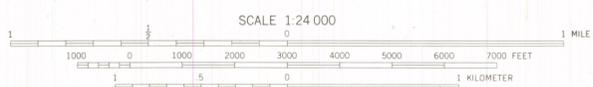


Base map from U.S. Geological Survey,  
Calico Peak quadrangle, 1964

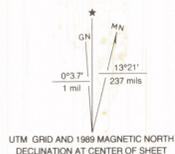


CONTOUR INTERVAL 40 FEET  
DOTTED LINES REPRESENT 20-FOOT CONTOURS  
NATIONAL GEODETIC VERTICAL DATUM OF 1929

# GEOLOGIC MAP OF THE CALICO PEAK QUADRANGLE, KANE COUNTY, UTAH

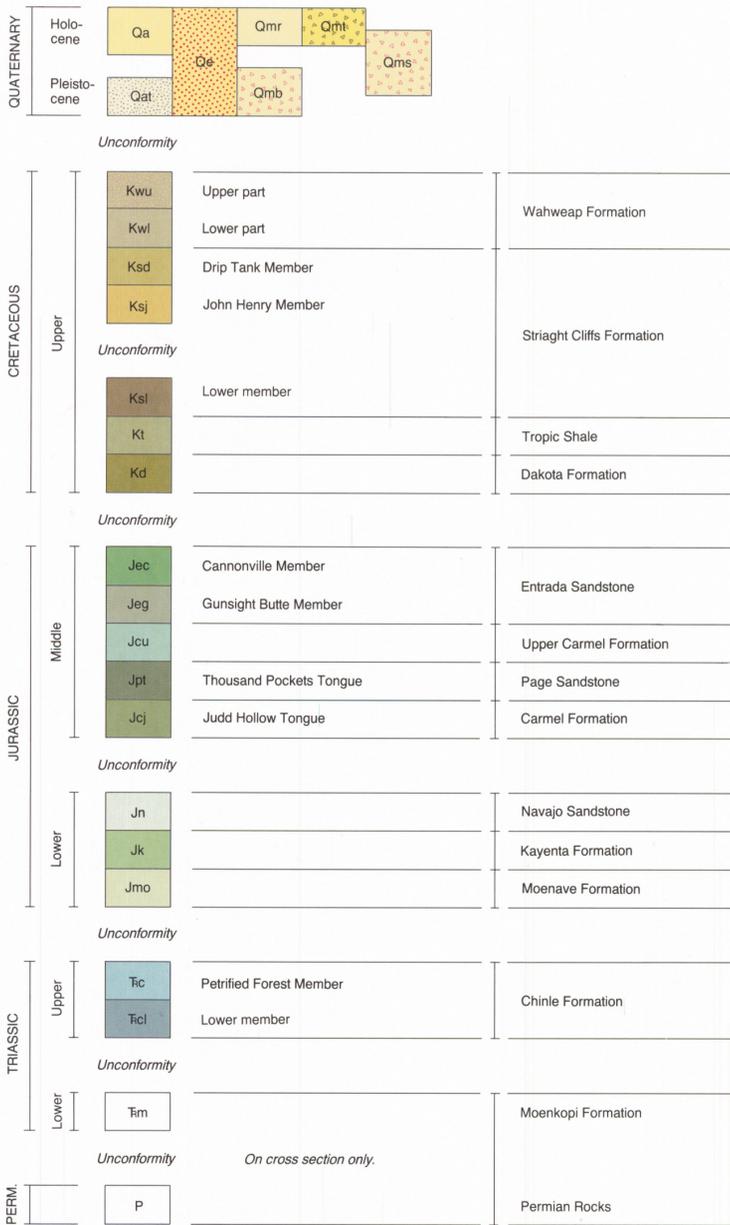
by

Hellmut H. Doelling and Fitzhugh D. Davis



Cartography by J.W. Parker

CORRELATION OF MAP UNITS

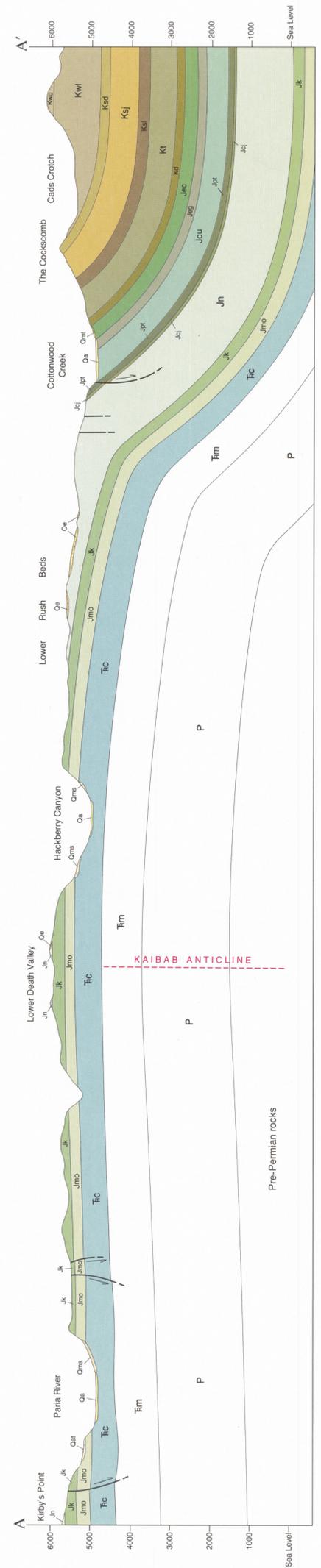
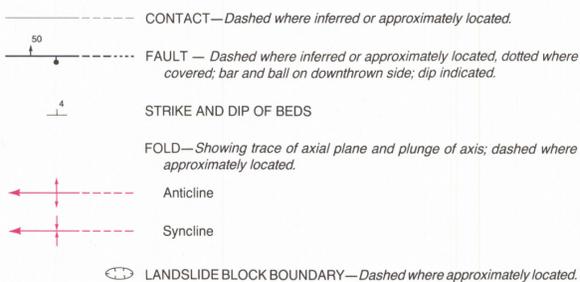


DESCRIPTION OF MAP UNITS

- Qa** Alluvium — Mostly channel, terrace and floodplain deposits of fine to coarse sand and silt, crudely stratified, with lenses of pebbles and cobbles; active channels contain numerous scattered cobbles and boulders; 0 to 40+ feet thick.
- Qat** Older terrace gravel deposits — Cobbles and pebbles of quartzite, siliceous limestone, and volcanic rocks in a sandy matrix transported to the quadrangle by the major streams and deposited at several elevations above the present streams.
- Qe** Eolian sand deposits — Fine sand of mixed eolian and subordinate alluvial origin deposited on ridges, benches, and hollows of bare rock sandstone areas, mostly derived from the Navajo Sandstone.
- Qmr** Rockfall deposits — Angular, mostly sandstone rubble at the foot of cliffs or in narrow steep walled canyons, largest fragments are as much as 35 feet in diameter, only the most recent large deposits are mapped.
- Qmt** Talus deposits — Small angular rock fragments and sand and shale debris derived from the Dakota that form a covering veneer on the steep slope of the Cannonville Member of the Entrada Sandstone along hogbacks of the Cockscomb, 1-2 feet thick.
- Qmb** Block landslide deposits — Rock masses that have slid down steep slopes without disintegrating along the Cockscomb, mostly of the Judd Hollow Tongue of the Carmel Formation and the lower member of the Straight Cliffs Formation.
- Qms** Undifferentiated mass-movement deposits — Mostly mixed rockfall and debris flow deposits that veneer the slopes of the Petrified Forest Member of the Chinle Formation; composed of large angular blocks of Moenave and Kayenta sandstone in a matrix of sandstone gravel and sand; many blocks are 15 to 20 feet thick.
- Kwu** Wahweap Formation — Interbedded sandstone and mudstone; sandstone is yellowish-gray, light brown, or olive gray, fine to medium grained, and ledge and cliff-forming; mudstone is olive green or olive gray, sandy, and slope-forming. Upper part (Kwu) is dominantly thick sandstone lenses with local conglomeratic lenses that form steep cliffs; lower part (Kwl) is less resistant and forms a steep slope beneath the cliff. Upper part is 350+ feet thick whereas the lower part is about 1100 feet thick.
- Kwl** Wahweap Formation — Lower part
- Ksd** Straight Cliffs Formation — Interbedded sandstone, gray shale, carbonaceous mudstone, claystone, and coal. Sandstone is grayish orange, yellowish gray, or yellowish brown, very fine to coarse grained, thin-bedded to massive, and cliff or ledge-forming; the other rock types are slope-formers. The Drip Tank Member (Ksd) is dominated by thick to massive sandstone lenses, forms cliffs, and is 200 to 380 feet thick. The John Henry Member (Ksj) forms a steep slope beneath the Drip Tank cliffs, 500 to 600 feet thick. The John Henry is separated from the lower member by a regional unconformity. The lower member (Ksl) has thick sandstone cliff-forming beds top and bottom with alternating hard and soft units between 300 to 380 feet thick. The middle part of the lower member contains thin discontinuous coal beds.
- Ksl** Straight Cliffs Formation — Lower member
- Kt** Tropic Shale — Drab medium gray slope-forming marine shale with thin beds of olive-gray and light-brown, very fine-grained sandstone in the upper 50 feet; 570 to 625 feet thick.
- Kd** Dakota Formation — Interbedded gray mudstone, carbonaceous shale, yellowish-gray to brown fine- to coarse-grained sandstone, claystone, and thin coal beds, upper beds resistant and form a prominent hogback; 75 to 150 feet thick.
- Jec** Entrada Sandstone — White or light-greenish-gray sandstone, fine- or very fine-grained in two members: Cannonville Member (Jec) is mostly slope and badlands forming and lightly banded with vermillion, maroon, or light brown, 350-390 feet thick; Gunsight Butte Member (Jeg) forms resistant monolithic outcrops that weather yellowish tan, 150 to 210 feet thick. Total Entrada Sandstone is 500 to 600 feet thick.
- Jeg** Entrada Sandstone — Gunsight Butte Member
- Jcu** Upper Carmel Formation — Mostly brightly colored, but poorly exposed very fine- to fine-grained sandstone, siltstone, and limestone, 490 to 580 feet thick; Winsor Member is color banded muddy sandstone that forms badlands, thicker to the north, 320 to 260 feet; Paria River Member is generally reddish, ledge and slope-forming with a 15 to 20 foot pinkish gray chippy limestone at top to north and a 100 foot white and massive eolian sandstone at top to south, thicker to south; 130 to 260 feet thick.
- Jpt** Thousand Pockets Tongue of Page Sandstone — White to pale pink, fine- to coarse-grained eolian sandstone, massive cliff-former, divided by a thin (11 to 29 foot) reddish siltstone and sandstone Carmel Formation tongue 30 to 40 feet above the base; 110 to 180 feet thick.
- Jcj** Judd Hollow Tongue of Carmel Formation — Reddish interbedded ledge and slope-forming fine- to medium grained sandstone, siltstone, and mudstone with subordinate lavender-gray resistant limestone to the south and tan-gray resistant limestone and limestone shale with subordinate reddish soft sandstone, siltstone and mudstone to the north, forms flatirons on dipping Navajo Sandstone; 45 to 100 feet thick.
- Jn** Navajo Sandstone — White to pale pink, fine- to coarse-grained eolian sandstone with sets of sweeping high angle crossbeds etched out by weathering, massive, forms bare rock outcrops as monoliths, domes, spires, arches, and great massive monuments, cliff-forming feature is enhanced in upper 350 to 450 feet and in lower 100 to 250 feet; 1350 to 1450 feet thick.
- Jk** Kayenta Formation — Mostly reddish-brown to white fine-grained sandstone lenses, in thick to massive beds, that form step-like ledges and cliffs with subordinate thinner siltstone, mudstone, clay-pellet conglomerate, and limestone beds; 200 to 335 feet thick.
- Jmo** Moenave Formation — Pale- to moderate-reddish-orange, fine- to very fine-grained thin to thick and sometimes massive planar sandstone beds, with reddish mudstone or siltstone partings and thin interbeds, generally forms a vertical cliff and regularly displays ripple marks and sand filled dessication cracks; 200 to 300 feet thick.
- Tic** Chinle Formation — Mostly colorfully banded mudstone containing interbeds of brown nodular limestone, muddy gray griststone or coarse-grained sandstone, siltstone, and claystone, forms a steep, smooth-appearing slope or badlands with weathered surfaces veneered with bentonitic mud (Petrified Forest Member, Tic); at base is crudely stratified, nearly white pebbly to gritty coarse-grained sandstone with a few interbeds of gray silty mudstone or siltstone (Monitor Butte Member, Ticl), total unit is 500 to 700 feet thick and incompletely exposed in the quadrangle.
- Ticl** Chinle Formation — Lower member
- Tm** Moenkopi Formation — Not exposed on quadrangle, but shown on cross-section; underlies Chinle Formation unconformably, mostly reddish-brown fine grained sandstone, brown siltstone, and gypsum, with a very resistant limestone member (Timpoweap Member) at the base, about 1,000 feet thick.
- P** Permian Rocks — Not exposed on quadrangle, but shown on cross-section; in descending order, Kaibab Formation, Toroweap Formation, Hermit Shale, Queantoweap Sandstone, and Pakoon Formation; about 2,200 feet thick.

FORMATION	SYMBOL	THICKNESS Feet (Meters)	LITHOLOGY
Wahweap Formation	Kwu	350+ (107+)	[Lithology diagram showing sandstone and mudstone layers]
	Kwl	1100 (335)	
Straight Cliffs Formation	Ksd	200-380 (61-116)	[Lithology diagram showing sandstone, shale, and coal layers]
	Ksj	500-600 (152-183)	
	Ksl	300-380 (91-116)	
Tropic Shale	Kt	570-625 (174-191)	[Lithology diagram showing shale layers]
Dakota Formation	Kd	75-150 (23-46)	[Lithology diagram showing sandstone, shale, and coal layers]
	Kd	75-150 (23-46)	
Entrada Sandstone	Jec	350-390 (107-119)	[Lithology diagram showing sandstone layers]
	Jeg	150-210 (46-64)	
Upper Carmel Formation	Jcu	490-580 (149-177)	[Lithology diagram showing sandstone, siltstone, and limestone layers]
Thousand Pockets Tongue	Jpt	110-180 (34-55)	[Lithology diagram showing sandstone layers]
Judd Hollow Tongue	Jcj	45-100 (14-30)	[Lithology diagram showing sandstone, siltstone, and mudstone layers]
Navajo Sandstone	Jn	1350-1450 (411-442)	[Lithology diagram showing massive sandstone layers]
Kayenta Formation	Jk	200-335 (61-102)	[Lithology diagram showing sandstone lenses]
Moenave Formation	Jmo	200-300 (61-91)	[Lithology diagram showing planar sandstone beds]
Chinle Formation	Tic	500-700 (152-213)	[Lithology diagram showing banded mudstone layers]
	Ticl	500-700 (152-213)	

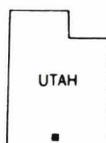
MAP SYMBOLS



**GEOLOGIC MAP OF THE CALICO PEAK QUADRANGLE,  
KANE COUNTY, UTAH**

*by*

*Hellmut H. Doelling and Fitzhugh D. Davis*



# GEOLOGIC MAP OF THE CALICO PEAK QUADRANGLE, KANE COUNTY, UTAH

by

*Hellmut H. Doelling<sup>1</sup> and Fitzhugh D. Davis<sup>1</sup>*

## ABSTRACT

The Calico Peak quadrangle is at the eastern end of the colorful Vermilion Cliffs and the western edge of the Kaiparowits Plateau in central Kane County, Utah. Bedrock strata are 7100 feet (2164 m) thick and range in age from Late Triassic to Late Cretaceous. The Late Triassic is represented by most of the 500 to 700-foot-thick (150-215 m) Chinle Formation, the Petrified Forest Member, and the upper part of the Monitor Butte Member. The Jurassic section, more than 3000 feet (900 m) thick, includes in ascending order the Moenave Formation (200 to 300 feet; 60-91 m), the Kayenta Formation (200 to 335 feet; 60-102 m), the Navajo Sandstone (1350 to 1450 feet; 411-442 m), the Judd Hollow Tongue of the Carmel Formation (45 to 100 feet; 13.7-30 m), the Thousand Pockets Tongue of the Page Sandstone (110 to 180 feet; 33-55 m), the upper Carmel Formation (490 to 580 feet; 150-177 m), and the Entrada Sandstone (500 to 600 feet; 46-183 m). A regional unconformity separates the Jurassic rocks from the Late Cretaceous strata. Late Cretaceous strata include, in ascending order, the Dakota Formation (75 to 150 feet thick; 23-45 m), the Tropic Shale (570 to 625 feet thick; 174-190 m), the Straight Cliffs Formation (1000 to 1300 feet thick; 305-396 m), and the Wahweap Formation (1450+ feet thick; 440+ m). Additionally, seven Quaternary units of fluvial, eolian, and various mass-movement origins were mapped.

The main structures within the quadrangle are two folds trending north or NNE: the Kaibab anticline and the East Kaibab monocline. Deep erosion of the monocline has produced the scenic and rugged Cockscomb on the steeply dipping Straight Cliffs Formation. Normal and reverse faults and joints within the quadrangle predominantly trend NNW and NNE. Ground water issues from numerous fault-controlled springs in the quadrangle. Rockhounding materials include petrified wood, siliceous concretions, ironstone concretions, and fossils. Petroleum potential exists on the Kaibab anticline. The chief geologic hazards are flooding, rockfall, and swelling and shrinking weathered rock materials and soils. Other than grazing, the main asset of the quadrangle could well be the scenic splendor.

## INTRODUCTION

The Calico Peak quadrangle comprises an area between the Cockscomb and the Paria River in central Kane County in the Colorado Plateaus physiographic province. The southwest corner of the quadrangle is at the intersection of 112° W. longitude and 37° 15' N. latitude. Its most imposing geographic feature is the Cockscomb, a magnificently exposed monocline trending NNE along the eastern margin of the quadrangle. The south-flowing Paria River passes through the southwest corner and the abandoned townsite of Paria is located on the east bank at the south margin of the quadrangle. Hackberry Canyon trends south across most of the quadrangle, then sharply turns east to join Cottonwood Creek along the Cockscomb. Cottonwood Creek also flows southerly, but within a structural strike valley along the Cockscomb. The stream valleys and canyons are steep-walled and partially filled with alluvium. In many places, streams have cut through the alluvium to bedrock.

The area is best described as bench and canyonlands country (figure 1). The rugged bare-rock or sand-covered benches between the canyons and the Cockscomb carry enigmatic names such as Lower and Upper Death Valley and the Rush Beds. Ridges, sloping sandy areas, shallow to deep gullies and washes, and isolated blocky knolls characterize this upland area. East of the Cockscomb the rocks plunge into the Kaiparowits Basin, which is characterized by mesas, benches, and buttes. The highest elevation (6634 feet; 2022 m) is at the top of a blocky knoll in the north-central part of the quadrangle, a remnant of the White Cliffs (figure 2). The lowest elevation (4730 feet; 1441 m) occurs where the Paria River flows out of the quadrangle along its southern margin.

Road access in the quadrangle area is limited. A county road reaches the southern margin of the area at Paria from U.S. Highway 89. Flooding along the Paria River makes it impractical to maintain roads northward in the Paria River valley. Ranchers and others who require access into the quadrangle at this location drive the Paria River channel with four-wheel-

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<sup>1</sup>Geologists, Utah Geological and Mineral Survey, Salt Lake City, Utah

drive vehicles when the river is not flooding. Another county road extends along the Cockscomb in the valley of Cottonwood Creek, continues northward to Grosvenor Arch and Cannonville, and joins U. S. 89 southeast of Adairville. There is no road access to the benches and they can only be reached on foot, by horseback, or by helicopter.

The area is used for winter grazing, recreational hiking, and sightseeing. The colorful rocks of the plateau are wonderfully sculpted by erosion. Two magnificent rock arches are present in the quadrangle, to say nothing of the classic East Kaibab monocline along the Cockscomb. Previous geologic work is limited to regional work, the latest of which includes mapping by Sargent and Hansen (1982) and Doelling and Davis (1989). Gregory (1948) made a reconnaissance map for his study of

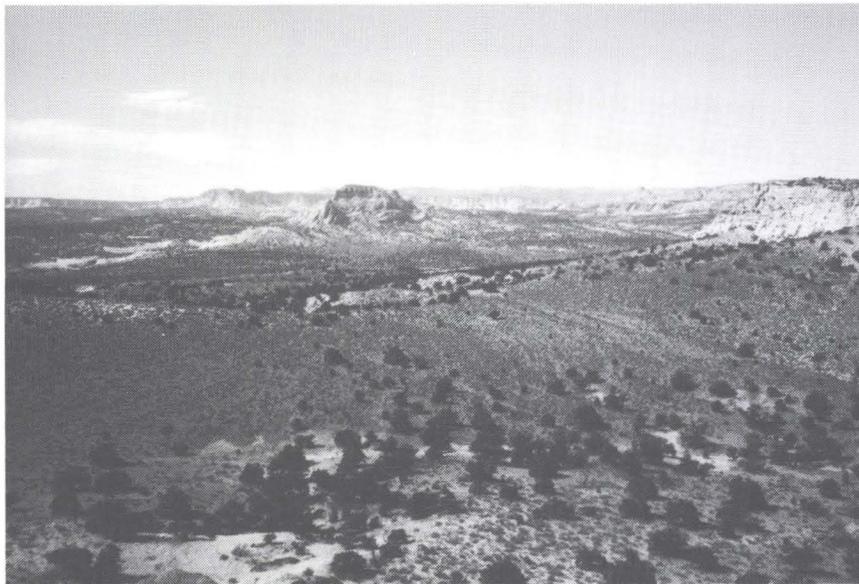
central Kane County. Blakey (1970) mapped the Paria NW (Fivemile Valley) quadrangle immediately to the south and Bowers (1983) mapped the Butler Valley quadrangle immediately to the northeast.

## STRATIGRAPHY

Bedrock formations in the Calico Peak quadrangle range from Late Triassic to Late Cretaceous. Additionally there are several varieties of Quaternary rocks. The oldest exposed bedrock unit is the Chinle Formation, the youngest is the Wahweap Formation. The total average thickness of the exposed bedrock units is about 7100 feet (2165 m). No deep drill holes



*Figure 1: View eastward across the southern part of the Calico Peak quadrangle showing upper benches and deeply incised canyons. The brightly banded Chinle Formation is the lower formation in the canyons, overlain by the cliff-forming Moenave Formation and the bench-forming Kayenta Formation. The light-colored remnants in the foreground and background are of the Navajo Sandstone.*



*Figure 2: View westward across the northern part of the Calico Peak quadrangle showing remnants of the White Cliffs with broad sandy areas at their base.*

are present in the quadrangle at this writing, but data from areas surrounding the quadrangle indicate the presence of an additional 6500 feet (1980 m) of strata above the Precambrian basement; Triassic (1000 feet; 305 m), Permian (2200 feet; 670 m), Pennsylvanian (200 feet; 60 m) Mississippian (600 feet; 183 m) Devonian (400 feet; 122 m), and Cambrian (2100 feet; 640 m).

### TRIASSIC ROCKS

**Chinle Formation (Tc)** — This unit is exposed at the foot of the canyon walls of the lower Paria River and along a segment of Hackberry Canyon. It is incompletely exposed in the Calico Peak quadrangle, but a complete section is present within a mile of the south boundary. In central Kane County, the Chinle Formation is usually divided into two members: a lower member, referred to as the Shinarump Member, and the Petrified Forest Member. In reality both the Shinarump and Monitor Butte members of the Chinle Formation are present in the lower member. Only the upper part, the Monitor Butte Member, is exposed in the quadrangle along the west bank of the Paria River just below Calico Peak itself. One-half mile (.8 km) to the south of the quadrangle the Shinarump is discontinuously exposed and present only in channels cut into the underlying Moenkopi Formation. The lower member (Tcl) is light-colored pebble conglomerate, gritstone and coarse-grained sandstone with a few interbeds of gray silty mudstone or siltstone. It is crudely stratified but exhibits few bedding planes, being generally massive in habit. It erodes into steep slopes and ledges below the sloping mudstones of the Petrified Forest Member. Locally it contains petrified wood and other plant fossils.

The Petrified Forest Member is a colorfully banded mudstone unit containing interbeds of nodular limestone, muddy gritstone or sandstone, siltstone and claystone. The color bands are bright and scenic with red, pink, reddish brown, lavender, purple, white, brown, yellow, maroon, black, and grayish-green. The steep slopes below the base of the Moenave Formation appear smooth and massive, but the outcrop surfaces are veneered with bentonitic mud. Thin to medium beds become apparent when this 6 to 12-inch (15-30 cm) coating is removed. Locally it contains petrified wood, siliceous beds and nodules and, at one horizon near its base, a thin coal bed.

The entire Chinle Formation ranges between 500 and 700 feet (150-215 m) in the quadrangle. Measurements around Paria vary from 497 feet (151 m) (Wilson, 1958), to 652 (199 m) (Stewart, Poole, and Wilson, 1972), to 711 feet (217 m) (Doelling and Davis, 1989). Some of the low measurements were taken where the lower member is missing. At Gingham Skirt Butte, a mile south of Paria, a complete section of the Petrified Forest Member is 556 feet (169 m) thick. A complete section of the Petrified Forest Member is not present in the quadrangle; the lower member is in fault contact with the Petrified Forest Member. The fault block exposing the lower member of the Chinle does expose the lowermost part of the Petrified Forest Member, however. The member contact is easily recognizable along a horizon where light pebbly sandstone is overlain by

less resistant, darker, bentonitic mudstone. Light-colored pebbly sandstone lenses, that resemble the lower member exposures, are occasionally found within the Petrified Forest Member. Notably, one occurs across the Paria River Valley opposite the outcrop of the lower member. These lenses are part of the Petrified Forest Member, and mudstones underlie as well as overlie them. Palynomorphs found in the thin coal bed of the Chinle Formation in the Calico Peak quadrangle give a Carnian age (Doelling and Davis, 1989). The Chinle Formation is widely recognized as having been deposited in a fluvial environment (Stewart, Poole, and Wilson, 1972, p. 87-100)

### JURASSIC ROCKS

**Moenave Formation (Jmo)** — The Moenave Formation in the past has generally been regarded as Triassic, but recent explanations by Pipiringos and O'Sullivan (1978) and Imlay (1980) provide evidence that the unit might be completely Jurassic in age. This age assignment is followed in this presentation, but no fossils or datable samples were found in the Moenave, Kayenta, or Navajo formations in this quadrangle to support the premise.

The Moenave Formation overlies the Chinle Formation unconformably, but when closely inspected, the contact appears to grade over a few feet. The mudstones of the Chinle become sandy toward the top and locally a few thin to medium beds of sandstone are present. The base of the Moenave is best placed above the last significant mudstone slope-former of the Chinle. The Wingate Sandstone, which occupies this interval to the east, has been recognized south of the Calico Peak quadrangle along the Cockscomb (Blakey, 1970, p. 53; Stewart, Poole, and Wilson, 1972, p. 262) in the basal part of the Moenave Formation. No attempt was made to differentiate the Wingate in the Calico Peak quadrangle and the entire interval between the Chinle and Kayenta formations was mapped and described as Moenave Formation. The regional relationship between the Wingate and Moenave formations has been described by Harshbarger, Repenning, and Irwin (1957, p. 8-17).

The Moenave is a pale to moderate reddish-orange fine-grained to very fine-grained sandstone or siltstone, in thin to thick and sometimes massive blocky beds, with sporadic thin, dark-red mudstone or siltstone partings and thin beds. It is quite resistant, forming unscalable, nearly vertical cliffs in the Paria River Canyon and along Hackberry Canyon. The dark red mudstone partings often exhibit desiccation cracks that are filled with the sandstone of the bed immediately above. The sandstones commonly display ripple-marks and cross-stratification. The cementation is generally calcareous, with iron oxides playing a lesser role but adding most of the color. The degree of cementation is light to medium.

In outcrops to the west the Moenave is divided into a lower Dinosaur Canyon Member, a middle Whitmore Point Member, and an upper Springdale Sandstone Member. In the Calico Peak quadrangle, the Whitmore Point Member is missing and the differences between the upper and lower members are subdued so no attempt was made to map them separately.

In this quadrangle, both the upper and lower members are cliff forming. However, the bedding in the lower member is not as massive as it is in the upper. The grain size in the lower is generally very fine whereas it is fine in the upper. Also the color in the lower member is a little darker.

The thickness of the Moenave Formation is variable in the Calico Peak quadrangle, ranging from 200 to 300 feet (60-90 m). The formation probably thins from the southwest to the northeast. Although there are no surface outcrops in the Butler Valley quadrangle to the northeast, Bowers (1983) reported 75 to 100 feet (23-100 m) of Wingate Sandstone in the subsurface. The Moenave is 205 feet (62 m) thick in Sec. 5, T. 41 S., R. 1 W. along Hackberry Canyon, 271 feet (82.6 m) thick in Sec. 14, T. 41 S., R. 2 W., about a mile west of Calico Peak (Stewart, Poole, and Wilson, 1972), and 281 feet (85.6 m) thick in Sec. 18, T. 41 S., R. 1 W. (Wilson, 1958). The Dinosaur Canyon Member is 105 feet, 119, and 144 feet (32, 36, 44 m) thick and the Springdale Sandstone Member is 100 feet, 152, and 137 feet (30, 46, 42 m) thick respectively in these three measured sections.

The Dinosaur Canyon Member of the Moenave is thought to have been deposited on a mud-flat over which sporadic shallow streams migrated. Local shallow bodies of water covered the mudflat that periodically desiccated and allowed deep mudcracks to form (Wilson, 1958, p. 78-80), whereas the Springdale Sandstone Member was deposited by shifting streams over a flood plain of low relief (Wilson, 1958, p. 105-107).

**Kayenta Formation (Jk)** — It overlies the Moenave at all locations in the Calico Peak quadrangle. It forms the surface of much of the high bench area between the Cockscomb and the west margin in the southern half of the quadrangle. The unit caps Calico Peak and is usually the highest unit exposed in the canyon cliffs.

The overall color of the Kayenta Formation is reddish-brown; it is generally darker than the reddish-orange of the underlying Moenave Formation and contrasts sharply with the overlying light pinkish-white Navajo Sandstone. The Kayenta is mostly sandstone, but variable amounts of siltstone, mudstone, clay-pellet conglomerate, and sandy limestone are also present. Locally these lithologies exhibit colors that vary from the dominant reddish-brown, and include white, pale red, orange, brown, lavender, pink, gray, and purple. The fresh color of the sandstone is usually a cream-white, but the exposed surfaces are heavily stained by the iron oxide materials present in the siltstones and mudstones. Occasional pale red streaks and bands are found in the fresh sandstones as well.

The sandstone is generally fine-grained, quartzose, sub-round to subangular, and well-sorted. Fine mica is present in some of the beds, as well as some coarse siliceous grains. The cementation is usually calcareous and the rocks are friable to hard. Most sandstone beds are lenticular and thickbedded to massive, show low-angle or high-angle crossbeds, and collectively form step-like ledges and cliffs. The mudstones and siltstones are present as partings and thin to medium beds between the sandstone lenses. Clay-pellet conglomerate beds

are usually gray, and medium-bedded and lenticular with individual pellets mostly multi-colored. Limestone beds are hard, mostly thin-bedded, gray, lavender or purple. They weather smooth and blocky.

The Kayenta Formation in the Calico Peak quadrangle resembles the formation as it is exposed on the east side of the Kaiparowits Plateau. Farther west it is finer grained, more uniformly reddish-brown in color, and a slope-former. The thickness of the Kayenta Formation in the Calico Peak quadrangle varies from 200 to 335 feet (61-102 m). The unit is 287 feet (87 m) thick in Hackberry Canyon (Sec. 8, T. 41 S., R. 1 W.) and 334 feet (102 m) thick on the north side of No Mans Mesa (Sec. 11, T. 41 S., R. 2 W.). Wilson (1958) measured a complete section of only 204 feet (62 m) just to the south of the quadrangle at the north end of Shurtz Gorge (Sec. 18, T. 41 S., R. 1 W.). Other sections of the Kayenta Formation measured to the south along the Cockscomb by Wilson all indicate thicknesses of approximately 200 feet (61 m). Bowers (1983) indicated the Kayenta is 400 to 450 feet (122-137 m) thick in the subsurface to the northeast in the Butler Valley quadrangle.

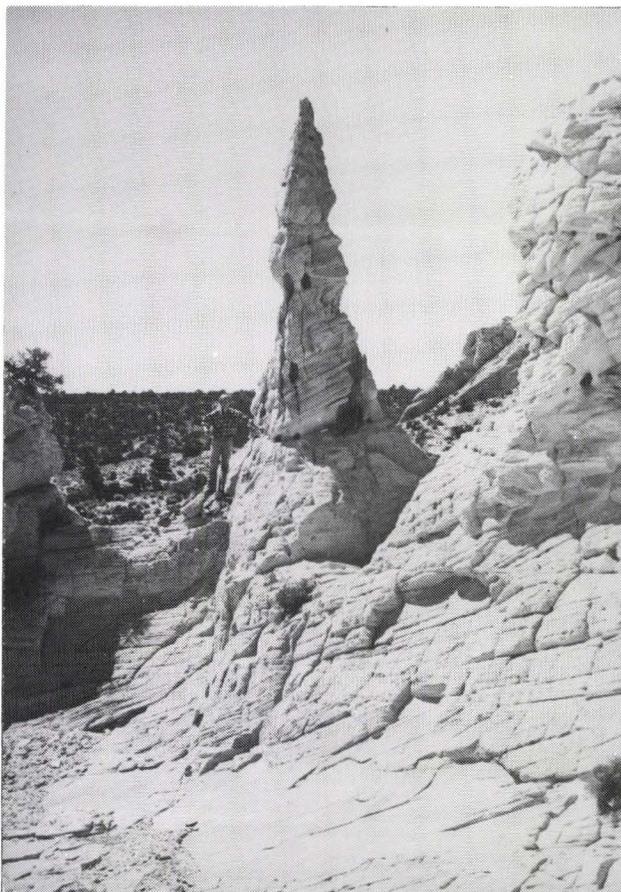
The contact between the Moenave and overlying Kayenta Formation is variable and sometimes difficult to place in the Calico Peak quadrangle. The contact occurs beneath the more lenticular and coarser grained sandstone beds of the overlying unit. These sandstones are more variable in color and lithology, with crossbeds at higher angles. The Kayenta sandstones form cliffy ledges rather than vertical cliffs and are far less blocky weathering. The contact appears to be gradational and irregular along much of the Paria River; locally it is sharp along a bedding plane.

The depositional environment of the Kayenta Formation is dominantly fluvial. However, eolian high-angle cross stratification occurs in many of the sandstone beds, especially near the top. Generally, the Kayenta sandstones represent ancient stream channels separated by thin overbank, lacustrine, and floodplain deposits. Near the top, the desert environments that dominated the Navajo Sandstone deposition made their introduction. These windblown sand sheets probably join the main mass of the overlying Navajo Sandstone somewhere to the east. The environments of deposition and the intertonguing relationship with the Navajo have been described in detail by Wilson, 1958, p. 111-116, and p. 130-133.

**Navajo Sandstone (Jn)** — The predominantly exposed unit in the Calico Peak quadrangle, it is present on the surface of most of the high benches between the Cockscomb and the Paria River Canyon, in the northern half of the quadrangle. It forms bare-rock outcrops as small cliffs, monuments, domes, and low ridges; sand derived from the Navajo Sandstone fills or veneers swales and other low places (figure 3).

The Navajo is white to pale pink and composed of friable and massive sandstone. The sand grains are fine to coarse grained, siliceous and lightly cemented with calcite. The eolian high-angle, large-scale cross stratification is its trademark and individual crossbed sets vary in thickness to as much as 30 feet (9 m). The formation can be crudely subdivided into three parts, a lower cliffy part, 100 to 250 feet (30-76 m) thick that is often stained brown; a middle softer part about 700 feet (213

m) thick; and an upper "White Cliffs" part, about 350 to 450 feet (106-137 m) thick. The lower cliffy part forms many monuments and domes that rest on the upper surface of the Kayenta Formation. These rock monuments and domes are often half buried in Navajo-derived sand. Locally, in this lower part, the cross stratification is contorted and otherwise deformed. The middle part forms sloping bare-rock surfaces, with ridge tops and hollows filled with Navajo-derived sand. Locally the sandstone is cemented by iron oxides to form ironstone concretions and contorted sheets of ironstone. Remnants of the White Cliffs, a few still capped by the Carmel Formation, occur to the north. East-tilted White Cliffs are aligned north-south  $\frac{1}{2}$  to  $1\frac{1}{2}$  miles (.8-2.4 km) to the west of the Cockscomb.



**Figure 3.** Bare-rock exposures of the Navajo Sandstone form minarets, domes, and other unusual erosional features.

The Navajo Sandstone is 1360 feet (414.5 m) thick as measured along Hackberry Canyon in Sec. 9, T. 41 S., R. 1 W. Finding suitable places to measure the Navajo is difficult because of its great thickness and lack of marker beds. It is thought to thicken northward and westward and its thickness probably ranges between 1350 and 1450 feet (411-442 m). Bowers (1983) estimated the Navajo in the Butler Valley quadrangle to the northeast as 1550 to 1700 feet (472-518 m). The Navajo may be somewhat attenuated by faults along the steeply folded Cockscomb.

The contact between the Navajo Sandstone and the underlying Kayenta Formation is generally sharp. The reddish color of the Kayenta is replaced by the cream-white of the Navajo, thick to massive fluvial sandstone lenses are replaced by massive eolian sandstone with sweeping high-angle, large-scale cross stratification. However, eolian sandstone horizons often occur in the upper parts of the Kayenta and thin Kayenta-like mudstone is often found in the lower part of the Navajo, indicating an intertonguing relationship. Locally it is difficult to place the contact.

The Navajo was probably deposited as sand dunes in an Early Jurassic desert. The formation of contorted cross stratification and ironstone concretions and sheets was penecontemporaneous with deposition. The cause of this deformation might be groundshaking that occurred during Jurassic earthquakes.

**Judd Hollow Tongue of the Carmel Formation (Jcj)** — This thin unit overlies the Navajo Sandstone disconformably and is exposed in flatirons along the west side of the Cockscomb and on isolated remnants of the White Cliffs, mostly in the northeast corner of the quadrangle. To the south it is composed of interbedded sandstone, siltstone, and mudstone with subordinate limestone. To the north it is composed of limestone and fissile limestone or calcareous shale with subordinate sandstone, siltstone, and mudstone.

The Judd Hollow sandstones are reddish brown, light brown, or tan, in some places mottled. The sandstone is fine to medium grained, calcareous, and thin to medium bedded. Individual beds vary greatly in thickness over short distances along strike. The often sandy siltstones and mudstones are usually darker in color and can be mottled as well. They are less resistant than the sandstones and form partings and slopes. In the southern exposures, the limestones are tan, gray, or grayish brown; partly thin to medium bedded and blocky, partly fissile. The ratio of clastic rocks to limestone is about 4:1, but northwardly the percentage of limestone and fissile limestone increases and they become the dominant rock type with a ratio of limestone and limestone shale to clastic rocks of 2:1. In the north limestone beds are mostly gray-tan and fissile to medium bedded, some contain poorly preserved fossils. The medium-bedded units are hard, weather blocky, and form resistant ledges, while the fissile limestone forms steep slopes. The northern clastic rocks are similar to those in the south but are usually less mottled. To the north most of the clastic rocks occur at the top of the unit.

To the west of the Calico Peak quadrangle, the Judd Hollow Tongue can be subdivided into two members, an upper Crystal Creek Member of sandstone, siltstone, and mudstone, and a lower Co-op Creek Member dominated by tan-gray limestone and limestone shale (Doelling and Davis, 1989). These units can be subdivided in the Calico Peak quadrangle as well but are too thin to map separately. In the Calico Peak quadrangle the Co-op Creek equivalent is mostly sandstone, but a few limestone beds appear at the top and mark the division with the Crystal Creek equivalent. Southeastwardly the Judd Hollow Tongue is principally composed of reddish-brown clastic rocks (Phoenix, 1963, p. 33).

The disconformity at the base of the Judd Hollow Tongue is an easily identifiable sharp contact. The upper surface of the Navajo Sandstone was eroded nearly flat before the Judd Hollow was deposited. The initial Judd Hollow unit is usually a thin to medium bed of reworked Navajo Sandstone. The reworked Navajo layer is usually overlain by a few feet of maroon or reddish brown slope-forming siltstone or mudstone, even where limestone and shaly limestones dominate.

The thickness of the Judd Hollow Tongue ranges from 45 to 100 feet (13.7-30 m) in the Calico Peak quadrangle, becoming generally thicker to the north. This increase in thickness is irregular and may indicate some structural attenuation along the Cockscomb. In Sec. 9, T. 41 S., R. 1 W. the Judd Hollow is 45 feet (13.7 m) thick with 18 feet (5.5 m) assigned to the Crystal Creek Member and 27 feet (8.2 m) assigned to the Co-op Creek Member. In Sec. 4, T. 39 S., R. 1 W., on a northern mesa above the Rush Beds, the Judd Hollow is 74 feet (22.4 m) thick with 27 feet (8.2 m) assigned to the Crystal Creek Member and 47 feet (14 m) assigned to the Co-op Creek Member.

The Judd Hollow Tongue was deposited marginal to a sea which invaded southern Utah from the north in Middle Jurassic time (Hintze, 1973, p. 64). The deeper part of this sea lay to the west of the Calico Peak quadrangle. The limestone beds at the top of the Co-op Creek Member of the Judd Hollow indicate a maximum level of transgression for the sea during Judd Hollow time.

**Thousand Pockets Tongue of the Page Sandstone (Jpt)** — A sandstone unit, resembling the Navajo Sandstone, of white to pale pink, fine to coarse-grained siliceous windblown sand. It is massive, resistant and exhibits high-angle sweeping cross stratification. The unit is friable and loosely cemented with calcium carbonate. It is exposed along the Cockscomb, forming much of the west wall along Cottonwood Creek and also capping a White Cliffs mesa in the northeast, where it is generally poorly exposed.

A thin tongue of the Carmel Formation is conspicuously present within the Thousand Pockets Tongue sandstone along much of its exposure. This tongue consists of reddish to chocolate brown siltstone and fine-grained sandstone. Some is mottled to greenish gray. The Carmel Tongue is much less resistant than the Thousand Pockets Tongue sandstone and forms a recess or earthy slope.

The Thousand Pockets Tongue, including the thin Carmel tongue, ranges from 110 to 180 feet (33.5-55 m) in thickness in the Calico Peak quadrangle. Excluding structurally attenuated sections, it thickens southward along the Cockscomb. The Carmel Tongue is usually found one-third of the way above the base of the Thousand Pockets Tongue. The thickness of the Carmel Tongue is variable and generally thicker in northern exposures, ranging from 11 to 29 feet (3.3-8.8 m). The Thousand Pockets Tongue is approximately 172 feet (52 m) thick at the mouth of Hackberry Canyon, Sec. 9, T. 41 S., R. 1 W., and 140 feet (43 m) thick on the White Cliffs mesa.

The lower contact with the Judd Hollow Tongue is sharp and exhibits a relief of 1 or 2 feet (.3-.6 m). However, the contact does not represent a significant period of erosion or

nondeposition. The Thousand Pockets Tongue was deposited in an eolian near-shore environment during a regression of the Carmel sea in Middle Jurassic time. The Thousand Pockets Tongue pinches out about 20 miles (32 km) to the west.

**Upper Carmel Formation (Jcu)** — This unit is poorly exposed in the Calico Peak quadrangle and generally is covered by the alluvium of Cottonwood Creek along the Cockscomb. Occasionally the deep reddish lower part appears "plastered" on the Thousand Pockets wall. Exposures improve to the north and a complete section may be exposed in the adjacent Horse Canyon quadrangle in Sec. 14, T. 40 S., R. 1 W. At that location both the Paria River Member and Winsor Member of Thompson and Stokes (1970) are recognizable. These members are not differentiated on the Calico Peak map. In the Calico Peak quadrangle the exposures of the Upper Carmel Formation are mostly of the Paria River Member, a mostly fine-grained sandstone and interbedded siltstone and mudstone. The overall color is a deep red, imparted to the member by the siltstones and mudstones. The sandstones are pale red, white, or light brown in color; they are calcareous, and weather blocky. Siltstone and mudstone generally form earthy slopes. In northern sections, where the top is exposed, is a 15-20 foot (4.5-6 m) thickness of pinkish-gray silty, sandy, and muddy, chippy-weathering limestone unit. It forms a weak ledge at the top of the member. The Winsor Member is only partially exposed in the quadrangle and consists mostly of muddy, very fine-grained sandstone and siltstone. Its color alternates from white to maroon, orange, light brown, grayish green, and red each 1 or 2 feet (.3-.6 m). It usually weathers into earthy slopes, rarely indicating the thickness or nature of the beds; the outcrops develop badlands with irregular ribs and swales.

The upper Carmel Formation is about 490 feet (149 m) thick in Sec. 14, T. 40 S., R. 1 W., in the adjacent Horse Canyon quadrangle. The Winsor Member is 360 feet (109 m) thick and the Paria River Member is 130 feet (39 m) thick. About two miles (3.2 km) to the south of the Calico Peak quadrangle the upper Carmel is about 580 feet (176 m) thick. This section differs in that a chippy-weathering limestone unit is not present at the top of the Paria River Member. A greenish-gray to white massive eolian sandstone divides the two members. The Winsor is about 320 feet (97 m) thick, the eolian sandstone is 100 feet (30 m) thick, and the Paria River Member is about 160 feet (48 m) thick.

The lower contact of the upper Carmel Formation is sharp and easily recognizable. A thin to medium bed of tan, reworked, Thousand Pockets Tongue sandstone covers its undulating surface. The maximum amount of relief is about 2 feet (.6 m). Any of the Paria River lithologies may be found above the reworked bed. The upper Carmel Formation exhibits a wide range of depositional environments associated with shallow marine and near-shore continental conditions (Blakey, 1970, p. 85). The eolian sandstone to the south and the chippy-weathering limestone to the north at the top of the Paria River Member are probably time-stratigraphic counterparts and indicate a maximum extension of a transgressional phase of the late Carmel sea.

**Entrada Sandstone** — Two members of the Entrada Sandstone are identifiable in the Calico Peak quadrangle, in ascending order, the Gunsight Butte (Jeg) and the Cannonville members (Jec). These form discontinuous exposures on the east side of Cottonwood Creek valley underneath the hogback produced by the overlying Dakota Formation. The Gunsight Butte Member forms a line of bare-rock monoliths in the southern half of the outcrop belt. The Cannonville Member, which is not as resistant, generally forms a steep slope or badlands beneath the hogback-forming Dakota Sandstone above. Its surface is often covered by talus rubble from the Dakota. The top of the Cannonville Member is more resistant in the northern part of the quadrangle and locally erodes into monoliths resembling those of the Gunsight Butte Member.

The sand grains of the Entrada Sandstone are mostly fine or very fine grained, subround to subangular, and frosted. Cementation is calcareous or argillaceous and the rock is friable. Coarse sand grains are often found aligned with the cross-stratification laminae. Sandstone of the Gunsight Butte Member is white where fresh and weathers to a yellowish tan; weathering usually does not etch out the high-angle cross stratification as it does in the Navajo Sandstone. The Gunsight Butte Member usually comprises a single massive unit and calcareous cementation is dominant.

The Cannonville Member sandstone is mostly white or light greenish gray but is lightly banded with vermilion, maroon, or light brown. The sands are mostly argillaceous. Cross stratification, where observable, is low angle. It contains sporadic interbeds of mudstone, shale, and siltstone, some of which are brilliantly or darkly colored. One particularly noticeable dark-purple bentonitic mudstone is obvious at many outcrops. The hard, resistant sandstone present at the top in northern sections has a light olive-green color, weathers yellow and exhibits high-angle cross stratification. Calcareous cementation is dominant.

The Entrada Sandstone is 524 feet (160 m) thick in Secs. 9 and 10, T. 41 S., R. 1 W. along the Cockscomb. The Cannonville Member is 366 feet (111 m) thick and the Gunsight Butte Member is 158 feet (48 m) thick. The unit thickens northward and Bowers (1983) reported 700 feet (213 m) in the Butler Valley quadrangle to the northeast. To the south Blakey (1970) reported only 328 feet (100 m) of Entrada in the Five-mile Valley quadrangle at West Cove. The Entrada probably ranges from 500 to 600 feet (152-183 m) in the Calico Peak quadrangle; local sections may be structurally attenuated where steeply folded.

The Entrada overlies the Carmel Formation with apparent conformity; the contact is sharp, rocks beneath are reddish and slope-forming, rocks above are resistant and white. The Entrada was probably deposited under a mix of eolian, deltaic, fluvial, and lacustrine conditions in Late Jurassic time (Blakey, 1970, p. 95).

## CRETACEOUS ROCKS

**Dakota Formation (Kd)** — This unit forms an impressive line of hogbacks along the Cockscomb on the east side of Cotton-

wood Creek. The hogbacks occur between the valley of Cottonwood Creek to the west and the swales formed by the softer Tropic Shale to the east. The Dakota is a heterogeneous unit of mudstone, gray and carbonaceous shale, sandstone, claystone, coal, and coquina.

Sandstone comprises no more than 20 percent of the unit, is yellowish gray to medium brown, and varies from fine to coarse grained. Most units are medium grained and medium bedded. Sandstone, cemented with calcite, is the most resistant lithotype and weathers into blocky ledges. Although sandstone can be found anywhere in the heterogeneous unit, it is usually thicker bedded and more concentrated at the top. The uppermost sandstone beds hold up the hogback ridge. Shale and mudstone are the most abundant rock types and are of various shades of gray, the shade dependent upon the amount of carbon; carbonaceous shales and mudstones often contain visible plant fragments. Much of the shale is sandy. Claystone is not common and is generally found near the base of the formation, where it is quickly recognized by the bentonitic "popcorn" surface it generates upon weathering. Claystone can be very light in color, but where interspersed with carbonaceous mudstone is dark gray to black. Thin coal beds and coal stringers can occur anywhere within the formation. In this quadrangle, there are usually three prominent seams, one a few feet above the base, one in the middle of the unit, and one near the top. Each prominent seam averages 1.5 feet (.4 m) in thickness. The fresh coal is black and shiny, and weathered coal forms a black powder. One or two horizons of coquina, or fossiliferous sandstone, are interbedded with the upper sandstone units. The matrix is generally of sandstone and the cementation is calcareous; fossils are predominantly oysters. A discontinuous cobble conglomerate, usually found at the base of Dakota Sandstone in Kane County, is missing at most exposures in this quadrangle.

The thickness of the Dakota in the Calico Peak quadrangle ranges from 75 to 150 feet (23-45 m). Bowers (1983) reported that the Dakota is 100 to 200 feet (30-60 m) thick in the Butler Valley quadrangle to the northeast and Blakey (1970) measured 178 feet (54 m) of Dakota in the Five-mile Valley quadrangle to the south.

The lower contact of the Dakota with the Entrada Sandstone is a major unconformity. Upper Cretaceous rocks overlie Upper Jurassic rocks with the contact usually found in a slope. The white or light green Entrada sands are capped with gray to black carbonaceous shales or mudstones. Relief of several feet can often be demonstrated along the contact, although in many places it appears conformable. Regionally the contact is an angular unconformity, the rocks below dipping relatively slightly more to the east than the rocks above. The basal conglomerate, when present, is channeled into the Entrada and the remainder of the Dakota Formation may overlie it unconformably. The basal conglomerate may be Early Cretaceous in age (Doelling and Davis, 1989).

The Dakota Formation marks the entrance of a Cretaceous sea (Mancos Sea) into the region from the east and most of the unit was deposited in transitional and marine environments (lagoonal) during the transgressive phase (Peterson, 1969b, p. 157).

**Tropic Shale (Kt)** — This unit is exposed in a narrow band beneath the principal ridge of the Cockscomb and the hogbacks of the Dakota Formation. It is softer than the adjacent formations and weathers into slopes and badlands. The shale is medium-dark gray, fissile, and is predominantly calcareous. It is locally siliceous and contains very fine sand grains. The dry weathered surface is earthy and exhibits mudcrack polygons with widths of 1 to 2 inches (2.5-5 cm). Toward the top the unit becomes sandy and the upper 50 feet (15 m) is sandstone, light olive-gray weathering to light brown, very fine to fine grained, well sorted, calcareous, and platy to thick-bedded. Some of the beds show trace fossils and are bioturbated. Limestone nodules and marine fossils are often found in the lowermost part of the unit.

The Tropic Shale is 575 feet (175 m) thick in Sec. 15, T. 41 S., R. 1 W., and probably ranges from 570 to 625 feet (173-190 m) thick in the quadrangle. Bowers (1983) reports the Tropic to be 600 to 700 feet (183-213 m) thick in the Butler Valley quadrangle to the northeast and Blakey (1970) measured 605 feet (184.4 m) of Tropic in the Fivemile Valley quadrangle to the south.

The Tropic Shale-Dakota Formation contact is generally sharp and conformable. Resistant yellowish-gray sandstone or light brown coquina is followed immediately by dark-gray non-resistant shale. The Tropic Shale (Upper Cretaceous) was deposited in a shallow marine environment. The upper sandstone beds suggest a regression of shallow marine conditions during the latter part of Tropic Shale deposition.

**Straight Cliffs Formation** — The Straight Cliffs Formation of the Kaiparowits Plateau can be divided into four members (Peterson, 1969b). All four members are recognizable in the Calico Peak quadrangle, but the lower two members (Tibbet Canyon and Smoky Hollow members) are relatively thin and were mapped as one unit. In ascending order these are the lower (Ksl), John Henry (Ksj), and Drip Tank (Ksd) members. In the Calico Peak quadrangle the Straight Cliffs Formation forms the high cliff on the east side of the Cockscomb. The

lower member weathers and erodes into a convex-shaped slope exhibiting many ledges. The John Henry Member forms a concave slope with several weakly exposed ledges, and the Drip Tank Member forms the upper cliff and crest of the ridge (figure 4).

The lower or Tibbet Canyon Member portion of the lower member of the Straight Cliffs Formation consists of ledge-, slope-, and cliff-forming sandstone with gray mudstone partings. The sandstone is grayish orange, yellowish gray or yellowish brown, very fine to fine grained, moderately to well cemented with calcite, very thick bedded to massive, and it exhibits low- to high-angle cross stratification. The mudstone partings thicken locally and form slopes between the cliffs.

The upper or Smoky Hollow Member portion of the lower member consists of interbedded sandstone, gray and carbonaceous mudstone or shale, claystone, and coal. The sandstone beds are grayish orange, yellowish gray or yellowish brown, very fine to coarse-grained, calcareous, and thin to thick bedded. Some beds are friable, others are well-indurated. The uppermost sandstone bed is locally white, medium to coarse-grained, cliff-forming and resistant. The shales, mudstones and claystones appear in various shades of gray, dependent on the amount of carbonaceous matter they contain. They are thinly laminated to thin bedded and often contain small coaly fragments. Locally, thin lenticular coal beds are present; some have burned at the surface and reddened the surrounding rocks.

The John Henry Member also consists of interbedded sandstone, gray and carbonaceous mudstone, or shale. The descriptions of these units are similar to those of the Smoky Hollow. Where coal is present, the seams rarely exceed a few inches in thickness. Although the sandstone beds range from thin to thick, true cliff-formers are not common in this member with more of them being friable, cross stratified, and poorly indurated.

The Drip Tank Member is mostly dark yellowish-orange sandstone, fine to coarse-grained, thick bedded to massive,



**Figure 4:** View eastward across the Cockscomb showing exposures of the Upper Cretaceous Straight Cliffs (middle cliff) and Wahweap Formations (cliff on skyline). The rocks in the foreground are Navajo Sandstone.

cross stratified, and cliff forming. Locally the sandstones become conglomeratic. There are partings and thin interbeds of light-olive-gray mudstone up to several feet thick.

The Straight Cliffs Formation ranges from 1000 to 1300 feet (305-396 m) in thickness in the Calico Peak quadrangle. About 300 to 380 feet (91-116 m) are ascribed to the lower member (100 to 130 feet or 30-40 m of Tibbet Canyon Member and 200-250 feet or 61-76 m of Smoky Hollow Member), 500 to 600 feet (152-183 m) to the John Henry Member and 200 to 380 feet (61-116 m) to the Drip Tank Member. At the south end of the quadrangle, in Sec. 15, T. 41 S., R. 1 W., the Straight Cliffs Formation is 1276 feet (389 m) thick; the Tibbet Canyon is 100 feet (30 m), the Smoky Hollow is 217 feet (66 m), the John Henry is 570 feet (174 m), and the Drip Tank is 380 feet (116 m) (Blakey, 1970, p. 164 and 165). All are Late Cretaceous.

The lower contact with the Tropic Shale is gradational and placed beneath the first persistent massive bed of sandstone. Peterson (1969b) indicated the presence of a significant unconformity at the top of the lower member. The Tibbet Canyon was deposited as offshore sand, the Smoky Hollow represents lagoonal deposition, the John Henry and Drip Tank Members of the Calico Peak quadrangle are floodplain deposits (Peterson, 1969b, p. J6, J9, J17, and J19). The John Henry contains the important coal deposits of the Kaiparowits Plateau in lagoonal facies to the east.

**Wahweap Formation** — The Wahweap Formation outcrops east of the Cockscomb on the Kaiparowits Plateau and is exposed in the southeast corner of the quadrangle. It is mostly interbedded sandstone and mudstone and can be divided into lower (Kwl) and upper (Kwu) parts. The lower part is less resistant and forms a bench on the Kaiparowits Plateau developed on the resistant Drip Tank Member of the Straight Cliffs Formation. It also forms a steep slope below the more resistant, more sandy and cliffy upper part of the Wahweap Formation (figure 4).

The sandstone of the lower part is mostly yellowish gray, light gray, or light brown, fine to medium grained, in medium to thick beds. These are calcareous and argillaceous; the individual beds are harder where the calcareous cementation is prominent and friable where it is weak or missing. Locally, coarser grained varieties appear, including gritstone and pebble conglomerate. Many of the sandstones provide a "salt and pepper" appearance upon close inspection and others exhibit low-angle cross stratification. The mudstones are olive green or olive gray, often sandy, and slope forming. Locally, thin beds of very fine-grained sandstone appear in the mudstone units.

The upper part of the Wahweap Formation is mostly cliff-forming sandstone in thick to massive lenses. The sandstone is yellowish gray, light brown, or olive gray and mostly medium grained. The grains are subangular to angular. Many beds have 6 inches to 2 feet (15-60 cm) of gritstone or pebble conglomerate at their base. Calcareous cement is dominant, but varying amounts of iron oxide are also present. The sandstone cliffs, each 20 to 30 feet (6-9 m) thick, are separated by 8 to 15 feet (2.5-4.5 m) of sandy, olive-gray mudstone and

poorly cemented yellowish-gray, slope-forming medium-grained sandstone. The cliffy sandstones locally contain iron concretions, twigs of petrified wood, and scattered petrified dinosaur bones.

The Wahweap Formation (Late Cretaceous) is the youngest consolidated unit exposed in the Calico Peak quadrangle and as such does not display its complete thickness. Most of it is considered to be present, however, its estimated 1450 feet (442 m) compares well or exceeds complete sections measured elsewhere in the Kaiparowits Plateau. Bowers (1983) reported the Wahweap Formation to be 1200 to 1400 feet (365-426 m) thick in the Butler Valley quadrangle to the northeast. The unit ranges from 535 to 1620 feet (163-494 m) in thickness in Garfield County (Doelling, 1975, p. 49). The lower Wahweap in Secs. 2 and 3, T. 41 S., R. 1 W. is 1108 feet (338 m) thick. The inaccessible upper Wahweap was not measured but was estimated to be about 350 feet (107 m) thick on the basis of topographic contours.

The contact of the Wahweap Formation with the Straight Cliffs is conformable and gradational. The contact is placed immediately above the cliff-forming, often coarse-grained Drip Tank sandstone or immediately below the softer olive-gray mudstones of the Wahweap Formation. The lenticular nature of the sandstones and types of fossils indicate the Wahweap to have been deposited in a fluvial environment.

## QUATERNARY DEPOSITS

The Quaternary deposits of the Calico Peak quadrangle have been divided into 7 units and include alluvium, mixed eolian and alluvial deposits, alluvial terrace deposits and four varieties of mass movement deposits.

**Mass movement deposits** — The larger, more prominent talus (Qmt), rockfall (Qmr), block slide (Qmb), and undifferentiated mass movement deposits (Qms) have been mapped in the quadrangle. The block slides have all occurred along the Cockscomb. Most involve the Judd Hollow Tongue of the Carmel Formation. The Judd Hollow dips eastward 25 to 30 degrees as a flatiron on the Navajo Sandstone and even more steeply just west of the valley of Cottonwood Creek. Hard, rough-weathering limestone at the top of the thin unit has locally slipped down the slope on an incompetent reddish siltstone bed found at the base. The blocks have locally ridden over lower outcrops of the Judd Hollow or over the Thousand Pockets Tongue of the Page Sandstone. The blocks are somewhat shattered but are generally coherent; large cracks can often be observed on the limestone surfaces higher up the dip slope. The largest of these landslide blocks is about 400 feet (122 m) long and 300 feet (91 m) wide.

Another group of landslide blocks occur in Straight Cliffs Formation rocks. The Straight Cliffs Formation forms the highest ridge of the Cockscomb, but its lower members dip steeply eastward, opposite to the slope of the cliff. Nevertheless, in a few places, blocks of the lower member have broken away from the cliff face and the slip plane is parallel to the slope of the cliff and cuts across the bedding. The landslide blocks appear as slight westward-projecting salients along the

otherwise straight front of the Straight Cliffs outcrops. These are coherent and difficult to separate from the bedrock outcrops. The largest involve several hundred feet of strata.

Rockfall deposits (Qmr) consist of angular, mostly sandstone rubble at the foot of cliffs, steep slopes, or in narrow steep-walled canyons. All bedrock units contribute to the deposits, but the larger deposits invariably contain materials from the Kayenta, Straight Cliffs, and upper part of the Wahweap Formations. Rockfall events occur less frequently along Navajo Sandstone and Thousand Pockets Tongue cliffs and large deposits are therefore less frequently encountered. Small rockfall deposits collect at the foot of slope-forming units that contain a few ledge-formers. Only the largest and most recent rockfall deposits were mapped.

The rockfall deposits of the Calico Peak quadrangle are all Holocene in age and are being slowly destroyed by flash floods and other normal weathering and erosional processes. Rockfall blocks and debris soon disintegrate into sand because the contributing sandstone formations are poorly cemented and friable.

A very large rockfall occurred in upper Hackberry Canyon in the early spring of 1988. Rocks of the Kayenta Formation, undercut by the stream along the west wall of the canyon, peeled off and shattered across the 100-foot-wide (30 m) valley to the east wall. Green shrubs and brush were uprooted and a temporary dam was created which impounded the creek to form a lake 6 to 8 feet (1.8-2.4 m) deep. The water soon broke through the dam of shattered blocks and rubble and the lake disappeared in the summertime. Rock rubble stretched 100 yards (91 m) along the canyon; the deposit was as high as 35 feet (10.6 m) above the stream bed, and the largest fragments were 35 x 25 x 20 feet (10.6 x 7.6 x 6 m) in size. Hogeeye Canyon and the unnamed Paria River tributary canyon to the south also contain recently fallen deposits that block or nearly block the canyons that were derived from the Kayenta Formation. The short westward-sloping canyon tributaries of Cottonwood Creek, cut into the Straight Cliffs Formation, are choked with rockfall debris. The larger of these rockfall accumulations have fallen from the Drip Tank Member of the Straight Cliffs Formation.

Talus deposits composed of sandstone fragments and other debris from the Dakota Formation litter the slopes of the Cannonville Member of the Entrada Sandstone along the hogbacks of the Cockscomb. These have been mapped where they cover significant parts of the slope. These deposits range from 1 to 2 feet (.3-.6 m) in thickness.

Undifferentiated mass movement deposits (Qms) occur as blankets on the slopes of the Petrified Forest Member of the Chinle Formation and contain debris from the overlying cliffs,

ledges, and steep slopes of the Moenave and Kayenta Formations. These blankets are mostly less than 20 feet (6 m) thick, but locally may reach 40 feet (12 m) in thickness. Large angular blocks of Moenave Formation are incorporated in the deposits, some 10 feet (3 m) in diameter, but most are 6 inches to 2 feet (.6 m) in diameter. In places the fallen Moenave blocks have only shattered and show no further disintegration. The angular blocks are scattered in a matrix of sandstone gravel and sand, all bearing the reddish color of the Moenave. In some places the deposits are clast supported, in others they are matrix supported.

It is presumed that these deposits are largely Pleistocene debris flows, rockfall, and rock slides that fell or flowed on very slippery Chinle mudstone surfaces and moved down-slope. Presently these deposits remain only beneath the Moenave cliffs and on ridges. The material has been removed from most of the drainages.

**Eolian sand deposits (Qe)** — Sand sheets are prevalent over much of the northern half of the quadrangle along ridges, benches and in hollows. They mostly consist of cream-white, or tan, silty, fine sand that has not moved very far from its Navajo Sandstone source. The sand has been moved around repeatedly by blowing wind and by water flowing in sheets and shallow channels; the deposits of either can't be separated generally. The dominant process in the formation of these deposits is eolian. The deposits are 0-20 feet (0-6 m) thick over irregular sandstone bedrock surfaces, many of the sand sheets on the benches are stabilized by sagebrush, and ridgetop sand is mostly windblown.

**Alluvial terrace deposits (Qat)** — Remnants of Pleistocene river and stream channel deposits were mapped on the canyon ledges and slopes adjacent to the Paria River and Hackberry Creek. The composition of all of these alluvial terrace deposits (Qat) are similar; fine to coarse sand with subrounded to well-rounded pebbles and cobbles that consist of purple quartzite, light-gray quartzite, dark-gray and black siliceous limestone, and two or three igneous rock types. All of these rocks were transported into the region by these drainages from sources north of the quadrangle. The thickness of the deposits ranges from 2 or 3 feet (.6-.9 m) to about 25 feet (7.6 m).

Map relationships are quite interesting for the terrace deposits along the Paria River. Most of them are deposited in places where former meanderings of the stream eroded the Moenave Formation. Apparently the Moenave Formation provided much resistance to erosion when the ancient river was downcutting through this area. In Hackberry Canyon the terrace deposits lie on the Moenave Formation, the Kayenta Formation, and the Navajo Sandstone.

Paria River		Hackberry Canyon	
Elevation in feet above the present stream	No. of deposits	Elevation in feet above the present stream	No. of deposits
75-85	2	40-80	8
120-145	2	120-160	5
185-205	2	180-200	7
285-305	3	240-280	3
345	1	360	1

The alluvial terrace deposits along the Paria River and in Hackberry Canyon can be divided into 5 relative age groups based on their topographic heights above the present stream beds. The highest deposits are the oldest.

We believe that all the alluvial terraces were deposited during the Pleistocene epoch and, during that time, the rivers and streams were probably larger.

**Alluvium (Qa)** — Alluvial deposits are present in the channels and floodplains of the three principal perennial drainages on the quadrangle: the Paria River, Hackberry Canyon Creek, and Cottonwood Creek. The alluvium of these three drainages contains locally derived material as well as debris eroded from highlands north of the quadrangle.

The Paria River alluvium consists of silt, fine to coarse sand, and pebbles, cobbles, and boulders. The sand is chiefly fine, mostly rounded to subangular, and is both arkosic and quartzose. The gravel and boulders are mainly tan and reddish-brown sandstone, gray limestone, and brown, yellow, purple, black and gray quartzite. The alluvium is possibly 25 to 40 feet (7.6-12 m) thick over an irregular bedrock surface. Except during flood stages, the river has shallow braided flowing channels that meander across a fairly broad floodplain. The positions of the flowing channels can change daily or weekly. Adjacent to the old Paria townsite, the river has eroded through 10 feet (3 m) of its old floodplain on the east side; the cutbank has thin alternating beds of reddish-brown and greenish-gray silt and very fine sand. In other places cutbanks expose lenses of gravel that are interbedded with the silt and sand. On the west side of the river the channel bank is about 3 feet (1 m) high, on top of which is a terrace of older, much more extensive floodplain. Just south of the mouth of Kitchen Canyon the river has eroded a 2-foot-deep (.6 m) channel into a narrow terrace. About 6 feet (1.8 m) above that (8 feet or 2.4 m above the river) is the remnant of an older and wider terrace. Farther to the north, in the western part of Sec. 26, T. 40 S., R. 2 W., the river has incised an 8-foot-deep (2.4 m) channel into a broad, flat terrace.

Along most of Hackberry Canyon the alluvium is mainly silty quartzose sand with angular to subrounded sandstone

gravel and boulders. The alluvium shallowly overlies bedrock. In the wider part of Hackberry Canyon, the thickness of alluvium reaches 30 feet (9 m) on the flanks of the canyon. Here the alluvium is mostly sand with lenses of gravel derived from the local rocks (angular) and from cobbles and pebbles brought in by the stream from the north (subangular to rounded). These exotic cobbles and pebbles are quartzite, silicified limestone and chert, and volcanic materials. The locally derived clasts are dominantly red sandstone. Most of the sand in the alluvium is unmistakably derived from the Navajo Sandstone.

The alluvium in Cottonwood Creek Canyon is mainly silty fine sand. The sand is mostly quartzose, subangular to subrounded grains. Pockets and thin lenses of pebbles and cobbles are present in the stream channel, mostly reddish-brown sandstone, gray limestone, and tan and gray quartzite. The alluvium is 15 to almost 40 feet (4.6-12 m) thick. Cottonwood Creek meanders in a channel deeply entrenched into this alluvium. In the NENE Sec. 9, T. 41 S., R. 1 W., just north of the mouth of Hackberry Canyon, the most recent downcutting by the stream has left banks 15 feet (4.5 m) high adjacent to the channel. In the banks are thin beds of light-gray silty fine sand and tan beds of silty quartzose sand interbedded with thin lenses of sandstone and limestone gravel. On top of the bank is a wide, flat, older floodplain extending at least 300 feet (91 m) to the west and to a much lesser distance to the east. In the NW Sec. 23, T. 40 S., R. 1 W. (unsurveyed), Cottonwood Creek is entrenched between banks 24 feet (7.3 m) high on the east and 40 feet (12 m) high on the west. In the banks are thin beds of silty, fine sand and sandy silt alternating light-gray and tan in color. Narrow surface remnants on top of these banks represent an even older floodplain. About ½ mile (.8 km) farther north, two terraces are present on the west side of the creek. The lower one is approximately 20 feet (6 m) above the creek and the upper one is about 45 feet (13.7 m) above creek level. The material in both is mostly silty quartzose sand with a few pebbles. Cottonwood Creek has locally eroded and shallowly incised the bedrock along its course.



**Figure 5:** The East Kaibab monocline is the most imposing structural feature on the quadrangle. This view is northerly along the strike of the Tropic Shale. The brown hogback to the left is Dakota Formation, the cliffs to the right are Straight Cliffs Formation.

## STRUCTURAL GEOLOGY

The Calico Peak quadrangle is located at the eastern edge of the High Plateaus, Grand Staircase, and Kaibab uplift physiographic areas, just east of which the rocks are downfolded into the Kaiparowits Basin. The rocks west of the Cockscomb are warped and cut by numerous faults and joints. The Cockscomb is the geomorphic representation of a major downfold known as the East Kaibab monocline.

**East Kaibab monocline** — The principal structural feature of the Calico Peak quadrangle is the East Kaibab monocline. The strata dip 45 to 65 degrees along the steep eastern part of the fold where erosion has produced the topographically rugged Cockscomb of the Straight Cliffs Formation (figure 5). Flexure of beds has resulted in an elevation differential of 6000 feet (1829 m), lower to the southeast, across the axial plane. The Navajo Sandstone and all younger bedrock units are folded. Cottonwood Creek follows the NNE trend of the axis of the fold in the southeastern part of the quadrangle. At the north end of the feature in the quadrangle the axis of the fold veers more northeasterly as it enters into the Horse Flat quadrangle. Normal faults parallel the fold along the Thousand Pockets-Carmel Formation contact that have their downthrown blocks to the east. It is difficult to estimate the displacements of these faults because they parallel the strikes of the beds, but they are presumed not to be large in most cases. Some fault traces are buried under the alluvium of Cottonwood Creek and are inferred on the basis of loss of stratigraphic section.

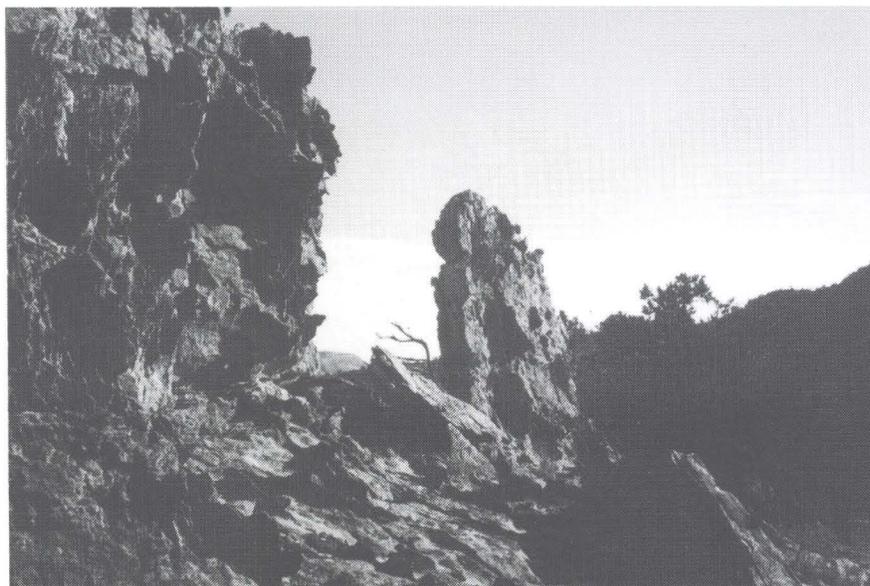
A series of faults splay southwesterly from a bend in the monoclinical axis and cut the rocks to the west of the aforementioned normal faults. These splaying faults angle or bend into the normal faults as they cut into the valley of Cottonwood Creek and are generally high-angle reverse faults or back-thrusts of small displacement, usually much less than 50 feet (15 m). The traces of these faults are quite obvious in the Navajo Sandstone, standing as ridges of shattered rock re-

cemented by hard calcite (figure 6). At the northeast margin of the quadrangle, strata west and opposite the bend in the monocline dip less steeply into the fold than strata south of the bend.

**Paria River fault zone** — A series of faults, trending northwesterly, subparallel the Paria River valley. They cut the rocks on both sides of the river. These are high-angle faults with as much as 100 feet (30 m) of displacement. The downthrown blocks are generally down toward the river but some fault traces cross the river. The blocks between the river and the faults are tilted slightly riverward. These faults are thought to die out in the Chinle Formation with the blocks sliding toward the river on glide planes in the incompetent Petrified Forest Member of the Chinle Formation. These are probably Pliocene or early Pleistocene faults, having formed when the climate probably was much wetter. Faults that cross the river may have formed when the course of the river was different. Locally, low-angle faults and tilted beds are found in the Chinle Formation, which supports the above argument. Generally, the debris flow deposits cover the fault traces, but in a few local places it appears that the Qat deposits have been cut.

**Faults and joints in the Navajo Sandstone** — Faults and joints in the Navajo Sandstone trend NNW or NNE with a dominant trend of NNW; these are especially well developed at the north end of Hackberry Canyon and in the northwest corner of the quadrangle. Only the more prominent of these features were mapped. A small amount of vertical movement can be demonstrated in most of those mapped, but accurate measurements of displacement cannot be made because of the lack of reliable marker beds in the Navajo Sandstone.

**Kaibab anticline** — The anticlinal axis of the Kaibab anticline trends sinuously northward, mostly between Hackberry Canyon and the Paria River. It crosses the Paria River about 1 mile (1.6 km) north of the abandoned townsite of Paria. The axis plunges northward about 2 degrees. To the south, where



*Figure 6: These linear rough outcrops occur along a fault trace in the Navajo Sandstone. The calcareously recemented fractured rocks are more resistant than the adjacent friable sandstone bedrock.*

the axis is within three miles (4.8 km) of the East Kaibab monocline, dips on the east flank are moderate, about 14 or 15 degrees. These become more gentle northward, perhaps as low as 1 or 2 degrees. Dips of strata on the west flank are quite gentle, ranging from 2 to 5 degrees.

**Other folds** — The axes of two folds, the Butler Valley anticline and the Hackberry Canyon syncline, were mapped in the northeast part of the quadrangle. These folds are more prominently displayed to the north. The Butler Valley anticlinal fold trends north-south and plunges southward in the Calico Peak quadrangle. It flattens out and disappears in the south end of Sec. 3, T. 40 S., R. 1 W. Dips on the east flank are very gentle for ½ mile (.8 km) after which the strata bend steeply into the East Kaibab monocline. The axis of the Hackberry Canyon syncline appears to strike NNW, plunges to the north and dies away in the northwest corner of Sec. 3, T. 40 S., R. 1 W. Dips between the two axes are very gentle, probably not exceeding a few degrees. The strata on the west flank also dip very gently.

## ECONOMIC GEOLOGY

No significant economic mineral deposits have been discovered to date in the Calico Peak quadrangle. Ground water, tourist curio materials, sand and gravel, coal, building stone, and petroleum resources have been identified in and around the quadrangle.

**Ground water** — Numerous springs issue from the rocks of the Calico Peak quadrangle. Many of the sandstone units, such as the Navajo and Kayenta Sandstones, are considered good reservoir rock. Springs issue from rock fractures, such as joints and faults, from along bedding planes, and from alluvium. The flow from the springs varies seasonally and according to wet and dry climatic periods. Some average several tens of gallons per minute. The quality of this water is essentially good, containing less than 500 ppm dissolved solids (Price, 1977). The potential for finding plentiful quantities of ground water in wells from eolian sandstone and alluvium is considered good.

**Tourist-curio materials** — Tourist-curio materials found in the quadrangle include petrified wood, siliceous concretions, ironstone concretions, and fossils. Colorful logs of petrified wood, along with siliceous concretions, are plentiful along some of the colorful horizons of the Petrified Forest Member of the Chinle Formation. The materials have excellent color, polish beautifully and have been locally gathered and mined. Logs have been found with diameters exceeding 1 foot. Interesting ironstone concretions and contorted sheets are found in the Navajo Sandstone on the bench lands which represent the chemical deposits of iron-laden ground water. The iron impregnates the sandstone irregularly creating interesting swirls, contortions, and other patterns in the rock. The ironstone concretions and contorted sheets can be gathered and sold to tourists, as is, or the ironstone-impregnated sandstone can be slabbed and roughly polished to make picture rock. Fossil oysters are plentiful in the coquina at the top of the Dakota Formation along the Cockscomb.

**Sand and gravel** — A limited amount of sand and gravel for construction is available in the Calico Peak quadrangle, mostly in the Paria River bed and from the scattered alluvial terrace deposits. The sandstone cobbles derived from the local sandstone units are too friable and weak to be of use. However, the exotic pebbles and cobbles carried into the area by the streams are of quartzite, siliceous limestone, and other hard materials. The blocky limestone units exposed in the Judd Hollow Tongue along the northern part of the Cockscomb are suitable for use as road base and paving aggregate when crushed.

**Coal** — Thin coal beds are present in the quadrangle in the Chinle Formation, the Dakota Formation, and Smoky Hollow Member of the Straight Cliffs Formation. This coal is presently considered uneconomical to mine. As much as 14 inches (35.5 cm) of coal in a lens covering several hundred acres occurs near the base of the Petrified Forest Member in Sec. 13, T. 41 S., R. 2 W., and in Sec. 18, T. 41 S., R. 1 W. along the southern margin of the quadrangle on the west side of the Paria River. Three samples indicate an average of 32.8 percent moisture, 36.4 percent volatile matter, 18.0 percent fixed carbon, and 12.5 percent ash. The coal has an average heat value of only 4867 Btu/lb and contains 3.2 percent sulfur.

Coal beds as thick as 3 feet (1m) are known to be present in the Dakota Formation along the Cockscomb. These coal beds dip 30 to 55 degrees eastward in the hogback. Three principal seams are usually present, one near the base, one in the middle, and one near the top of the formation. The average thickness of each is about 1.5 feet (.4 m) and they are encased in mudstone, shale or sandstone. The lower two beds are locally missing and often contain splits of bone (impure coal). The upper bed is the most persistent. The Dakota coals contain 5 to 8 percent moisture, 40 to 45 percent volatile matter, 38 to 42 percent fixed carbon, and 5 to 10 percent ash on an as-received basis. The heat value ranges from 10,000 to 11,000 Btu/lb and the sulfur content is between 1.5 and 2 percent.

Coal beds in the Smoky Hollow Member of the Straight Cliffs Formation are locally 3 or 4 feet (1-1.2 m) thick, but are discontinuous and contain several rock and bone splits. Little suitable coal is present along most of the outcrop length. The major coal seams of the Kaiparowits Plateau are present in the John Henry Member of the Straight Cliffs Formation. They are not present in this quadrangle and only thin, discontinuous stringers of coaly material are present in this unit.

**Building stone** — The exposed rock formations contain stone that is too weak for most construction purposes. The flat-bedded blocky weathering Moenave sandstones were used as foundation materials for the pioneer buildings in Paria. Exotic quartzite boulders and cobbles found in the Paria River bed and in most of the alluvial terrace deposits are attractive and could be used as field stone in walls, rock gardens, and around terraces.

**Petroleum** — Petroleum shows have appeared in subsurface rocks penetrated in nearby drill holes (Pan-American Petroleum #1-X Paria, NESW Sec. 16, T. 40 S., R. 2 W. and Marathon #1 Govt Butler Valley, NENE Sec. 22, T. 39 S., 1 W.), principally in the Timpowep Member of the Moenkopi

Formation and the Kaibab Formation. The Kaibab anticline, even though down the plunge and indicating no closure, may provide the best potential for petroleum traps in the Calico Peak quadrangle. The Timpoweap Member of the Moenkopi Formation should be found 2200 to 2700 feet (670-823 m) beneath the surface.

**Metallic minerals** — No metallic mineral prospects are present in the quadrangle and no strong signs of metallic mineralization have been discovered. The Chinle Formation is mineralized with uranium and copper minerals in the Fivemile Pass quadrangle to the south. These occurrences are small and widely scattered along the Cockscomb. Faults paralleling the East Kaibab monocline cutting the Navajo Sandstone in the Fivemile Pass quadrangle are locally mineralized with small amounts of copper, silver, and lead. No such mineralization has been found in the Calico Peak quadrangle. An anomalous gold content was reported in the Chinle Formation shales and an attempt to mine these occurred in 1912 near the abandoned townsite of Paria (Lawson, 1912).

## GEOLOGIC HAZARDS

Flooding of the Paria River, flash flooding in canyons, and mass movements, especially rockfalls, are the chief natural hazards in the Calico Peak quadrangle. The activities of man have and can enhance the potential for geology-related hazards.

**Flooding** — The Paria River floods its floodplain seasonally. This happens during the spring snowmelt or after a summertime cloudburst rainfall occurring anywhere in its drainage basin. Cottonwood Creek and Hackberry Wash also experience flooding, but the peak flows are usually contained within their deeply entrenched channels. Summer flash floods can occur in, or issue from, any canyon no matter how small. As expected, much erosion occurs along the stream banks

during flooding. Road crossings and roadways close to the channels are often destroyed. Road crossings remain wet and soggy for a considerable time after flash flooding has ceased and motorists are occasionally caught in soft places (figure 7). Sheet flooding regularly damages roads by producing closely spaced rivulets and deep gullies.

**Rockfall** — Rockfall is a natural process of cliff erosion and activity occurs regularly. The rubble at the base of cliffs attests to the fact that rockfall events are very common, although rarely observed. The Kayenta and Straight Cliffs Formation cliffs are especially active. Hikers should be aware of this when walking near or under cliffs and steep slopes. Rockfall events are often quite large, large enough to block major canyons. These events are probably more active in late winter or early spring as snowmelt seeps into joints and cracks in the rock and lubricates fine-grained materials in rock partings.

**Swelling and shrinking soil** — Construction of any kind, even a road, should be avoided where possible on the Chinle Formation and the Tropic Shale. These rock units, and derived soils, contain swelling and shrinking clays. In addition, they have poor load-bearing capacities, especially when wet. Hydraulic piping occurs in the Chinle Formation, in some places so extensive as to form small caverns. These become significant waterways during periods of torrential rainfall and the overlying materials can collapse into them. Clay-bearing shales and claystones are also locally found in the Wahweap, Straight Cliffs, and Dakota Formations.

**Earthquakes and groundshaking** — Even though there are many faults on the quadrangle, most appear to be currently inactive and seismic risk appears small. No earthquakes of magnitude 4.0 or greater have been recorded for central Kane County (Ward, 1979, fig. 3). Central Kane County lies astride the boundary of seismic zones U-1 and U-2 (on a scale of 1 to 4) of the Seismic Zones for Construction in Utah (Ward, 1979, fig. 1) and is considered relatively inactive. However, earthquake groundshaking, propagated from tectonically more active regions, may trigger rockfalls or cause landsliding.



*Figure 7: Flooding and quicksand present problems for motorists attempting to cross washes, creeks, and rivers during floods.*

**Other hazards** — Several types of landslide deposits occur in the Calico Peak quadrangle. Most are presumed to have been formed during wet climatic cycles. Presently, landsliding is more likely to occur in the spring along steep slopes and on clay-bearing materials. Except locally, there is no evidence of recent activity. The potential for activity would be expected to increase during and following a wet climatic interval. Presently most of the land is wilderness, but the limited roads constructed across the sandier areas on the benches between the Paria River and the Cockscomb have destabilized some of the eolian sand patches and are now covered with windblown sand. The few road trails present in this area, especially along the steeper inclines, are often impassable, even to jeeps. Irregularly spaced quicksand areas are usually present in the Paria River floodplain, shortly after flooding has occurred, and can entrap vehicles using the river bed as a road.

### GEOLOGIC SCENIC ATTRACTIONS

The Calico Peak quadrangle is the center of the Hackberry Canyon Wilderness Study Area. However, the most spectacular geologic scenic attraction is the East Kaibab monocline which forms the Cockscomb. The steeply tilted colorful rock formations are splendidly displayed in cliffs, hogbacks, strike valleys, and monoliths. Fine examples of block landslides, faults, and unusual erosional features can be seen along the Cockscomb.

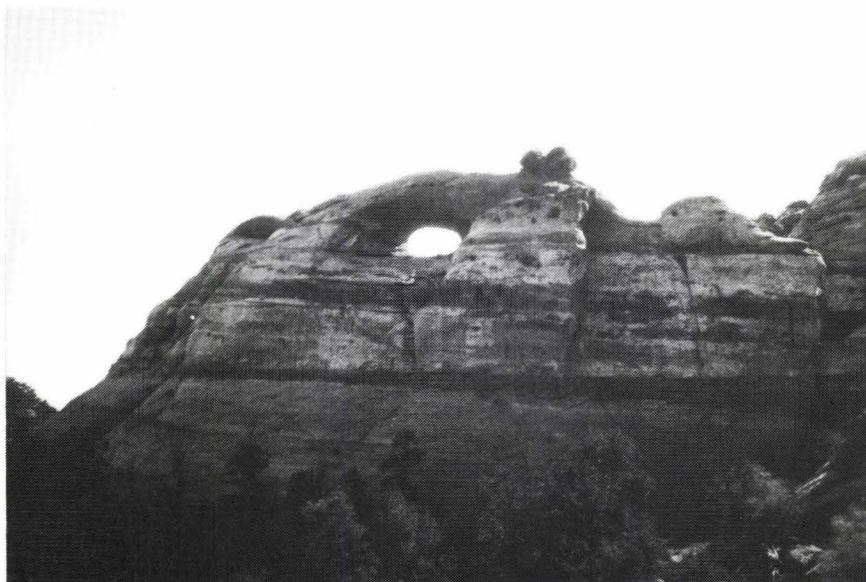
The Calico Peak quadrangle displays typical bench and canyonlands physiography with steep cliffs, narrow and deeply incised canyons, colorful formations, and a host of striking erosional monuments. In Hackberry Canyon, the Navajo Sandstone walls locally rise more than 300 feet (90 m) vertically above the stream bed. The Moenave and Kayenta

formations produce steep cliffs of 450 to 500 feet (122-152 m) along the walls of the Paria River and along most of its tributaries. The brightly banded outcrops of the Petrified Forest Member of the Chinle Formation are nowhere better displayed than along the canyon walls of the Paria River near the abandoned townsite of Paria. The area has been termed the "Land of the Sleeping Rainbow" by native Americans.

The rewards for those willing to undertake the strenuous hiking to reach the benches above the cliffs are great. Remarkable views of the canyons below and across the plateau country are possible along the cliff edges. Large masses of bare-rock Navajo Sandstone, with its sweeping high-angle cross stratification, occur at the top as remnants of the White Cliffs. Smaller monuments, domes, and arches occur nearly everywhere at the base of the Navajo. Two major rock arches occur on the quadrangle near the base of the Navajo. The first is Starlight Arch in SESE Sec. 10, T. 41 S., R. 2 W. on No Mans Mesa (figure 8); it is estimated to be approximately 30 feet (9 m) high and 50 feet (15 m) wide. The other is Sam Pollock Arch, about 60 feet (18 m) high and 70 feet (21 m) wide (Carter and Sargent, 1983), located in T. 40 S., R. 1 W., near the common corner of unsurveyed Secs. 19, 20, 29, and 30.

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**Figure 8:** Starlight Arch, one of the geologic scenic attractions of the Calico Peak quadrangle, cut in the Navajo Sandstone.

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