UTAH GEOLOGICAL AND MINERAL SURVEY
UTAH DEPARTMENT OF NATURAL RESOURCES
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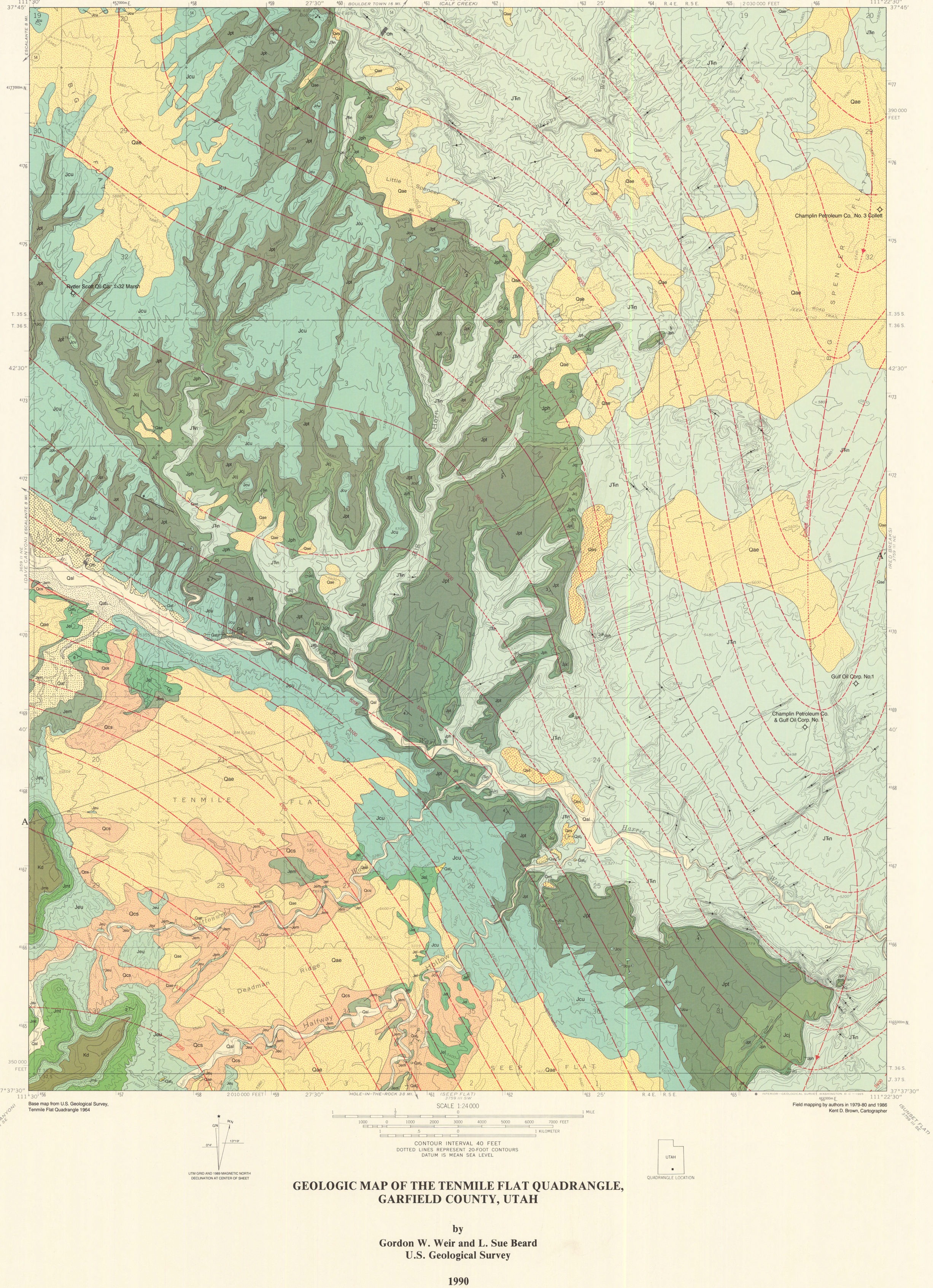
THE UNITED STATES GEOLOGICAL SURVEY

Plate 1
Utah Geological and Mineral Survey Map 118
Geologic Map of the Tenmile Flat Quadrangle



Base map from U.S. Geological Survey,
Tenmile Flat Quadrangle 1964

Field mapping by authors in 1979-80 and 1986
Kent D. Brown, Cartographer

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965

SCALE 1:24 000

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

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

UTM GRID AND 1989 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

QUADRANGLE LOCATION

GEOLOGIC MAP OF THE TENMILE FLAT QUADRANGLE, GARFIELD COUNTY, UTAH

by

Gordon W. Weir and L. Sue Beard
U.S. Geological Survey

1990

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Plate 2
Utah Geological and Mineral Survey Map 118
Geologic Map of the Tenmile Flat Quadrangle

MAP SYMBOLS

CONTACT — Boundaries of surficial deposits approximately located.

FAULT — Dashed where inferred; dotted where concealed; bar and ball on downthrown side.

ANTICLINE — Showing trace of axial plane and plunge of axis; dashed where approximately located.

STRIKE AND DIP OF BEDS

18 Inclined

STRIKE OF VERTICAL AND NEAR-VERTICAL JOINTS

BORROW PIT

OIL WELL — Dry hole, showing name of well.

STRUCTURE CONTOURS — Drawn on top of Navajo Sandstone. Long dashed where control less accurate. Short dashed where datum above land surface. Contour interval 100 ft.

DESCRIPTION OF MAP UNITS

Qfh — Artificial fill — *Unsorted gravel, sand, and silt used as highway fill in gully crossings.*

Qes — Wind-blown sand — *Fine grains of quartz and minor silt.*

Qae — Sheetwash alluvium and eolium — *Silt, sand, and small rock fragments.*

Qcs — Colluvial sand — *Fine sand below cliffs of the lower member of the Entrada Sandstone.*

Qal — Floodplain alluvium — *Fine sand and silt with local admixtures of gravel.*

Qaf — Fan alluvium — *Fine sand, silt, and small rock fragments.*

Qat_1 — Fine-grained terrace alluvium — *Silt and fine sand and rare small pebbles.*

Qat_2 — Intermediate gravel terrace alluvium — *Gravel consisting chiefly of cobbles of sandstone, conglomerate, and quartzite resting on surfaces about 40 to 100 feet above stream level.*

Qat_3 — High gravel terrace alluvium — *Gravel consisting chiefly of boulders of sandstone and conglomerate resting on surfaces about 150 to 200 feet above stream level.*

UNCONFORMITY

Kd — Dakota Formation — *Light-brown sandstone, carbonaceous shale and siltstone, and minor coal.*

UNCONFORMITY
Morrison Formation

Jms — Salt Wash Member — *Gray chert-pebble conglomerate, sandstone, and red or green mudstone.*

Jmt — Tidwell Member — *Light-yellowish-gray sandstone and red or green mudstone.*

UNCONFORMITY
Entrada Sandstone

Jeu — Upper member — *Light-gray to pale-orange, crossbedded, fine-grained sandstone.*

Jem — Middle member — *Reddish-brown, fine-grained silty sandstone, and red and gray sandy siltstone and mudstone.*

Jel — Lower member — *Reddish-brown, crossbedded, fine-grained sandstone and minor siltstone and mudstone.*

Jcu — Carmel Formation, upper member — *Reddish-brown shale, yellowish-brown fine-grained sandstone, micrograined limestone, and gypsum.*

Jpt — Page Sandstone, Thousand Pockets Tongue — *Gray, fine- to medium-grained, crossbedded sandstone, and minor reddish-brown mudstone, commonly contorted.*

Jcj — Carmel Formation, Judd Hollow Tongue — *Reddish-brown siltstone and fine-grained sandstone.*

Jpct (cross section only)

Jph — Page Sandstone, Harris Wash Tongue — *Light-grayish-orange, crossbedded, fine-grained sandstone; chert granules and small pebbles at base.*

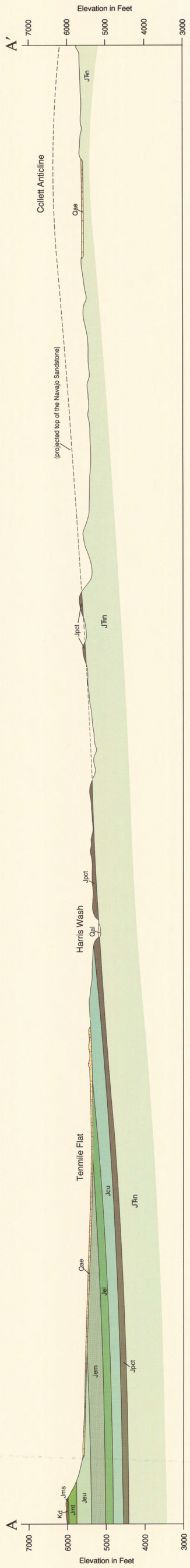
UNCONFORMITY

JTrn — Navajo Sandstone — *Light-grayish-orange, crossbedded, fine-grained sandstone.*

FORMATION		SYMBOL	THICKNESS (feet)		LITHOLOGY
Alluvium, eolium, colluvium		Q	0-25		
Dakota Formation		Kd	100+		
Morrison Formation	Salt Wash member	Jms	200-260	30-120	
	Tidwell member	Jmt		100-180	
Entrada Sandstone	Upper member	Jeu	850-1000	300-400	
	Middle member	Jem		310-420	
	Lower member	Jel		150-240	
Carmel Formation	Upper member	Jcu	220-400		
Page Sandstone	Thousand Pockets Tongue	Jpt	110-170	30-80	
Carmel Fm.	Judd Hollow Tng.	Jcj		15-40	
Page Sandstone	Harris Wash Tongue	Jph		30-80	
Navajo Sandstone		JTrn	700+		

CORRELATION OF MAP UNITS

Qaf, Qal, Qcs, Qae, Qes, Qfh, Qat_1	Holocene	QUATERNARY
Qat_2	Holocene (?) and Pleistocene	
Qat_3	Pleistocene	
UNCONFORMITY		
Kd	Upper Cretaceous	CRETACEOUS
UNCONFORMITY		
Jms, Jmt	Upper Jurassic	JURASSIC
UNCONFORMITY		
Jeu, Jem, Jel, Jcu, Jpt, Jcj, Jph	Middle Jurassic	
UNCONFORMITY		
JTrn	Lower Jurassic and Upper Triassic (?)	JURASSIC AND TRIASSIC (?)



GEOLOGIC MAP OF THE TENMILE FLAT QUADRANGLE, GARFIELD COUNTY, UTAH

By

Gordon W. Weir and L. Sue Beard

U.S. Geological Survey

UTAH GEOLOGICAL AND MINERAL SURVEY
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MAP 118 **1990**

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GEOLOGIC MAP OF THE TENMILE FLAT QUADRANGLE, GARFIELD COUNTY, UTAH

By

Gordon W. Weir[1] and L. Sue Beard[1]

INTRODUCTION

The Tenmile Flat quadrangle, south-central Garfield County, lies in the Kaiparowits Plateau-Teasdale anticline section of the Colorado Plateau physiographic province (Stokes, 1977). Mesas in the southwest corner of the quadrangle are spurs from the Kaiparowits Plateau. Extensive flats lie in the northwestern, northeastern, and southwestern parts of the quadrangle. Most of the quadrangle, however, is part of a gently arched rock tableland, intricately dissected by many gullies and small canyons. Total relief in the quadrangle is about 1350 feet (411 m), but local relief is commonly less than 100 feet (30 m) except near the mesas in the southwest corner of the map and along Harris Wash in the southeast corner.

The quadrangle area is visited occasionally by cattlemen and tourists but there are no permanent dwellings. Escalante (1980 population, 652), the nearest town, lies about 8 miles (13 km) by road to the northwest. The only paved road is the Escalante-Boulder highway in the northwestern part of the quadrangle. The Hole-in-the-Rock Road in the southwestern part of of the quadrangle is graded but may be impassable in wet weather. Other roads shown on the map generally are useable only by four-wheel-drive vehicles because of drifting sand and rocky terrain. Much of the quadrangle is accessible only by foot.

Part of the quadrangle is covered by desert vegetation and part is bare rock mantled irregularly by patches of sand. Alvey Wash and Harris Wash, the only permanent streams, have large ranges in seasonal and annual flow. The major periods of flow are in the spring in response to melting of snow in nearby highlands and in mid-summer as the result of sporadic torrential downpours.

The area was included in smaller scale geologic maps by Hackman and Wyant (1973), Doelling (1974), Sargent and Hansen (1982), and Williams (1985), and in part by Weir and Beard (1981a, b). Hackman (1955) compiled a photogeologic map of the quadrangle at the 1:24,000 scale. The present geologic map is based on field work by G. W. Weir in 1979-80 and 1986, assisted by D. P. Bauer in 1979, and by L. S. Beard in 1980, assisted by D. C. Ferris.

STRATIGRAPHY

Bedrock formations exposed in the Tenmile Flat quadrangle range in age from Triassic (?) and Jurassic to Late Cretaceous and total about 3000 feet (914 m). Thin Quaternary surficial deposits cover much of the area.

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[1]*Geological Survey, Flagstaff, Arizona*

TRIASSIC(?) AND JURASSIC SYSTEMS

Upper Triassic(?) and Lower Jurassic Series

Navajo Sandstone (JTrn) — The formation is composed almost wholly of well-sorted, subrounded, frosted, very fine to medium grains of clear quartz and very small amounts of white chert and feldspar. The sandstone is mostly very light grayish orange, but locally reddish-gray to yellowish-orange rock is conspicuous. Reddish-orange to black iron staining occurs sporadically. The rock is poorly to well cemented by calcite and weathers to yield loose sand. The sandstone is characterized by large-scale trough sets, commonly 6 to 18 feet (1.8-5.4 m) thick, of high-angle crossbeds. Contorted beds are locally common; tabular beds are rare. Grayish-red silstone is irregularly interstratified in sparse thin lenses. In the northeastern part of the quadrangle the Navajo contains abundant dark-brown spheroidal liminitic concretions mostly less than an inch in diameter. The formation erodes to form towering cliffs, fin-like ridges, irregularly rounded knobs, and hummocky mesa tops, commonly mantled with a thin layer of locally derived sand. In the Tenmile Flat quadrangle the base of the formation is below drainage; about 700 feet (213 m) is exposed. The total thickness of the Navajo is about 1200 to 1500 feet (365-457 m) as indicated by logs of exploratory wells in the area (Heylmun and others, 1965, p. 68-71, and unpublished records in the files of the Utah Geological and Mineral Survey and the U.S. Bureau of Land Management, Salt Lake City, Utah).

JURASSIC SYSTEM

Middle Jurassic Series

Harris Wash Tongue of the Page Sandstone (Jph) — The lower tongue is light-grayish-orange, fine-grained quartz sandstone in large-scale trough sets, commonly 3 to 18 feet (1-5.4 m) thick. The Harris Wash is lithologically similar to the underlying Navajo Sandstone and was included in the Navajo by most previous workers. It is separated from that formation by an obscure unconformity marked by sparse granules and very small pebbles of chert (Peterson and Pipiringos, 1979, p. B20-B29). The Harris Wash forms a ledge that caps cliffs and mesas carved in the Navajo Sandstone. The unit, which ranges in thickness from about 30 to 80 feet (9-24 m), is separated from the Thousand Pockets Tongue of the Page Sandstone by the Judd Hollow Tongue of the Carmel Formation.

Thousand Pockets Tongue of the Page Sandstone (Jpt) — The upper tongue is mostly yellowish-gray to very light gray, fine- to medium-grained quartz sandstone. A conspicuous layer, 3 to 9 feet (1-3 m) thick, of reddish-brown calcitic siltstone lies near the middle of the tongue. Trough and planar sets of crossbeds are dominant in the sandstone, but tabular beds are present. Much of the bedding is wavy. Locally the whole unit is contorted. The tongue forms a ledge that caps mesas in the west-central and northwestern parts of quadrangle. The Thousand Pockets ranges irregularly in thickness from about 30 to 80 feet (9-24 m).

Judd Hollow Tongue of the Carmel Formation (Jcj) — This unit, interstratified between tongues of the Page Sandstone, consists of thin beds of moderate-reddish-brown siltstone, light-gray to reddish-brown fine-grained sandstone, and yellowish-gray to pale-orange very fine-grained limestone. The base of the tongue is commonly a thin set, several inches to a few feet thick, of iron-stained tabular beds of sandstone. All but the basal beds are commonly contorted along with beds in the overlying Thousand Pockets Tongue of the Page Sandstone. The Judd Hollow is a poorly exposed slope-forming unit of irregular thickness ranging from about 15 to 40 feet (4.5-12 m).

Upper member of the Carmel Formation (Jcu) — This unit constitutes the bulk of the formation and is composed of shale and sandstone interbedded with lesser amounts of limestone and gypsum. The silty to clayey shale is reddish brown mottled with greenish gray and light grayish yellow. The sandstone is moderate reddish brown and yellowish gray, very fine to fine grained, commonly silty, and poorly to firmly cemented by calcite and locally by gypsum and iron oxides. The limestone is light gray and yellowish gray, micrograined, and in places silty and dolomitic. The limestone is in ledge-forming sets of laminae and thin beds, commonly crinkled, and weathers to yield abundant platy fragments. Shell fragments occur in a few beds. Gypsum, commonly clayey to fine sandy, mostly light gray, locally reddish brown and yellowish green, occurs in lenses as much as 10 feet (3 m) thick, composed of irregular thin beds in the upper part of the formation. The gypsum layers and enclosing beds are commonly contorted. The upper member is generally poorly exposed on an irregular slope interrupted by minor ledges. It is about 220 to 400 feet (67-121 m) thick.

Lower member of the Entrada Sandstone (Jel) — The basal member is reddish-brown, crossbedded, very fine to fine-grained, and in part silty sandstone. Interstratified with the sandstone are sparse sets of dusky-red mudstone and very sparse thin beds of light-yellowish-gray, fine-grained sandstone. The member is fairly resistant and forms steep slopes and rounded ledges. The lower member includes the lower part of the Gunsight Butte Member of the Entrada as determined by Thompson and Stokes (1970). The lower member as mapped in this quadrangle ranges in thickness from about 150 to 240 feet (45-73 m).

Middle member of the Entrada Sandstone (Jem) — The middle member is composed of alternating sets of thin beds of reddish-brown, fine-grained silty sandstone and dusky-red and light-brownish-gray sandy siltstone and mudstone. The member is much less resistant than the upper and lower members. It is mostly covered by sheetwash alluvium and eolium (Qae) and colluvial sand (Qcs). Upper and lower contacts are poorly exposed and generally obscure because of intergrading and probable intertonguing. The middle member includes rocks assigned by Thompson and Stokes (1970) to their Cannonville Member and probably also to the upper part of their Gunsight Butte Member of the Entrada. The middle member of the Entrada as mapped in this quadrangle ranges in thickness from about 310 to 420 feet (94-128 m).

Upper member of the Entrada Sandstone (Jeu) — The upper member is composed of light-gray to pale-orange,

fine-grained sandstone in trough and planar sets of high-angle crossbeds bounded by flat truncation planes. It is fairly resistant and forms conspicuous light-colored, rounded cliffs in the southwest corner of the quadrangle. The upper member of the Entrada as mapped in this quadrangle is approximately equivalent to the Escalante Member of the Entrada of Thompson and Stokes (1970). The upper member ranges from about 300 to 400 feet (91-121 m) in thickness. The total thickness of the formation ranges from about 850 to 1000 feet (260-305 m).

Upper Jurassic Series

Tidwell Member of the Morrison Formation (Jm) — The lower member consists of sandstone, mudstone intergrading with siltstone, and minor limestone. The sandstone is light gray and light yellowish gray, fine grained, and laminated to thin bedded. Mudstone and siltstone is greenish gray and reddish brown. Gray limestone, micrograined but locally recrystallized to coarse grained, is in lenses 1 to 2 feet (.3-.6 m) thick. The basal contact is a regional unconformity (Peterson, Fred, 1980, p. 69-70; 1988, p. 35-42). The member is about 100 to 180 feet (30-54 m) thick in this quadrangle.

Salt Wash Member of the Morrison Formation (Jm) —This member of the Morrison Formation consists mainly of ledge-forming, light-yellowish-gray to grayish-green, fine- to medium-grained sandstone and conglomerate. The conglomerate is characterized by abundant small pebbles of red and green chert, although gray chert and quartz pebbles are also common. A few sets of grayish-yellow-green and dark-reddish-brown mudstone form recesses between the sandstone ledges. The Salt Wash is about 30 to 120 feet (9-37 m) thick in the cliffs west and southwest of Tenmile Flat. The total thickness of the Morrison Formation ranges from about 200 to 260 feet (60-79 m).

CRETACEOUS SYSTEM

Upper Cretaceous Series

Dakota Formation (Kd) — The Dakota Formation consists chiefly of ledge-forming lenses of light-brown, fine- to medium-grained sandstone, mostly crossbedded. It is interstratified with olive-gray to black, slightly to very carbonaceous shale and gray siltstone, and a few thin beds of coal. Iron-stained impressions of fossil plant material are common in sandstone. Most shale contains flakes of black carbonaceous material and in places grades to very carbonaceous mudstone and thin lenses of coal; these lithologies form slopes and are poorly exposed. At the base is a southward-truncating regional unconformity, commonly marked by channels filled with iron-stained lenses of conglomerate composed chiefly of pebbles and cobbles of gray chert. Only about the lower 100 feet (30 m) of Dakota crops out in this quadrangle; in the adjoining Dave Canyon quadrangle the formation is as much as 150 feet (45 m) thick (Zeller, 1973b).

QUATERNARY SYSTEM

Pleistocene Series

High terrace gravel (Qat_3) — Remnants of high gravel alluvium rest on surfaces about 150 to 200 feet (45-60 m) above nearby streams in sec. 4, T. 37 S., R. 4 E. and in sec. 26, T. 36 S., R. 4 E. The gravel is composed of boulders and subrounded blocks of sandstone, as much as 3 feet (1 m) across, and pebbles of white quartz and green and black chert derived from Cretaceous formations and from the Morrison Formation in a matrix of yellow-brown sand. The material is similar to the young pediment gravels of Williams (1985) that are included in the sheetwash alluvium and eolium (Qae). The gravel is weakly cemented and weathers to yield many boulders and pebbles that obscure the basal contact. The high terrace gravel is estimated to be as much as 25 feet (7.6 m) thick.

Pleistocene and Holocene(?) Series

Intermediate terrace gravel (Qat_2) — Remnants of intermediate gravels rest on surfaces about 40 to 100 feet (12-30 m) above Alvey and Harris Washes in the western part of the quadrangle and along Halfway Hollow in the southern part of the quadrangle. The gravels consist of blocks and slabs and pebbles to cobbles of sandstone and conglomerate from the Dakota and Morrison Formations and chert pebbles from the conglomerates. Gravels along Alvey and Harris Washes also contain abundant pebbles and cobbles of quartzite, as much as 10 inches (25.4 cm) across, derived from Cretaceous or Tertiary formations north of the quadrangle, and sparse pebbles and cobbles of basaltic andesite from the Tertiary volcanic rocks of the Aquarius Plateau north of the quadrangle. The deposits are weathered to irregular heaps of stones and reddish- or yellowish-brown fine sand. They are probably not more than 10 feet (3 m) thick.

Holocene Series

Fine-grained terrace alluvium (Qat_1) — These low-level terrace deposits consist of medium-gray to grayish-orange-pink silt and sand and rare pebbles of sandstone in laminated, ripple-laminated, and graded beds and trough sets of low-angle crossbeds. The deposit on the south side of Alvey Wash near the west edge of the quadrangle is about 20 feet (6 m) thick. Other similar deposits, too small to show separately, are included in floodplain alluvium (Qal) along the larger drainages such as Halfway Hollow and Harris and Cottonwood Washes.

Fan alluvium (Qaf) — Fan alluvium in this quadrangle is similar to the fine-grained terrace alluvium (Qat_1) with which it intergrades. The fan alluvium, however, is locally coarser grained and rests on gentle to moderate slopes, commonly flanked by higher ground. The deposits consist of reddish-brown to reddish-orange silt and fine sand, derived from the

Entrada Sandstone, and silt, sand, and abundant small platy debris of shale, sandstone, and limestone derived from the upper member of the Carmel Formation. The material forms a veneer, probably not more than 10 feet (3 m) thick, on a terrace cut into the Entrada and the Carmel that slopes gently toward Alvey Wash near the west edge of the quadrangle. A few small patches of fan alluvium, derived largely from the Navajo Sandstone along Harris Wash, are included in the floodplain alluvium (Qal).

Floodplain alluvium (Qal) — Alluvium on modern floodplains and in channels in this quadrangle consists mostly of yellowish-gray to grayish-orange-pink fine sand and silt with local admixtures of gravel made up of pebbles to cobbles of sandstone, quartzite, and basaltic andesite. Ripple laminations, trough crossbedding, graded bedding and imbricated gravels occur locally. The mapped alluvium includes small areas of fine-textured terrace alluvium (Qat_1) and fan alluvium (Qaf). The alluvium probably attains a thickness of about 30 feet (9 m) in Harris Wash.

Colluvial sand (Qcs) — Slopes bordering flats in the southwestern part of the quadrangle are mantled with thin colluvium derived mainly from alluvial sand and silt covering the flats. Locally the colluvium includes pebbles and cobbles of Morrison and Dakota sandstone and conglomerate derived from patches of pediment gravel in the alluvial sand. Cliffs of the lower member of the Entrada Sandstone near the west edge of the quadrangle are bordered by a slope deposit of reddish-brown fine sand. The material seems to have formed by the disintegration of blocks of sandstone spalled from the cliffs. The colluvium in places is probably as much as 15 feet (4.5 m) thick. Contacts are generalized and locally arbitrary.

Sheetwash alluvium and eolium (Qae) — These deposits were formed chiefly by water flowing in sheets and shallow channels and in part later modified by wind. They consist mainly of yellowish-brown to dark-reddish-brown and grayish-orange-pink silt, sand and small rock fragments. In the southwestern part of the quadrangle, they include coarse gravels in the young pediment alluvium of Williams (1985). Only relatively large areas are shown; much of the Entrada and Navajo Sandstone is covered by irregular small patches of sheetwash alluvium and eolium; contacts are generalized. The deposits on Tenmile Flat probably attain a thickness of about 20 feet (6 m).

Wind-blown sand (Qes) — The eolian deposits are composed of light-grayish-orange to pale-red fine sand, derived mainly from the Navajo Sandstone on which most of the deposits rest. Bedding is generally obscure but in part the sand is in small-scale trough and planar sets of low-angle crossbeds. The sand forms many broad, thin sheets and small dunes that are elongated northeasterly. Some sand has been stabilized by desert grasses, but most of the sheets and dunes are probably altered during windstorms. The mapped wind-blown sand commonly intergrades with similar but dominantly water-laid deposits (Qae). Only relatively large areas are shown; much of the Navajo Sandstone is covered by irregular small patches of wind-blown or residual sand; contacts are generalized. The eolian deposits probably reach a maximum thickness of about 20 feet (6 m) on the east side of cliffs about 2 miles (3 km) southwest of Big Spencer Flats.

Artificial fill (Qfh) — Unsorted reddish-brown, pebble- to boulder-size gravel and sand and silt has been used as fill for gully crossings on the Escalante-Boulder highway and the road to Hole-in-the Rock. The material was probably obtained from the borrow pit near the north edge of the map about a mile northeast of Big Flat.

STRUCTURAL GEOLOGY

The major structure of the Tenmile Flat quadrangle is the broad Collett anticline, whose south-plunging axis lies near the east border of the quadrangle. Dips are gentle, commonly ranging from 2 to 5 degrees.

The only fault in the quadrangle is in secs. 8 and 9, T. 36 S., R. 4 E. The fault is about 2000 feet (609 m) long and has a displacement of only 5 feet (1.5 m), dropping the upper member of the Carmel Formation down on the north against the Thousand Pockets Member of the Page Sandstone.

The Navajo Sandstone, which crops out in the eastern part of the quadrangle, is cut by many vertical and near-vertical joints. The joints are mostly closely spaced, and although locally obscure, are generally conspicuous because they control many small topographic forms. Not all joints are shown on the map; the symbols indicate representative well-defined sets of joints. Northwesterly and northeasterly trends are dominant.

ECONOMIC GEOLOGY

No mines or mineral prospects are present in the quadrangle area. Geochemical reconnaissance, which included all but the southwestern part of the quadrangle as well as nearby areas on the north, east and south, did not indicate the presence of mineral terranes (Weir and Lane, 1981a, b, 1983).

Small, low-grade uranium-copper deposits are in Triassic formations in the Circle Cliffs about 15 miles (24 km) northeast of this quadrangle (Davidson, 1967, p. 65-91; Doelling, 1975, p. 107-109, 131-135). The same Triassic formations underlie the Tenmile Flat quadrangle at a depth of more than 2000 feet (609 m) and perhaps contain similar small, low-grade deposits.

The oil and gas potential of the Tenmile Flat quadrangle has been tested by four wells in the quadrangle and a well a few hundred feet east of the quadrangle boundary (table 1). All the wells were dry. Four of the wells were drilled on the Collett anticline, the major structure of the quadrangle. Shows of oil were noted in Permian strata in a well on this anticline about 1.3 miles (2 km) north of the quadrangle (Weir and Lane, 1981b, table F). Oil is produced in the Upper Valley field (Peterson, P.R., 1973; Sharp, 1976), about 14 miles (22.5 km) west of this quadrangle, from Triassic and Permian strata from the west flank of a fold similar to the Collett anticline. Wells on the similar Escalante anticline, about 10 miles (16 km) northwest of the quadrangle, had flows of CO_2 gas, and two of the wells were completed for possible production of carbon dioxide (Brandt, 1987). By analogy with these productive folds, the Collett anticline in the Tenmile Flat quadrangle may have a potential for commercial oil and gas that has not been fully

Table 1. Record of exploratory wells drilled in and near the Tenmile Flat quadrangle.
[Sources of data: unpublished records of the Utah Geological and Mineral Survey and the U.S. Bureau of Land Management, Salt Lake City, Utah.]

Section	Operator	Well	Total depth (feet)	Year Completed	Oldest formation penetrated	Remarks
			Tenmile Flat quadrangle			
			T.35 S., R. 4 E.			
32	Ryder Scott Oil	1-32 Marsh	6,000	1981	Cedar Mesa Sandstone Member of Cutler Formation (Permian)	Dry hole
			T. 35 S., R. 5 E.			
32	Champlin Petroleum Co.	3 Collett	3,150	1971	Cedar Mesa Sandstone Member of Cutler Formation (Permian)	Dry hole Collett anticline
			T. 36 S., R. 5 E.			
17	Gulf Oil Corp.	1	3,182	1970	Cedar Mesa Sandstone Member of Cutler Formation (Permian)	Dry hole Collett anticline
20	Champlin Oil	1	2,434	1975	Kaibab Limestone (Permian)	Dry hole Collett anticline
			Red Breaks quadrangle			
			T. 36 S., R. 5 E.			
17	Gulf Oil Corp.	1-A	2,628	1973	Timpoweap Member of Moenkopi Formation (Triassic)	Dry hole Collett anticline

tested.

A few lenses of coal, about 1 foot (.3 m) thick and less than 100 feet (30 m) long, are interstratified with gray shale and brown sandstone of the Dakota Formation on the mesas in the southwest corner of the quadrangle. These lenses have no commercial potential, because large reserves of good quality coal in thick beds are in the Kaiparowits basin in adjacent quadrangles (Zeller 1973a, b; Zeller and Stephens, 1973).

Gypsum occurs in wavy layers and pod-like lenses, as much as 12 feet (3.6 m) thick, irregularly interstratified with reddish-brown mudstone and siltstone and yellowish-gray sandstone and limestone in the upper part of the upper member of the Carmel Formation. According to Doelling (1975, p. 149) some gypsum has been mined for local use from the Carmel near Escalante, probably for agricultural purposes. However, the gypsum in the Tenmile Flat quadrangle has little potential for commercial development, because much of it is clayey or silty and is irregularly distributed, generally in contorted layers less than 3 feet (1 m) thick.

Road material has been quarried on a small scale in and near the quadrangle from Quaternary surficial deposits and from the upper member of the Carmel Formation. None of this material has been trucked more than few miles.

Of interest to mineral collectors are small, dark-brown, spheroidal limonitic concretions in the Navajo Sandstone in the northeastern part of the quadrangle. The spheroids, known to collectors as "Moqui marbles" or "Navajo cherries" (Carter and Sargent, 1983; Doelling 1975, p. 156), range from a fraction of an inch to about 4 inches (10 cm) in diameter. They consist of a layer of brownish-black iron oxides enclosing loosely cemented sand. They have weathered out of the Navajo in abundance on Big Spencer Flats.

Collectors also find large crystals of gypsum which occur sporadically in the upper member of the Carmel Formation. Fragments of dinosaur bone from the Morrison Formation and petrified wood from Cretaceous strata are sparsely and erratically distributed in alluvial deposits.

A major natural resource in the quadrangle is the canyon and rock-monument scenery created by the erosion of the Navajo Sandstone. Most hikers explore the desert south of the Big Spencer Flats or walk in the canyon of Harris Wash, which leads eastward to the Escalante River and the Glen Canyon National Recreation Area (U.S. Bureau of Land Management, 1979; Lambrechtse, 1985).

GEOLOGIC HAZARDS

Floods are the chief natural hazard in the Tenmile Flat quadrangle. Summertime cloudbursts in the northern part of the quadrangle or adjacent areas can result in flash floods suddenly coursing down narrow canyons such as Harris or Phipps Washes. In addition, temporary dams formed by slide-rock may give way to release an unexpected torrent far downstream. Hikers in the canyons in the eastern part of the quadrangle should also beware of falling rocks and the possibility of quicksand along stream courses. Motorists traveling the Old Sheffield Road or unmapped trails should be prepared to deal with thick patches of loose sand.

Care should be taken for any construction on surficial deposits. Colluvium (Qcs) and alluvial and eolian sand (Qes) may be unstable even on moderate slopes. Mudstone in the Carmel, Morrison, and Dakota Formations may slide when

disturbed. Gypsiferous layers in the Carmel Formation may collapse because of solution of the gypsum.

Seismic risks appear small. Only two earthquakes of magnitude 4.0 or greater centered in eastern Garfield County have been recorded (Ward, 1979, figure 1). Faults in the area show no evidence of geologically recent movement. The Tenmile Flat quadrangle lies in the relatively inactive seismic zone U-1 (on a scale of 1 to 4) of the Utah Uniform Building Code (Ward, 1979, fig. 3). Earthquakes transmitted from tectonically more active regions, however, may cause rockfalls or sliding of slope deposits.

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