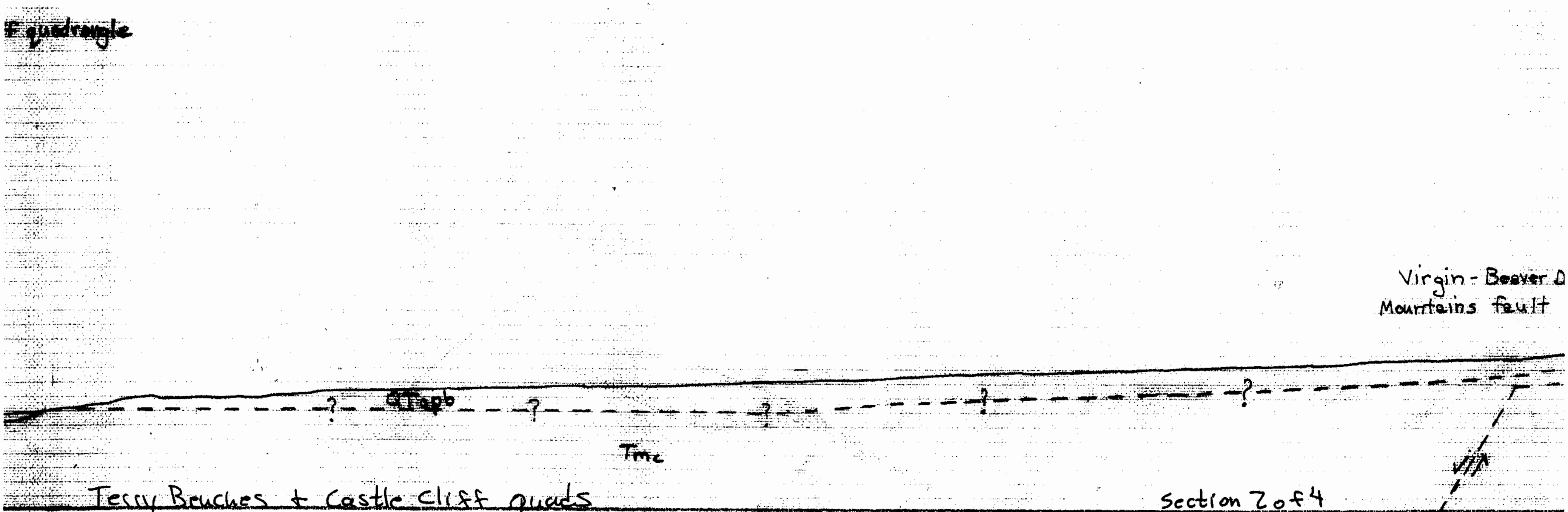
West Mountain Peak quadrangle
J.M. Hayden, J.B. Ehler, November 2005

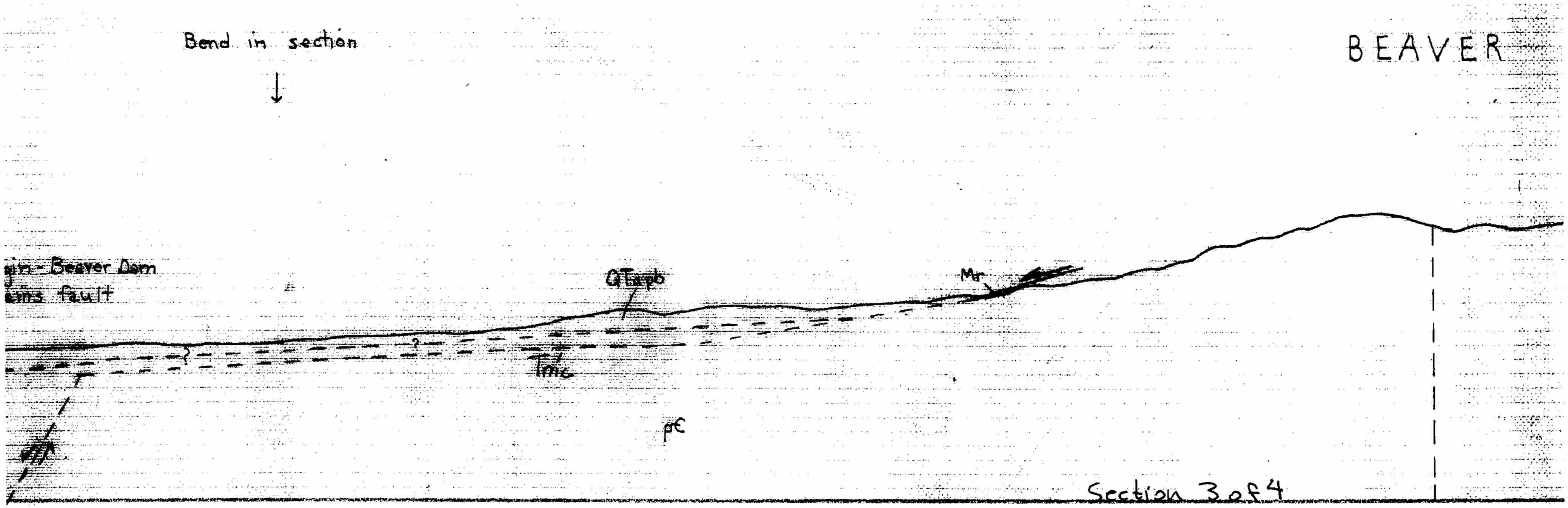
CORRELATION OF SURFICIAL DEPOSITS

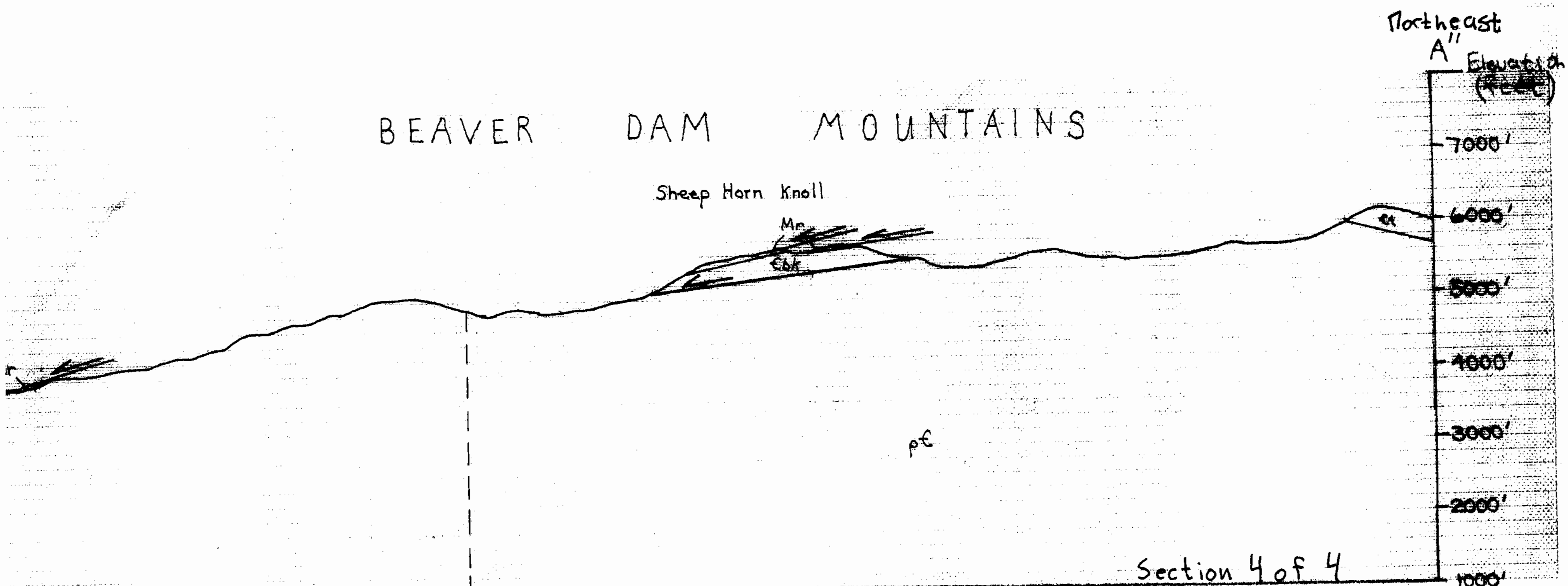


Castle Cliff and Terry Benches quadrangles
J.M. Hayden, J.B. Ehler, November 2005


Southwest
A
Elevation (feet)
7000'
6000'
5000'
4000'
3000'
2000'
1000'
A'
Terry Benches quadrangle
Castle Cliff qua
A'
Initial Mesa
Qeac
Beaver Dam Wash
QTapb
Qa
Tmc
Section 1 of 4


quadrangle
Virgin-Beaver D
Mountains fault
QTapb
Tmc
Terry Benches + Castle Cliff quads
Section 2 of 4





Castle Cliff & Terry Benches quads November 2005 J.M. Hayden J.B. Ehler

Thin surficial deposits not shown