U.S. DEPARTMENT OF THE INTERIOR U.S. GEOLOGICAL SURVEY





NOTE

The Middle Jurassic San Rafael Group consists of sandstone, siltstone, and shale. In the study area (see Index map), the San Rafael Group is mostly concealed beneath younger rocks but does crop out along Comb Ridge and in the canyon of the Dolores River in the western and eastern parts of the study area respectively. In an intervening area along Montezuma Creek, the upper part of the San Rafael Group crops out for about 10 mi; at one locality (sec. 11) all of the group is exposed.

In the study area, two unconformities are associated with the rocks described herein. The unconformities separate the San Rafael Group from the underlying Lower Jurassic Navajo Sandstone and the overlying Upper Jurassic Morrison Formation. The unconformities-termed J-2 at the base of the San Rafael and J-5 at the top-are also recognized throughout much of the Western Interior of the United States (Pipiringos and O'Sullivan, 1978). The J-5 unconformity is the datum used to construct the line of graphic sections and the restored stratigraphic diagram of this report. The locations of the drill holes and measured sections are shown in table 1.

NAVAJO SANDSTONE

The Navajo Sandstone, of eolian origin, underlies the San Rafael Group throughout the area. Near Blanding, Utah, the Navajo Sandstone is about 455 ft thick at the Tenneco Oil Co. drill hole (sec. 4) and is about 405 ft thick at the White Canyon Mining Co. drill hole (sec. 14) in Montezuma Canyon. The Navajo is beveled eastward by the J-2 unconformity at the base of the San Rafael Group and is 141 ft thick at exposures near Dove Creek, Colo. (Shawe and others, 1968, fig. 17).

SAN RAFAEL GROUP

The San Rafael Group consists of, in ascending order, the Carmel Formation, Entrada Sandstone, and Wanakah Formation; several subdivisions are recognized within the Entrada and Wanakah. At Black Steer Knoll, Utah (sec. 1), the Entrada Sandstone is made up of (ascending) middle sandstone, red member, and salmon sandstone. The middle sandstone was first recognized by Witkind (1964, p. 19) in the Abajo Mountains area about 10 mi north of Black Steer Knoll. The name "middle sandstone" as used by Witkind (1964) is retained, but the sandstone is at the base of the Entrada Sandstone near Black Steer Knoll. East of Black Steer Knoll, within the study area, the Entrada Sandstone consists of the Slick Rock Member and the underlying red member; the latter is the only subdivision of the Entrada recognized from Black Steer Knoll to the Dolores River. The Wanakah Formation, near Black Steer Knoll, consists of (ascending) lower member, bed at Butler Wash, middle member, Horse Mesa Member, and upper member. In most of the area, the lower member and the bed at Butler Wash are not recognized. In the Dove Creek area (secs. 19–22), the middle member of the Wanakah is successively underlain by the siltstone member and the bed at Mesa Creek. The middle member and the Horse Mesa Member are present throughout the area. The upper member is present in the eastern and western parts but is absent in an area extending from Montezuma Canyon (sec. 11) to Dove Creek (sec. 18).

The Wanakah Formation and Entrada Sandstone, in part, interfinger laterally. The lower member and the bed at Butler Wash of the Wanakah grade into the Slick Rock Member of the Entrada Sandstone, in the subsurface, east of Black Steer Knoll. The interrelationship just described is duplicated in exposures at Mancos Jim Butte (O'Sullivan, 1980), about 4 mi north of Black Steer Knoll.

An ancient, structurally high positive area covered part of southeastern Utah and affected deposition of the lower part of the San Rafael Group. In the Abajo Mountains area, about 5 mi west of Monticello, Utah, Witkind (1964, p. 83) found "***that, shortly after the Carmel sea advanced across the mapped areas, an ancestral highland began to rise near the locality now occupied by the Causeway. Thus, the absence from this general locality of strata *** deposited during this phase of the advance of the Carmel sea, implies that the rapid elevation of the ancestral highland restricted the waters of the Carmel sea." The ancient highland is termed the "Causeway High" (O'Sullivan, 1996, p. 191) from its surface expression near the Causeway, a topographic feature in the Abajo Mountains. The positive feature is narrow on the outcrop but covers a broad area in the subsurface beneath the incised plain that stretches eastward from the Abajo Mountains. The Causeway High in the Blanding area is defined by the landward limits of the Carmel Formation and middle sandstone of the Entrada Sandstone.

CARMEL FORMATION

The Carmel Formation near Blanding is at the base of the San Rafael Group. Near Black Steer Knoll, the Carmel is probably a fluvial water-laid deposit consisting of yellowishgray, fine- to medium-grained, flatbedded sandstone containing three beds of greenish-gray shale ranging in thickness from 0.5 to 1.5 ft. Traced southward toward Bluff, the Carmel grades laterally into red siltstone and shale interbedded with thin gray sandstone, of marginal marine origin, that is widespread in southeast Utah and adjacent areas. The yellowish-gray sandstone in the Carmel in the Blanding area is a local facies, which probably was eroded from the Navajo Sandstone exposed on the ancient Causeway High. The Carmel Formation is 115 ft thick at Black Steer Knoll (sec. 1) and thins to 17 ft at the Tenneco Oil Co. drill hole (sec. 3) on the Causeway High. The Carmel is not now recognized to the east in the Tenneco Oil Co. drill hole (sec. 4).

ENTRADA SANDSTONE

The Entrada Sandstone conformably overlies the Carmel Formation in the western part of the area and uncomformably overlies the Navajo Sandstone in the eastern part of the area. Throughout the area the Entrada averages 177 ft in thickness but varies in thickness because of pronounced stratigraphic changes from place to place. The thickness of the Entrada ranges from 90 ft at the Read and Stevens drill hole (sec. 22) to 260 ft at the Davis Oil Co. drill hole (sec. 2).

The middle sandstone, probably of dune and interdune origin, is the basal unit of the Entrada at Black Steer Knoll (sec. 1). The middle sandstone consists of yellowish-gray, finealong Comb Ridge. The bed at Butler Wash is a gray and brown, fine-grained to very fine grained sandstone. Bedding is usually flat but crossbeds are present at many places.

0.5-5 ft thick. Beds of reddish-brown siltstone or clay separate many of the sandstone ledges. The thickness of the bed at Mesa Creek averages about 19 ft in the study area. The previous mapping usage (see O'Sullivan, 1991)

grained, crossbedded sandstone. It commonly forms a ledge above the Carmel Formation. The sandstone is about 85 ft thick at Black Steer Knoll and thins eastward to 30 ft at the

Tenneco Oil Co. drill hole (sec. 3). The middle sandstone may lap onto the Causeway High

near the Tenneco Oil Co. drill hole (sec. 4) about 8 mi east of Black Steer Knoll. As shown

on the line of section, the middle sandstone overlaps the underlying Carmel Formation in

the subsurface. At exposures in the Dry Valley–Slick Rock area north and northeast of Mon-

ticello, the middle sandstone also overlaps the underlying Dewey Bridge Member of the

Entrada Sandstone, which is an equivalent of the Carmel Formation (O'Sullivan, 1996, fig.

da is somewhat uncertain. In the subsurface in the Blanding area, the Carmel is mostly

sandstone as it is at surface exposures. The sandstone in the Carmel and in the middle

sandstone is difficult to distinguish from the underlying Navajo Sandstone on geophysical

logs of drill holes. Future analysis of drill hole logs may alter the extent of the Carmel and

middle sandstone as shown on the line of section. A useful stratigraphic control point is

found at Montezuma Canyon HL (sec. 11). There, the upper part of the Navajo Sandstone

Formation or middle sandstone is present.

at Pacific Natural Gas Co. drill hole (sec. 18).

at the Read and Stevens drill hole (sec. 22).

logs of drill holes or at the outcrop along Comb Ridge.

is exposed and is directly overlain by the red member of the Entrada Sandstone; no Carmel

The red member, possibly of marginal marine origin, is present throughout the

Blanding-Dove Creek area and overlies either the middle sandstone of the Entrada or the

Navajo Sandstone. It consists mostly of reddish-brown siltstone and silty sandstone, parts of

which tend to form hoodoos, stone babies, or goblins. The thickness of the red member

averages about 40 ft and ranges from 60 ft at the Tenneco Oil Co. drill hole (sec. 3) to 16 ft

da Sandstone at Black Steer Knoll. The salmon sandstone merges with the Slick Rock

Member in the subsurface between Black Steer Knoll (sec. 1) and the Davis Oil Co. drill hole

(sec. 2). The salmon sandstone is a reddish-tan, fine-grained sandstone that is crossbedded

Slick Rock Member is mainly a fine-grained to very fine grained sandstone, but it contains

disseminated sparse, well-rounded grains of clear quartz. The coarse grains in the Slick

Rock Member, which are informally termed "Entrada berries" contrast markedly with the

fine-grained matrix. The Slick Rock Member was deposited in a sequence of alternating

WANAKAH FORMATION

Four subdivisions of the Wanakah Formation are red-bed units: the lower, middle,

sandstone and minor thin red clay beds; all four members tend to form slopes. The lower

member is 36 ft thick at Black Steer Knoll (sec. 1). In the subsurface, the lower member

merges into the Slick Rock Member of the Entrada west of the Davis Oil Co. drill hole (sec.

2) and east of Black Steer Knoll. The middle member averages about 35 ft in thickness,

ranging from 27 ft at the Pacific Natural Gas Co. drill hole (sec. 18) to 42 ft at the Conti-

nental Oil Co. drill hole (sec. 17). The upper member is absent at the top of the Wanakah

Formation from Montezuma Canyon HL (sec. 11) to the Pacific Natural Gas Co. drill hole

much as 26 ft thick at Black Steer Knoll (sec. 1). The siltstone member is present from the

Skyline Oil Co. drill hole (sec. 6) eastward to the Dolores River. The siltstone member aver-

ages about 17 ft in thickness, ranging from 5 ft at Montezuma Canyon HL (sec. 11) to 40 ft

fine-grained to very fine grained, hard, resistant, flatbedded sandstone. The bed is mostly

gray but is reddish tan and mottled or streaked gray at some localities. At exposures in

Montezuma Canyon, bed V ranges from 4.1 ft thick at Montezuma Canyon HL (sec. 11) to

6.3 ft at Montezuma Canyon 94-1 (sec. 8). Near the Dolores River, bed V is thinner and is

0.8 ft thick at Dolores River C (sec. 21) and 1.2 ft thick at Dove Creek (sec. 20). At the sur-

face bed V forms a prominent ledge and commonly overhangs underlying parts of the silt-

stone member. In the subsurface, bed V tends to make a conspicuous spike, particularly on

the gamma-ray curve of the geophysical log. Bed V and the underlying parts of the siltstone

member merge into the Slick Rock Member of the Entrada west of the Skyline Oil Co. drill

hole (sec. 6). Farther west, it is difficult to distinguish the siltstone member and bed V on

River. The bed consists of reddish-tan and gray, fine-to-medium-grained sandstone in bed

The bed at Mesa Creek is at the base of the Wanakah Formation near the Dolores

A thin sandstone, termed "bed V" forms the top of the siltstone member. Bed V is a

(sec. 18). Where present, the upper member averages about 10 ft in thickness and is as

The Slick Rock Member overlies the red member throughout most of the area. The

and flatbedded. At Black Steer Knoll the salmon sandstone is about 55 ft thick.

Stevens drill hole (sec. 22) to 170 ft at the Tenneco Oil Co. drill hole (sec. 5).

and Mobil Oil Corp. drill hole (sec. 16) to 184 ft at Black Steer Knoll (sec. 1).

The salmon sandstone, possibly of dune and interdune origin, is at the top of the Entra-

The subsurface extent of the Carmel Formation and the middle sandstone of the Entra-

bed merges with the Entrada Sandstone in the subsurface between the Pacific Natural Gas Co. drill hole (sec. 18) and the Continental Oil Co. drill hole (sec. 19) and is, in effect, a tongue of the Entrada. It is, however, assigned to the Wanakah Formation because of The bed at Butler Wash is present at Black Steer Knoll and is exposed for many miles

Crossbeds in the bed at Butler Wash are of eolian origin (Condon, 1989). Locally, the unit

Skyline Oil Co. drill hole (sec. 6).

sandstones of eolian origin. The Bluff Sandstone Member at its type locality near the town of Bluff, Utah, is about 230 ft thick. It thins northward along Comb Ridge to 160 ft at Black Mesa Butte 17 mi north of Bluff. The Bluff Sandstone Member wedges out into the Tidwell Member about 2 mi south of Black Steer Knoll (O'Sullivan, 1980). In Colorado, the Junction Creek Sandstone Member is over 400 ft thick at a locality near Salter Canyon. From Salter Canyon, the Junction Creek interfingers with the Tidwell and thins northward to a pinchout on the Dolores River about 7 mi east of Dove Creek. upper, and siltstone members. The four units are mostly red siltstone and thin red and gray

crossbedded and flatbedded units. The crossbedded units are eolian deposits; the flatbedded units are interpreted as interdune deposits (see Shawe and others, 1968, p. A41–A45). The The Bluff and Junction Creek Sandstone Members of the Morrison Formation are thick Slick Rock Member averages about 135 ft in thickness, ranging from 67 ft at the Read and The Wanakah Formation, probably of marginal marine origin, makes up the upper part of the San Rafael Group. The formation, comprising seven subdivisions, overlies or laterally replaces the upper part of the Entrada Sandstone. Throughout the area the Wanakah averages about 80 ft in thickness, ranging from 53 ft at both Montezuma Canyon 95-3 (sec. 13)

Olson and Hedlund (1973), was recently designated as a member of the Morrison Formation (O'Sullivan, 1997). In other parts of the study area the Tidwell Member is at the base of the Morrison and also overlies and interfingers with the Bluff and Junction Creek Sandstone Members. The line of section of this report crosses the northern limit of the Bluff Sandstone Sandstone Member and Junction Creek Sandstone Member at several places. BLUFF SANDSTONE MEMBER AND JUNCTION CREEK SANDSTONE MEMBER

members are in reports by Craig and others (1955), Huff and Lesure (1965), and Shawe and others (1968). In part of the Blanding–Dove Creek area, the basal member of the Morrison Formation is the Bluff Sandstone Member in Utah and the equivalent Junction Creek Sandstone Member in Colorado. The Junction Creek, previously ranked as a formation in Colorado by

16) to 25 ft at Montezuma Canyon 94-1 (sec. 8). The Horse Mesa Member has previously been referred to as "the bed at Black Steer Knoll," which now is no longer used in Utah and Colorado (see O'Sullivan, 1997). The Morrison Formation, of continental origin, unconformably overlies the Wanakah Formation. The Morrison Formation is 700–800 ft thick (Craig and others, 1955, fig. 30) in the Blanding–Dove Creek area and is made up of several members; only the lower part of the formation is discussed here. Further details of the Morrison Formation and its various

The Horse Mesa Member overlies the middle member and underlies either the upper member, where present, or the Morrison Formation. The Horse Mesa Member is a gray and reddish-tan, fine-grained, flat and crossbedded sandstone. At the surface the member forms a prominent ledge or cliff; in parts of Montezuma Canyon the cliff is broken into several ledges. According to Condon and Huffman (1988, p. 7, 11), the Horse Mesa Member was deposited in eolian dune, interdune, and sabkha environments. Throughout the area, the Horse Mesa Member averages about 16 ft in thickness, ranging from 11 ft at both the Houston Oil and Minerals Corp. drill hole (sec. 15) and the Mobil Oil Corp. drill hole (sec.

Wanakah for mapping purposes.



RESTORED STRATIGRAPHIC DIAGRAM

contains thin reddish-brown siltstone beds. At Black Steer Knoll (sec. 1) the bed at Butler Wash is 72 ft thick. The bed merges with the Entrada, in the subsurface, between Black Steer Knoll (sec. 1) and the Davis Oil Co. drill hole (sec. 2) and is therefore a tongue of the Entrada. The bed at Butler Wash, however, is assigned to the Wanakah Formation partly because it was previously included with the Wanakah along Comb Ridge (O'Sullivan, 1980)

and partly because it crops out in such a narrow band that the bed is best combined with the

MORRISON FORMATION

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Bluff in southeastern Utah, in Huffman, A.C., Jr., Lund, W.R., and Godwin, L.H., eds.,

38°00'

37°45'

37°30'

37°15'

Mancos Jim

Butte

Black Mesa

Butte

Black Steer

Knoll

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Table 1. Number, name and location of drill holes and measured sections

[The following U.S. Geological Survey topographic maps were used to locate my sections measured in the field: Brushy Basin Wash (1957), scale 1:62,500; Monticello (1957), scale 1:62,500; Monument

Canyon (1957), scale 1:62,500; Secret Canyon (1964), scale 1:24,000] Section Name Location

Black Steer Knoll SW1/4 NW1/4 and NW1/4 SW1/4 and

NW1/4 SE1/4 and SE1/4 NE1/4 sec. 7; SW1/4 and SE1/4 NW1/4 sec. 8; and NW1/4 NE1/4 sec. 18, T. 36 S., R. 21 E. Davis Oil Co. sec. 32, T. 35 S., R. 22 E. Johnson Creek State 2. Tenneco Oil Co. sec. 8, T. 36 S., R. 22 E. Tenneco Blanding 8-16. Tenneco Oil Co. sec. 15, T. 36 S., R. 22 E. Tenneco Blanding 15-7 sec. 8, T. 36 S., R. 23 E. Tenneco Oil Co. Bullpup unit 1-8. sec. 22, T. 36 S., R. 23 E. Skyline Oil Co. Mustang unit 22-43. sec. 29, T. 36 S., R. 24 E. MCOR Resources Devil Canvon 1-29. NE1/4 SE1/4 sec. 23, T. 36 S., R. 24 E. Montezuma Canyon 94-1 SE1/4 SW1/4 NE1/4 sec. 11, T. 36 S., R. 24 E. Montezuma Canyon

Pan American Petroleum

sec. 33, T. 35 S., R. 24 E.

NE1/4 NW1/4 sec. 11, T. 35 S. R. 24 E. Section from Huff and Lesure (1965, p. 83–85). sec. 4, T. 35 S., R. 24 E.

NW1/4 SE1/4 NE1/4 sec. 34, T. 34 S., R. 24 E.

sec. 23, T. 34 S., R. 24 E.

sec. 7, T. 34 S., R. 25 E. sec. 13, T. 34 S., R. 25 E.

sec. 12, T. 40 N., R. 20 W.

sec. 10, T. 41 N., R. 19 W.

sec. 17, T. 41 N., R. 18 W. From lat 37°47'47" N., long 108°50'06" W. to

lat 37°47'50" N., long 108°50'15" W. From lat 37°50′56″ N., long 108°48′40″W. to lat 37°50'58" N., long 108°48'44" W. sec. 34, T. 42 N., R. 18 W.

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CORRELATION OF JURASSIC SAN RAFAEL GROUP AND RELATED ROCKS FROM BLANDING, UTAH, TO DOVE CREEK, COLORADO

Montezuma Canvon 1

Montezuma Canyon HL

Big Canyon 1

Dove Creek

Dolores River C

Read and Stevens

Shenandoah-Pinto 1->

20

21

22

By Robert B. O'Sullivan 1998

The Bluff Sandstone Member, along the line of section, crops out in Montezuma Canyon. It consists of reddish-tan and gray, fine-grained to very fine grained, flatbedded sandstone containing sparse to abundant coarse grains. The Bluff forms a cliff broken into ledges separated by thin layers of reddish-brown siltstone. Along Montezuma Canyon, the Bluff represents deposition on the distal margin of a dune field which lay to the south. The member is 0–18 ft thick at exposures in Montezuma Canyon. The Bluff is thickest, 36 ft, at the The Junction Creek Sandstone Member is present along the line of section at only one locality in the study area. It is 16 ft thick in the Continental Oil Co. drill hole (sec. 17).

Most of the line of section in Colorado lies north of the pinchout of the Junction Creek Sandstone Member of the Morrison Formation. TIDWELL MEMBER

The color, lithology, and thickness of the Tidwell Member are varied. The member consists primarily of red or gray slope-forming siltstone. Gray ledge-forming sandstones, in which bedding is flat or not apparent, crop out at many localities. Thin beds of red clay constitute a minor lithology throughout the member. The thickness of the Tidwell Member varies because of interfingering with the overlying Salt Wash Member and, where present, the underlying Junction Creek and Bluff Sandstone Members. The Tidwell Member averages

about 45 ft in thickness, ranging from 19 ft at Montezuma Canyon HL (sec. 11) to about 90 ft at Black Steer Knoll (sec. 1). A conspicuous marker bed, named for convenience "bed A," is at the base of the Tidwell Member, where it rests on the Wanakah Formation. Bed A commonly is a gray, finegrained, flatbedded sandstone that contains coarse to very coarse grains at most localities. Green clay galls, as much as 1/2 in. across, are present at Dolores River C (sec. 21). The thickness ranges from about 1 ft at Montezuma Creek 95-3 (sec. 13) to 6.5 ft at Black Steer

Knoll (sec. 1). The basal contact is sharp and bed A generally overhangs the underlying

Wanakah Formation. SALT WASH MEMBER The Salt Wash Member overlies and interfingers with the Tidwell Member throughout the Blanding-Dove Creek area. The Salt Wash consists of a sequence of thick, light-colored sandstone ledges interbedded with red and gray siltstone and shale. The Salt Wash, of fluviatile origin, is 370 ft thick in upper Montezuma Canyon (Huff and Lesure, 1965, p. 87).

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Cow Springs Sandstone, and adjacent rocks from Bluff, Utah, to Lupton, Arizona:

U.S. Geological Survey Oil and Gas Investigations Chart OC-131, 1 sheet.

Federal-Friedman 1 13 Montezuma Canyon 95-3. 14 White Canyon Mining Co. Frost 1 15 Houston Oil and Minerals Corp. Waldemear 43-7. Mobil Oil Corp. Utah A 1. Continental Oil Co. Baumgartner-Sane 1. 18 Pacific Natural Gas Co. F.A. Sitton Continental Oil Co. 19

12 Sinclair Oil and Gas Co.



INDEX MAP SHOWING LOCATIONS OF DRILL HOLES AND MEASURED SECTIONS





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