UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

STRATIGRAPHIC SECTIONS OF THE SHINARUMP, MONITOR BUTTE, AND MOSS BACK MEMBERS OF THE UPPER TRIASSIC CHINLE FORMATION IN THE NORTHERN PART OF THE WHITE CANYON, RED CANYON, AND BLUE NOTCH CANYON AREA, SOUTHEASTERN UTAH

By

Russell F. Dubiel

Open-File Report 83-188

1983

Contents

List of Illustrations

STRATIGRAPHIC SECTIONS OF THE SHINARUMP, MONITOR BUTTE,AND MOSS BACK MEMBERS OF THE UPPER TRIASSIC CHINLE FORMATION IN THE NORTHERN PART OF THE WHITE CANYON, RED CANYON, AND BLUE NOTCH CANYON AREA, SOUTHEASTERN UTAH

By Russell F. Dubiel

INTRODUCTION

This report describes nine detailed stratigraphic sections of the Shinarump, Monitor Butte, and Moss Back Members of the Chinle Formation (Upper Triassic) measured in the White Canyon, Red Canyon and Blue Notch Canyon areas of southeastern Utah. Seven sections previously described from the White Canyon and Red Canyon area (Dubiel, 1982) (fig. 1), together with these nine additional sections, depict a series of continental beds deposited in a complex fluvial-deltaic-lacustrine system. Uranium mineralization in the White Canyon and adjacent areas is restricted to fluvial channel-sandstones of the Shinarump and Monitor Butte Members (Finch, 1959; Lewis and Campbell, 1965; Thaden and others, 1964). Additionally, the Moss Back Member appears to be sedimentologically similar to the Shinarump and Monitor Butte Members. For these reasons, the Petrified Forest Member and upper red-bed part of the Chinle Formation, both of which have been described by Stewart and others (1972a) and Thaden and others (1964), are not included in this report. Depositional environments are interpreted from rock types, thicknesses, bedding and sedimentary structures, fossils and burrows, and vertical and horizontal facies relationships.

The author would like to express his gratitude to Jacques Robertson, Christine Turner-Peterson, and Jennie Ridgley for helpful comments to improve this manuscript.

DEPOSITIONAL ENVIRONMENTS RECOGNIZED IN THE CHINLE FORMATION

Units in the lower part of the Chinle Formation exhibit complex relationships categorized by interfingering and gradational contacts and marked facies changes within small horizontal distances. This complexity is a result of shifting environments in the depositional system. Facies interpretation (Harms and others, 1975; Reineck and Singh, 1975; Reading, 1978) allows the correlation of sections (fig. 2,3, and 4) by assigining specific depostional environments to recognized genetic units. Criteria used to categorize lithofacies and their inferred depositional environments have been previously discussed (Dubiel, 1982).

Meandering stream deposits, recognized in the Chinle Formation, are characterized by coarse-grained and sometimes conglomeratic sandstones that exhibit a fining upward sequence in grain size from sandstone to mudstone and an upward decrease in the size of sedimentary structures, generally from large-scale trough-crossbedding to medium- and small-scale trough-crossbedding. Horizontal laminations are present in the upper part of the section, but tabular planar crossbedding is rare. Point bar deposits are expressed as epsilon-bedding. Reduced fluvial flow on floodplains and in cut-off channels deposits finer grained siltstone, mudstone, and limestone. Organic-rich mudstone accumulates in oxbow lakes and in floodplain-lakes. These low-energy depositional environments lack coarse-grained sediments and

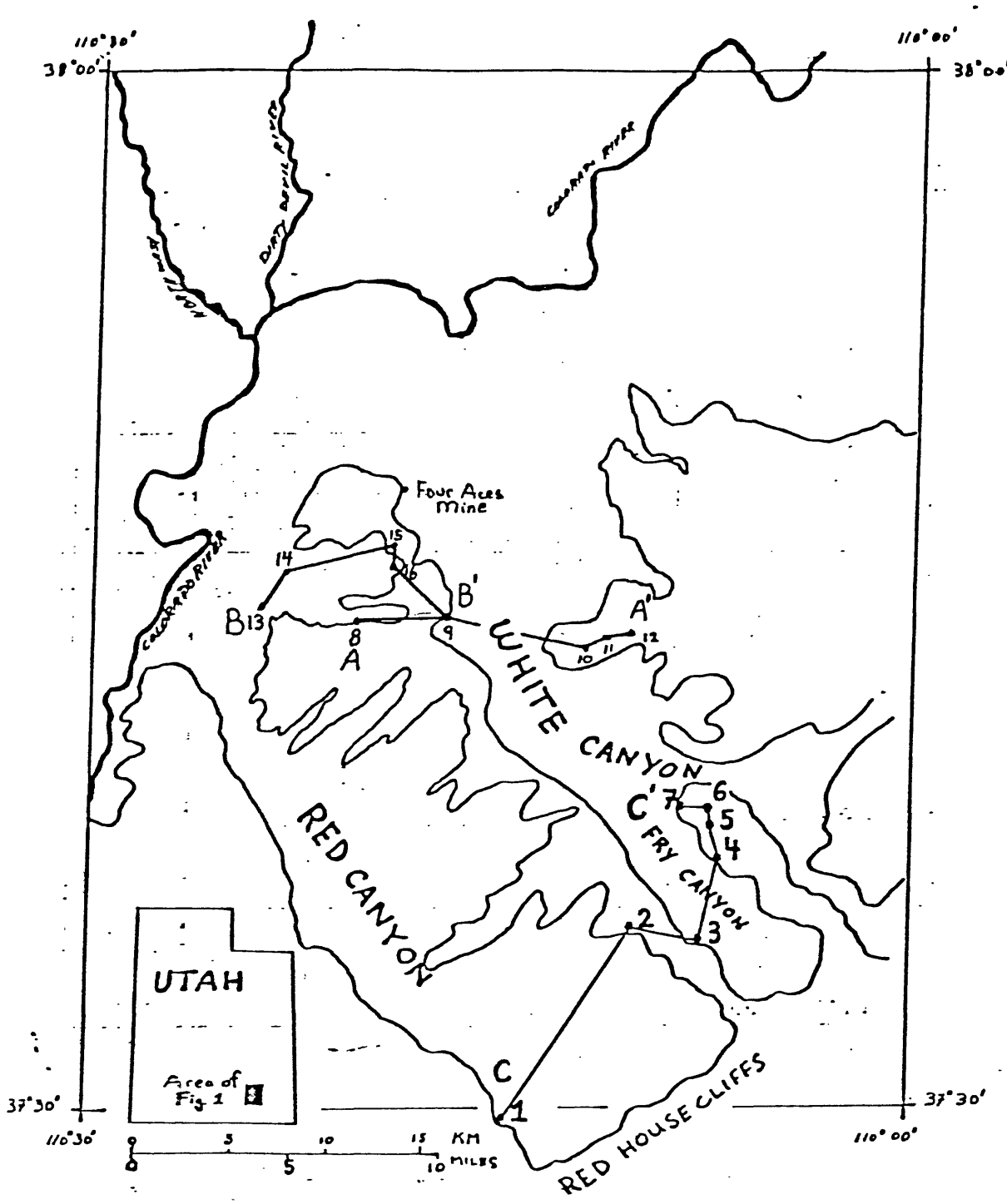

Figure 1.—Index map showing location of study area and stratigraphic sections in southeastern Utah. Measured sections numbered as in text.

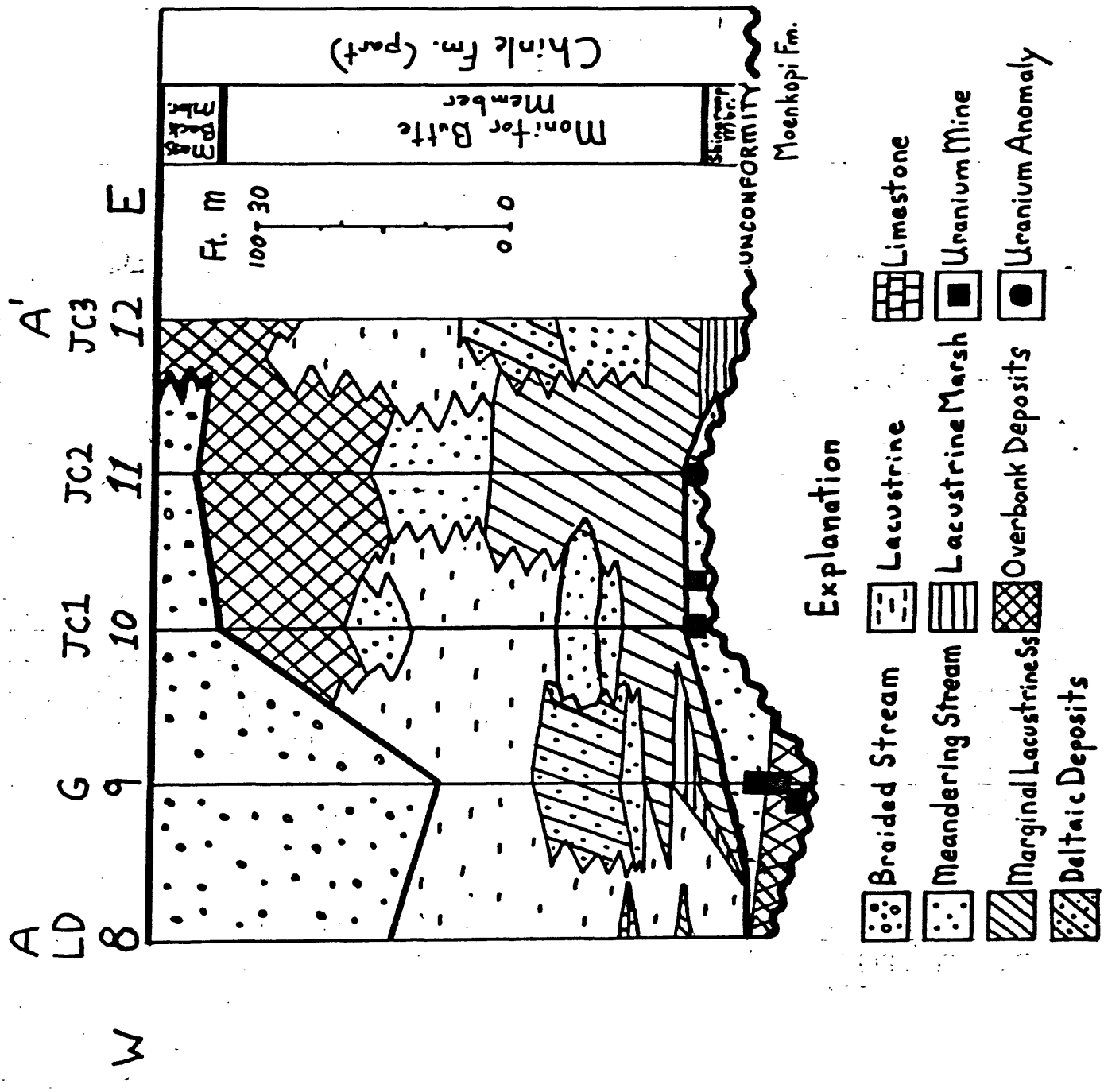

Figure 2.--Cross section across White Canyon showing facies relationships of the fluvial-deltaic-lacustrine system.

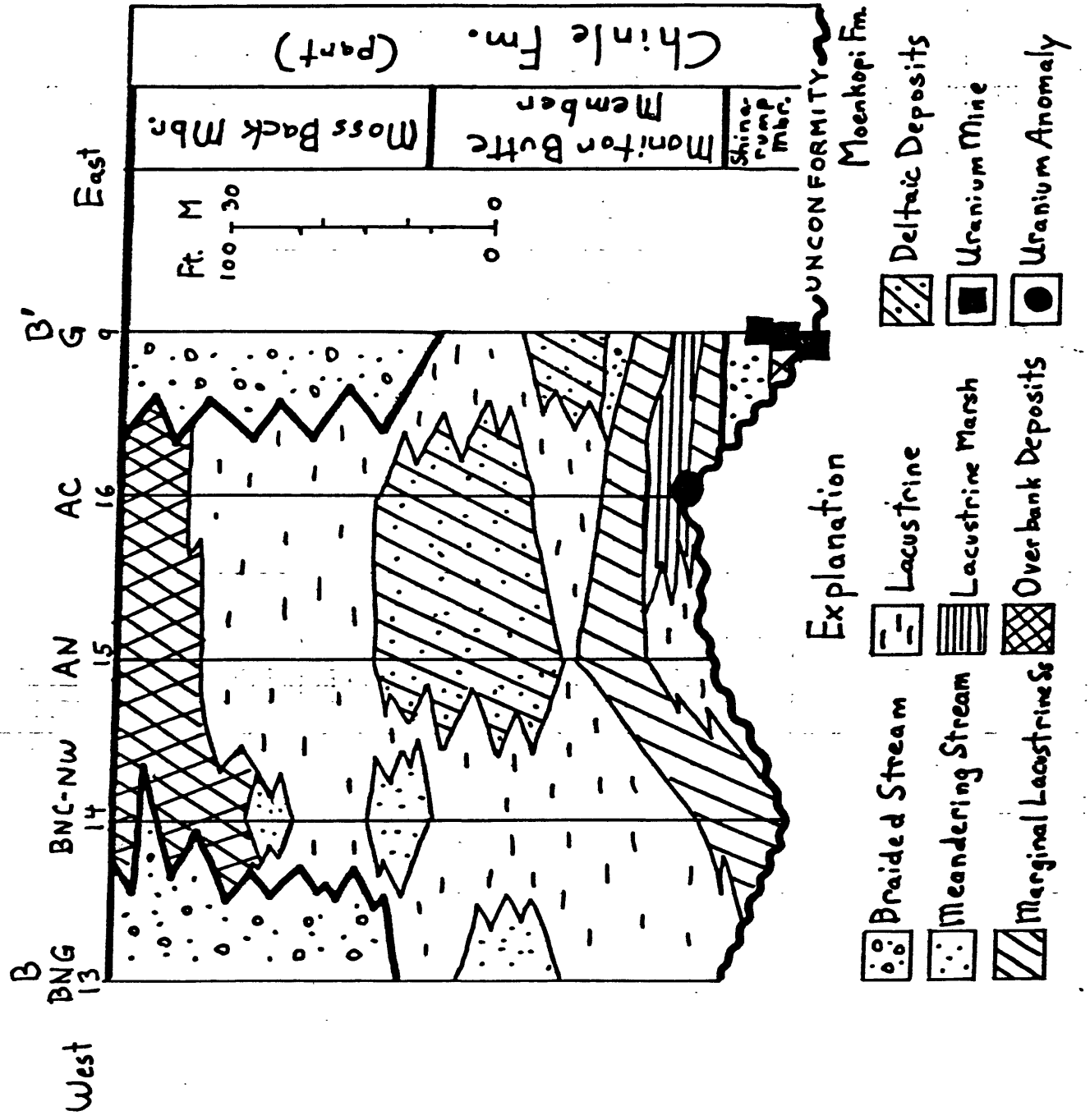

Figure 3.--Cross section along north wall of Blue Notch Canyon showing facies relationships of the fluvial-deltaic-lacustrine system.

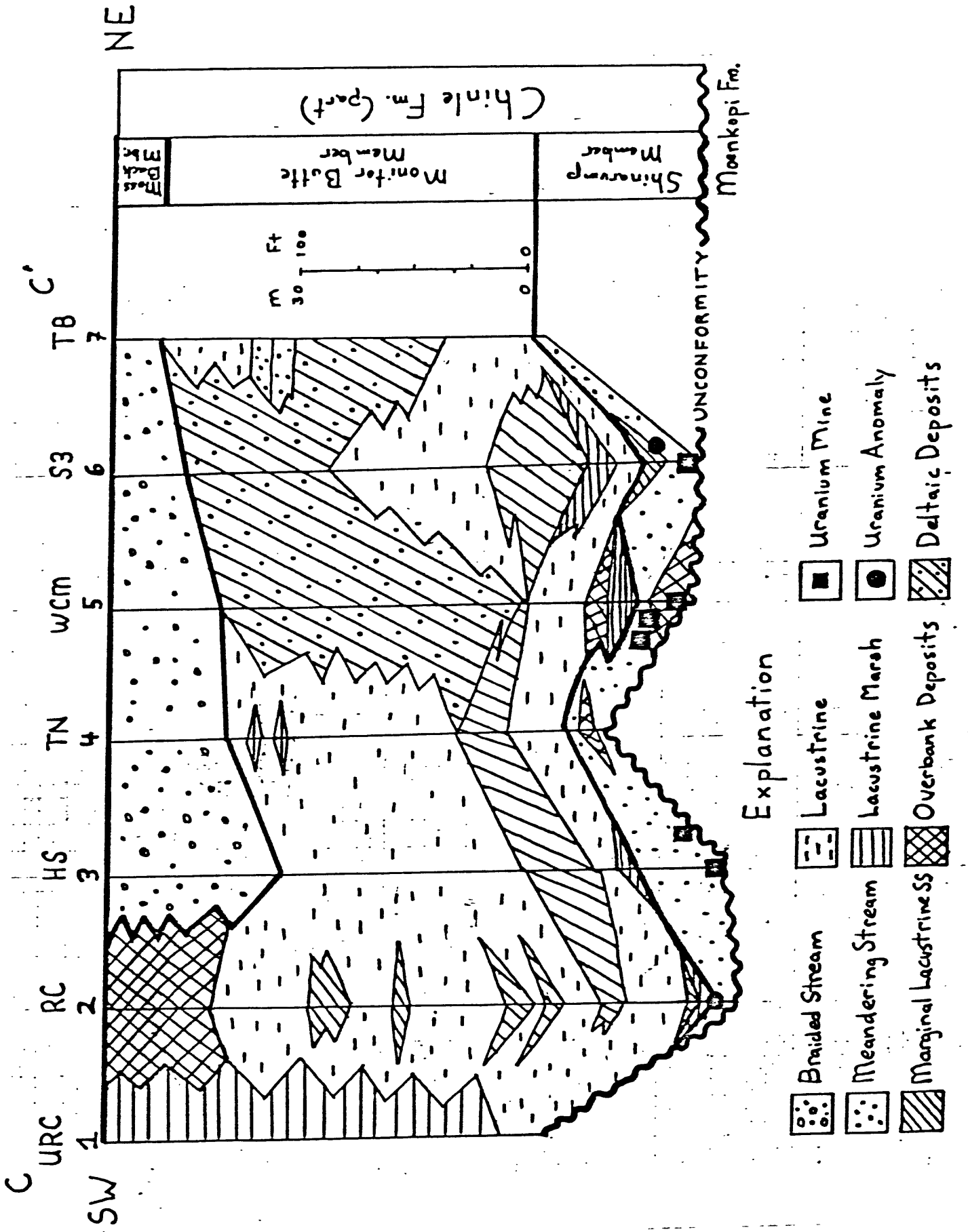

Figure 4.--Cross section in the White Canyon and Red Canyon area showing facies relationships of the fluvial-deltaic-lacustrine system (modified from Dubiel, 1982).

are characterized by laterally extensive beds and very thin, continuous horizontal laminations.

In contrast, braided stream deposits in the Chinle, are composed of coarse-grained and conglomeratic sandstone with very minor amounts of fine-grained sediments. Rather than a continuous fining-upward sequence of grain size, they comprise many incomplete fining-upward sequences from conglomerate or coarse-grained sandstone to medium- or fine-grained sandstone. Laminated mudstone and organic-rich mudstone are rare due to the continually shifting and aggrading channels. Overbank and floodplain deposits occur lateral to the braided channel system.

Lacustrine deposits can be subdivided into lacustrine, marsh, and marginal lacustrine deposits. Sandstone is restricted to the lake margins where wave- and fluvial-processes have the energy to transport and rework coarse-grained sediments. Finer-grained sediment is winnowed out and redeposited farther offshore as lacustrine mudstone. The marginal lacustrine sandstones may not exhibit sedimentary structures typical of some marine beaches, because of the lower energy regime characteristic of lacustrine shore processes, especially in lakes of small fetch. Lacustrine mudstones are similar to those found in oxbow lakes and in small floodplain lakes, differing only in geometry and lateral extent. They may be organic-rich and are characterized by laterally extensive beds and very thin horizontal laminations. Marginal lacustrine sandstone and lacustrine mudstone commonly contain burrows or exhibit a bioturbated texture as a result of lacustrine fauna. Fluvial sandstone does not commonly contain abundant burrows due to the constantly shifting substratum in channels and on migrating bars.

Transitional between the fluvial and lacustrine environments are deltaic deposits of sandstone, siltstone, and minor mudstone. Large- and small-scale foreset-bedding characterize the sediments deposited as a result of reduced sediment-carrying capacity from the high-energy fluvial- to the low-energy lacustrine-environment. Lateral to the major focus of clastic input are finer grained sediments of inter-deltaic bays. Silty and sandy reworked mudstone characterizes this depositional environment.

Delta-lobe switching resulted in the preservation of one, or several, of these subenvironments in succession. Additionally, this process resulted in delta abandonment, local transgression, and a reworking of sediment.

LITHOFACIES INTERPRETATION

Primary sedimentary structures, lateral and vertical facies relationships, and facies geometry, allow an interpretation of depositional environments in the study area. The Shinarump Member, interpreted as meandering stream deposits, consists of coarse-grained to conglomeratic sandstone and associated overbank siltstone and red mudstone. The sandstone generally occurs in channels, exhibits large- to small-scale trough-crossbedded lenticular units, and occupies scours cut into the underlying Triassic Moenkopi Formation. Epsilon crossbedding and fining-upward sequences are common. Paleocurrent measurements made on channels and trough crossbeds by the author and previous investigators (Stewart and others, 1972a, p. 20; Thaden and others, 1964, p. 54), indicate flow directions to the southwest and west for Shinarump streams in the study area.

Overlying the Shinarump fluvial sandstone and overbank deposits in places (figs. 2, 3, and 4) is black, thinly laminated, organic-rich mudstone at the base of the Monitor Butte Member that laterally extends for several hundred feet (tens of meters) and is up to 20 feet (6 m) thick. Assemblages of conchostracans (order Conchostraca, class Branchiopoda, phylum Arthropoda) (R. Forester, written commun., 1982; Tasch, 1978; Ash, 1978) found in the black mudstones attest to their lacustrine origin. The high organic content of the mudstones and analogy with modern conchostracan habitats suggest this environment can be further defined as lacustrine marsh. Lacustrine mudstone that overlies fluvial sandstone at the Gonaway Mine (section 9), the White Canyon Mine (section 5), the Hillside Mine (section 3), Red Canyon (section 2), and S3 (section 6) may represent abandoned channel fills or meander cut-off lake deposits. Lacustrine-marsh mudstone directly overlies and is in contact with the underlying Moenkopi Formation at the Apollo Claim (section 16), Jacob's Chair 3 (section 12), and the Four Aces Mine (fig. 1). Apparently, some marsh mudstone was not deposited in abandoned channel fills or meander-cutoff oxbow lakes, but in lakes that occupied low-energy floodplain environments in topographically low areas adjacent to the Shinarump fluvial system. The designation of the marsh environment should also be noted for black, conchostracan-bearing mudstones previously reported in a cross section in White and Red Canyons (Dubiel, 1982).

A particular burrowed and bioturbated, poorly sorted sandstone unit commonly occurs near the base of the Monitor Butte Member (figs. 2, 3, and 4). It is generally mottled yellow, white, and purple, and locally contains burrows up to 4 inch (10 cm) in diameter and 3 feet (1 m) long. This unit, interpreted as marginal lacustrine, was deposited during the relative expansion and transgression of a lacustrine body of water. The lake may represent an expansion of the floodplain lake environment lateral to Shinarump streams or a lake that existed to the west that Shinarump streams flowed into. Transgression occurred after Shinarump fluvial deposition and prior to the major portion of Monitor Butte deposition.

Monitor Butte Member mudstones, shown in the stratigraphic cross sections (figs. 2, 3, and 4), are characterized by laterally extensive horizontal beds and are composed of sandy and silty bentonitic mudstone and minor thin-bedded limestone. These mudstones and limestones are interpreted as lacustrine deposits. Red mudstones that contain 1 to 2 inch (2.5 to 5 cm) diameter calcareous nodules are interpreted as overbank-floodplain deposits. The presence of abundant carbonaceous fragments in gray and green lacustrine mudstones indicates that anaerobic conditions existed in the sediment at the time of deposition and inhibited oxidation of the organic-matter.

The remainder of the Monitor Butte Member is composed of green to gray, micaceous, cyclically bedded sandstone and siltstone; gray to greenish-gray, sandy, bentonitic mudstone; and isolated lenses of fluvial sandstone. Cyclic beds are from 2 to 6 feet (0.5 to 2 m) thick and coarsen upwards from gray mudstone to medium-grained sandstone. The beds in the lower portion of the cyclic sequence are predominantly mudstone and coarsen upward into sandy mudstone. In the middle portion of the sequence, the beds are composed of 4 inch (10 cm) thick gray mudstone at the base that coarsens upward into climbing-ripple laminated medium-grained sandstone. In the upper portion of the sequence the beds are composed of 4 inch (10 cm) thick gray mudstone at the base that coarsens up into foreset-bedded medium-grained sandstone. The

entire sequence coarsens upward. These cyclic beds are interpreted as prodelta- and distributary mouth bar-deposits of a river-dominated deltaic system (Dubiel, 1982)(sections 5, 6, 7, 9, 12, 15 and 16)(figs. 2, 3, 4, and 5). The overall, coarsening upward sequence represents a prograding delta source. The lower, muddy portion of a cycle represents a minor rise in lake level due to local compaction or subsidence and the upper climbing-ripple cross-laminated sandstone of a cycle represents subsequent clastic infilling. Water depth at this margin of the lake, which is inferred from foreset-thickness, varied from 2 to 6 feet. Oscillation ripples on upper bedding planes represent periods of standing water. At the time of Monitor Butte deltaic sedimentation, the rate of subsidence (Rs) of the depositional basin must have been slightly less, but roughly equal to the rate of depositional infilling (Rd), or Rd/Rs=1, to account for the vertically accreting cyclic beds and slightly prograding cyclic deltas. While cyclically bedded mudstone and sandstone were deposited as delta lobes at Jacob's Chair 3 (section 12), the Apollo (sections 15 and 16), the White Canyon (sections 5, 6 and 7), and the Gonaway (section 9) Mines, local transgression in the inter-delta areas resulted in the deposition of sandy, bentonitic, reworked lacustrine mudstone (sections 1, 2, 3, 4, 8, 10, 11, 13, and 14). Meandering streams flowed on the delta plain and locally eroded into underlying deposits.

The Moss Back Member overlies the Monitor Butte Member and is composed of laterally extensive coarse- to medium-grained sandstone characterized by medium- to small-scale trough-crossbedding, horizontal laminations, and abundant tabular-planar crossbedding. Planar crossbeds are inferred to be a product of the migration of transverse bars in the braided stream channel (Smith, 1970). Numerous conglomerate beds separate the Moss Back sandstone into several superposed, incomplete, fining-upward sequences, with a lack of siltstone or mudstone. The conglomerate beds are composed of well-rounded quartz, quartzite, and chert pebbles, and abundant intraclasts of rippled siltstone, calcareous nodules, and fragments of chert. The lithology of these intraclasts is identical to units of the underlying Monitor Butte Member. These conglomerate beds largely represent deposits of reworked Monitor Butte sediments that were cut into, eroded, and redeposited by Moss Back streams. The Moss Back Member is interpreted as braided stream deposits based on the laterally extensive, tabular, generally coarse-grained character of the sediments; numerous incomplete fining-upward sequences; abundance of tabular-planar crossbedding; and overall lack of fine-grained floodplain and channel cut-off sediments.

Moss Back braided stream and associated overbank and floodplain deposits overlie and scour into the Monitor Butte Member. Paleocurrent measurements taken on crossbeds and current lineations by the author, and previous investigators (Stewart and others, 1972a), suggest that Moss Back streams flowed northwest through the study area.

URANIUM MINERALIZATION

Uranium mineralization in the White Canyon, Red Canyon, and Blue Notch Canyon area appears to be related to specific facies in the depositional environment, occurring in basal fluvial sandstone of the Shinarump Member (figs. 2, 3, and 4) where it is overlain by, or lies a short lateral distance from, black organic-rich, lacustrine-marsh mudstone at the top of the

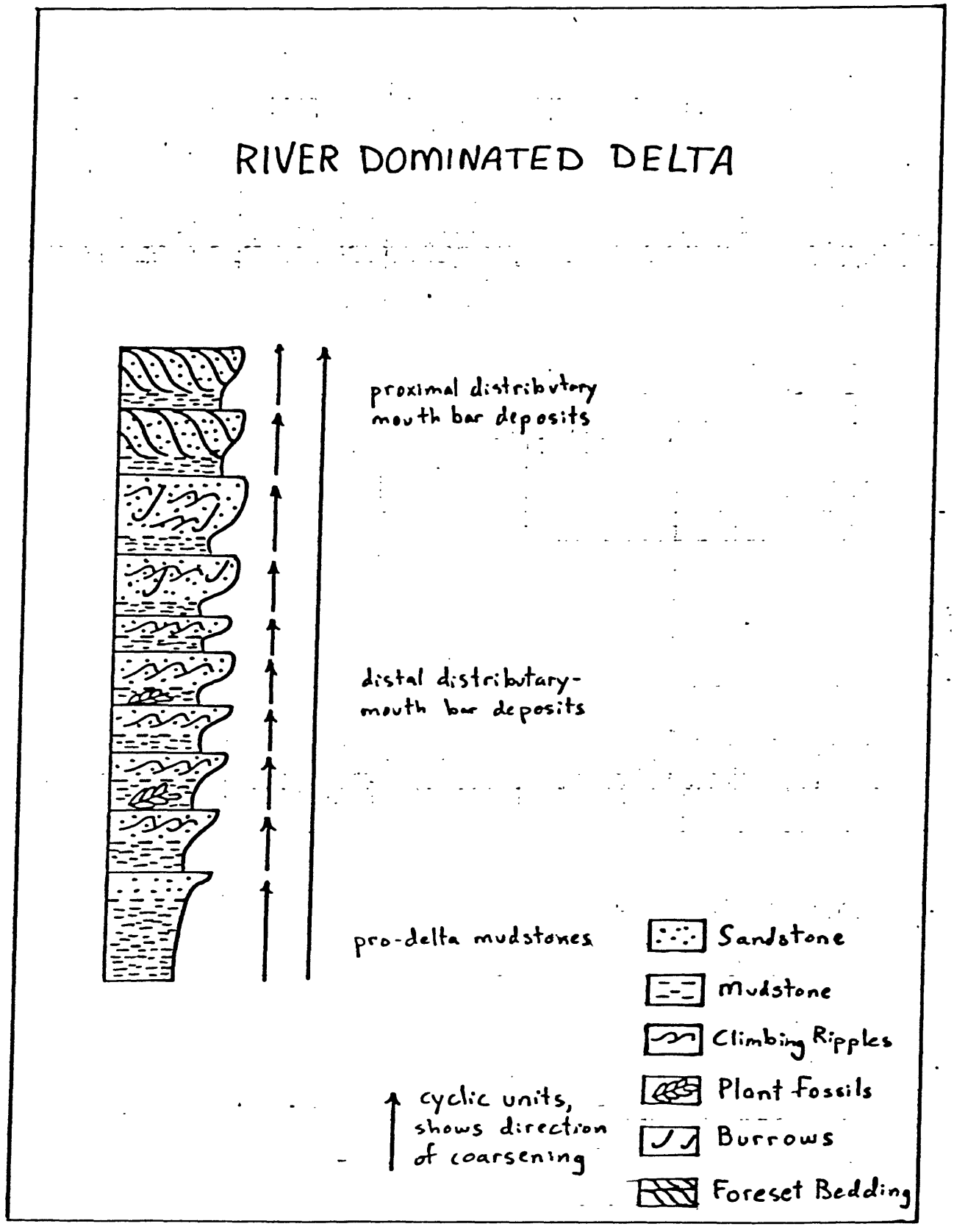

Figure 5.--Schematic diagram of a river-dominated deltaic sequence (modified from Miall,1979).

Shinarump Member or at the base of the Monitor Butte Member. A similar association with gray, carbonaceous lacustrine mudstone occurs in the Stockton and Lockatong Formations (Triassic) in the Newark Basin of Pennsylvania and New Jersey (Turner-Peterson, 1980) and in the Salt Wash Member of the Morrison Formation (Upper Jurassic) in the Henry Basin of southern Utah (Peterson, 1980). In the Henry Basin, the mudstone also occurs in depositional environments dominated by low-energy fluvial processes. A similar relationship was noted for the Chinle Formation in the San Rafael Swell between uranium mineralization and low-energy depositional environments lateral to Moss Back streams (Lupe, 1977). In addition to the association with organic-rich lacustrine-marsh mudstone, uranium mineralization in the study area is commonly overlain by green to gray, micaceous and carbonaceous, cyclic deltaic deposits or gray to greenish-gray, carbonaceous prodelta deposits of the Monitor Butte Member. The character of these sediments suggests that rapid, subaqueous deposition of detrital sediment along with the accumulation of abundant organic matter in the form of plant fragments may have influenced the localization of uranium mineralization by providing the locally reducing environment necessary to precipitate uranium. This reducing environment probably protected organic matter in mudstones and carbonaceous trash in host sandstones from oxidation. The reducing environment may have also protected the uranium from later oxidation.

MEASURED SECTIONS

Sections were measured using standardized section cards (Reynolds and others, 1975) denoting rock type, visual porosity estimate, median grain size by field estimate with hand lens and grain size chart, bedding parameters and sedimentary structures (McKee and Weir, 1953), biologic constituents, cement, and percent feldspar. Units as thin as 1 feet (15 cm) were measured, recorded, and characterized by these parameters. Paleocurrent measurements were taken on channels and crossbedded units. Measurements were recorded in the field in feet; later conversion to meters accounts for discrepancies in the addition of the meters column. A short phrase describing the interpreted depositional environment is included at the end of each unit description.

Section 8.--Last Day

[Section is on south wall of small tributary canyon in south wall of Blue Notch Canyon, in SE1/4 NW1/4 sec. 14, T. 35 S., R. 14 E., San Juan County, Utah. Section begins 0.3 mile (0.5 km) due east of adit halfway up the canyon and continues directly up slope to the top of the Moss Back Member]

	Thickness Feet	Meters
Chinle Formation (part):		
Petrified Forest Member (part):		
15. Sandstone, white, medium- to coarse-grained, thin- to thick-bedded, with trough and planar crossbeds; forms rounded, ledgy slope	10+	3+
Total Petrified Forest Member (part)	10+	3+
Moss Back Member:		
14. Sandstone, light-brown, coarse-grained, thin- to thick-bedded, with trough crossbeds that dip approximately N 35° W; forms steep cliff; braided stream	34	10.3
13. Sandstone, light-brown, coarse-grained thin-bedded, planar-crossbedded; forms cliff; braided stream	8	2.4
12. Mudstone, light-greenish-gray, slightly bentonitic, faint horizontal laminations; weathering produces prominent parting between sandstone units; overbank or pond deposit in braided stream	2	0.6
11. Sandstone, light-brown, calcareous, coarse- to medium-grained with pebble lag at base, (pebbles 1.5 inch (4 cm) maximum diameter), thick-bedded with faint trough crossbeds; basal contact scoured; forms steep cliff; braided stream	16	4.8
10. Sandstone, light-brown, fine-grained, thin- to thick-bedded, horizontal laminations at base, large-scale low-angle trough crossbeds at top; forms steep cliff; braided stream	12	3.6
9. Sandstone, light-brown, micaceous, fine-grained, thin-bedded; has horizontal laminations at base, tabular-planar crossbeds, and ripples at top; forms steep cliff; braided stream	10	3

8. Sandstone, light-brown, micaceous, very fine-grained with small 1 inch (2.5 cm) diameter limestone intra-clast lag at base; thin-bedded, rippled at top; basal contact scoured; forms steep cliff; braided stream	4	1.2
Total Moss Back Member	86	26
Monitor Butte Member:		
7. Mudstone, light- to medium-greenish-gray; contains silt and very fine-grained sand; structureless; weathers to gray slope; lacustrine	95	28.7
6. Limestone, gray to light-greenish-purple; clayey with limonite stain; forms small ledge; lacustrine	1	0.3
5. Mudstone, as in unit 7, light-brownish-gray; contains carbonized plant fragments; weathers to gray slope; lacustrine	22	6.6
4. Sandstone, light-gray, muddy, very fine-grained; forms thin ledge; marginal lacustrine	2	0.6
3. Siltstone, medium-gray, contains very fine-grained sand and carbonized plant fragments; weathers to gray slope; lacustrine	27	8.1
Total Monitor Butte Member	147	44.5
Shinarump Member:		
2. Sandstone, light- to medium-gray, very fine-grained, thin-bedded, with horizontal laminations; contains abundant carbonized plant fragments and leaf fragments; forms flaggy slope; fluvial, overbank; 400 feet (120 m) to the west this unit grades into a 20 feet (6 m)- thick fluvial sandstone	7	2.1
Total Shinarump Member	7	2.1
Total Chinle Formation (part)	240	72.7
Unconformity, based on regional studies (Stewart and others, 1972a, 1972b), contact sharp.		

Moenkopi Formation (part):

1. Siltstone, bleached olive-gray, micaceous, very thin-bedded; forms thin ledgy cliff; regional studies (Stewart and others, 1972b) suggest mudflat.....Not Measured

Section 9.--Gonaway

[Section is above Utah State Highway 95, directly opposite Ducket Crossing in White Canyon in SE1/4 SE1/4 sec. 8, T. 35 S., R. 16 E., San Juan County, Utah. A dirt road approaches the Happy Jack Mine and branches left to the Gonaway Mine. Section begins at base of adit and continues directly up to Moss Back Member]

	Thickness	
	Feet	Meters
Chinle Formation (part):		
Moss Back Member:		
13. Sandstone, light-brown to yellow-brown, fine- to medium-grained, calcareous, thick-bedded with rare shallow trough crossbeds; forms massive, steep cliff; braided stream	54	16.3
12. Sandstone, moderate-brown, fine-grained, calcareous, thick-bedded, structureless; forms steep cliff; braided stream	30	9
11. Sandstone, light-yellowish-brown, very coarse-grained, thick-bedded, with horizontal laminations and shallow trough crossbeds; forms massive cliff; braided stream	26	7.8
10. Conglomerate, moderate-brown, calcareous, with limestone intra-clast nodules, and chert and quartzite pebbles, as much as 3 inch (8 cm) in diameter; forms ledge; braided stream	2	0.6
Total Moss Back Member	112	33.9
Monitor Butte Member:		
9. Siltstone, moderate- to pale-red; weathers to rubble-covered slope; lacustrine, possibly overbank; 0.25 mile (0.4 km) to SW lower half of unit is composed of cyclically bedded fine-grained sandstone and siltstone, greenish-gray, and micaceous, thin- to thick-bedded; cycles are muddier at the base and coarsen upward to sand with climbing-ripple cross-laminations at the top; forms ledgy		

	slope; river-dominated deltaic distributary mouth bars.....73	22.1
8.	Sandstone, white to gray, very coarse to very fine grained and silty, very slightly calcareous; thin- and lenticular-bedded; trough-cross-bedded; forms flaggy cliff; channel trends SW; meandering stream.....7	2.1
7.	Sandstone, white to gray and mottled light-yellow; very fine grained with scattered, very coarse, well-rounded quartz grains, silicified, lenticular; has faint thin bedding; locally bioturbated with large, 3 inch (8 cm) by 1 feet (0.3 m) burrows, some extending into underlying mudstone unit; grades laterally into thin-bedded siltstone; marginal lacustrine.....14	4.2
6.	Siltstone and mudstone, gray, thin- to very thin bedded; wavy nonparallel laminations; partly covered, forms slope; marginal lacustrine. At Happy Jack Mine, 0.6 mile (1 km) to north, top half of unit 6 is black organic-rich, thinly laminated mudstone; lacustrine-marsh.....17	5.1
Total Monitor Butte Member.....	111	33.6

Shinarump Member:

5.	Sandstone, yellow-orange, very coarse to coarse-grained, some medium-grained, thick-bedded, massive to lenticular-bedded; current lineation N 30° W; forms steep cliff; meandering stream.....17	5.1
4.	Sandstone, gray, very fine grained with some fine- to medium-grained, very thin to thin-bedded, with 1 mm-thick horizontal laminations; small carbonized plant fragments; forms cliff; overbank, or possibly pond in overbank deposits.....14	4.2
3.	Mudstone, dark- to medium-gray, and interbedded siltstone; 1 mm-thick horizontal laminations; abundant carbonized plant fragments and whole leaves of Late Triassic flora; unit weathers to small recesses in cliff; pond in overbank deposits.....3	1

2. Sandstone, same as unit 4	3	1
Total Shinarump Member	37	11.2
Total Chinle Formation (part)	260	78.7

Unconformity, based on regional studies, contact sharp and erosional; local relief 10 feet (3 m).

Moenkopi Formation (part):

1. Siltstone, red-brown, micaceous, thin-bedded; regional studies suggest mudflat.....Not Measured

Section 10.--Jacob's Chair 1

[Section is below southwest corner of Jacob's Chair on dirt road leading from Gravel Crossing around south side of Jacob's Chair, NE1/4 NW1/4 sec. 19, T. 35 S., R. 16 E., San Juan County, Utah. Section begins at sharp curve of dirt road in large reentrant canyon between Jacob's Chair and remnant butte 0.9 mile (1.4 km) south of Jacob's Chair]

	Thickness	
	Feet	Meters
Chinle Formation (part):		
Moss Back Member:		
14. Sandstone, light-brown to yellow-brown; medium- to coarse-grained, structureless; forms steep cliff; braided stream	10	3
13. Sandstone, light-brown to yellow-brown, medium- to coarse-grained; shallow trough-crossbedded; forms cliff; braided stream	5	1.5
12. Sandstone, light-brown to moderate-brown, medium-grained, structureless, forms blocky cliff; braided stream	5	1.5
11. Mudstone, medium-light-gray to greenish-gray, horizontally laminated, weathers out between sandstone beds; deposited in ponded water in braided stream	1	0.3
10. Sandstone, light-brown to moderate-brown, very coarse- to medium-grained, structureless, contains numerous limestone nodule intra-clasts 1.5 inch (4 cm) to 3 inch (8 cm) in diameter at base; scoured, erosional base; forms ledgy cliff; braided stream	4	1.2
Total Moss Back Member	20	6

Monitor Butte Member:

9. Mudstone, medium-red to light-purple, slightly bentonitic, slightly silty; structure obscured in weathered slope; limestone nodules up to 3 inch (8 cm) in diameter increasing in abundance in top 10 feet (3 m) of unit, very abundant at top of unit; weathers to light-purple "popcorn" soil (Stewart and others, 1972a) with limestone nodules at top; overbank	53	16
8. Sandstone, light-greenish-gray, calcareous, micaceous, silty, thin-bedded, with horizontal laminations, and low-angle cross-beds, possibly shallow troughs; weathers to ledgy cliff with siltier units weathered back; meandering stream	25	7.5
7. Siltstone, light-greenish-gray, and very fine grained sandy siltstone; forms steep slope that obscures structure; lacustrine	60	18
6. Sandstone, light-gray to white, calcareous, fine-grained, thin-bedded, with ripple cross-laminations; forms ledgy cliff; meadering stream, possibly detlta distributory stream	10	3
5. Sandstone, yellow-orange to white, slightly calcareous, micaceous, coarse- to medium-grained, thin- to medium-bedded, horizontally bedded, with shallow trough crossbedding, climbing ripple cross-lamination, and megaripple crossbedding; forms small cliff; meandering stream	14	4.2
4. Siltstone, light- to medium-gray and mottled light-purple, silicified; contains scattered very coarse, well-rounded quartz grains, structureless, possibly bioturbated; 100 feet (30 m) to northeast unit is burrowed, burrows vertical, 2 inch (5 cm) in diameter by 2 feet (0.6 m) long; forms steep slope; marginal lacustrine	16	4.8
3. Sandstone, yellow-orange to white, mottled purple, very fine to medium-grained, thick-bedded with thin, horizontal laminations; forms steep blocky cliff; marginal lacustrine	10	3
Total Monitor Butte Member	186	56

Shinarump Member:

2. Sandstone, yellow-orange to white, very coarse to coarse-grained, thin- to thick-bedded lenticular with small-scale trough crossbeds; forms rounded cliff; meandering stream	10	3
Total Shinarump Member	10	3
Total Chinle Formation (part)	220	66.6

Unconformity, based on regional studies, contact sharp and erosional.

Moenkopi Formation:

1. Siltstone, red-brown, micaceous, thin-bedded; forms ledgy cliff; regional studies suggest mudflat	Not Measured

Section 11.--Jacob's Chair 2

[Section is at eastern end of Jacob's Chair above dirt road leading in from Gravel Crossing, in SE1/4 SW1/4 sec. 17, T. 35 S., R. 16 E., San Juan County, Utah. Section begins in bentonitic hills and continues directly up slope to Moss Back Member]

	Thickness Feet	Thickness Meters
Chinle Formation (part):		
Moss Back Member:		
13. Sandstone, light-brown, fine-grained, thin- to very thin bedded, with horizontal laminations and ripples; current direction from ripples approximately west; forms steep cliff; braided stream	3	1
12. Sandstone, light-brown, slightly calcareous, fine- to medium-grained, thin- to thick-bedded, horizontally laminated to very shallow trough-crossbedded with dip to north and northwest; forms steep cliff; braided stream	10	3
11. Sandstone, medium-brown, medium- to coarse-grained, with limestone nodule conglomerate at base; scoured surface at base; forms steep cliff; braided stream	2	0.6
Total Moss Back Member	15	4.5

Monitor Butte Member:

10.	Sandstone, light-greenish-gray, calcareous, slightly bentonitic, medium-grained, thin-bedded, interbedded with light-greenish-gray, micaceous, muddy, siltstone; "popcorn"-like weathered slope; forms steep slope with thin ledges; overbank.....66	20
9.	Siltstone, medium-red to light-purple, muddy, slightly bentonitic, with limestone nodules increasing in abundance toward top; forms "popcorn"-like weathered surface; overbank.....6	2
8.	Sandstone, medium-gray, calcareous, micaceous with some biotite, medium- to fine-grained, grades upward to very fine grained; large-scale shallow trough crossbeds with trough direction approximately WSW; forms slope; meandering stream.....33	10
7.	Sandstone, light-yellow to white, calcareous, clay matrix, medium-grained, thin-bedded, with 1 cm horizontal laminations, shallow-angle trough crossbeds, and climbing-ripple crossbedding; forms rounded knobby cliff; meandering stream.....15	4.5
6.	Sandstone, greenish-gray, micaceous, clayey, very fine-grained; weathers to slope; marginal lacustrine.....44	13.3
5.	Sandstone, light-gray to white, with brown, oxidized iron "freckles", very calcareous, medium- to fine-grained; medium-bedded with megaripple bedding, possibly small foreset bedding; forms rounded ledge; marginal lacustrine.....2	0.6
4.	Sandstone, white, mottled purple, silicified, very coarse to medium-grained, structureless; forms steep slope; marginal lacustrine.....18	5.4
3.	Sandstone, medium-gray to brown, weathered and mottled purple, fine-grained, thin-bedded with 1 mm-thick horizontal laminations and fine-grained carbon detritus; forms steep slope; marginal lacustrine.....13	3.9
Total Monitor Butte Member.....		197 59.6

Shinarump Member:

2. Sandstone, white, very slightly calcareous, coarse- to medium-grained; structureless or has faint horizontal laminations; gray clay clasts, and Cu in the form of malachite; contains fine-grained carbon detritus and Moenkopi rip-up clasts, scoured base; forms rounded ledge; meandering stream, overbank.....3 1

Total Shinarump Member.....3 1

Total Chinle Formation (part).....215 65.2

Unconformity, based on regional studies, contact sharp, erosional; local relief 4 inch (10 cm).

Moenkopi Formation (part):

1. Siltstone, red-brown, micaceous, thin-bedded; regional studies suggest mudflat.....Not Measured

Section 12.--Jacob's Chair 3

[Section is in low, bentonitic hills 1.5 mile (2.4 km) ENE of Jacob's Chair in NW1/4 SW1/4 sec. 16, T. 35 S., R. 16 E., San Juan County, Utah. Section is described from base of small knoll circled by dirt prospect road to a distinct white sandstone unit at the top and continues to top of adjacent hill to east]

	Thickness	
	Feet	Meters
Chinle Formation (part):		
Monitor Butte Member:		
20. Sandstone, medium-brown, calcareous, medium- to coarse-grained, thin-bedded, planar crossbedded; forms rounded, knobby cliff; at the same stratigraphic position as the Moss Back cliff in adjacent sections (Jacob's Chair 1 and Jacob's Chair 2); overbank deposit	22	6.6
19. Siltstone, medium-red to reddish-brown; very slightly bentonitic; weathers to slope; overbank deposit	19	5.7
18. Mudstone, medium-red, silty, with large, cylindrical 6 inch (15 cm) by 2 feet+ (0.6+ m) calcareous burrows (?) or root casts (?); forms slope; overbank deposit	10	3

17. Mudstone, as in unit 18, with burrow-like calcareous concretions, and rounded 3 inch (8 cm) limestone nodules that increase in abundance to top of unit; forms slope with indistinct nodular ledge at top; overbank deposit.....6 — 1.8

16. Mudstone, greenish-gray, bentonitic, contains scattered fine-grained sand; forms slope; overbank deposit.....14 — 4.2

15. Mudstone, medium-red, with limestone nodules up to 3 inch (8 cm) in diameter; overbank deposit.....10 — 3

14. Mudstone, greenish-gray, bentonitic, contains scattered fine-grained sand and interbedded fine-grained sandstone layers 6 inch (15 cm) thick; on hill to east this unit is cyclically interbedded with climbing-ripple cross-laminated sandstone; forms slope with thin-rounded ledges; marginal to near-shore lacustrine, possibly distal portion of river-dominated, vertically accreting delta.....76 — 23

13. Sandstone, white to yellow-orange, very calcareous, white clay matrix, unit fines upward from medium- to very fine grained, angular quartz sandstone; medium-bedded with medium- to thin-laminations and shallow, low-angle trough crossbeds; forms ledgy cliff; channel direction approximately WNW; meandering stream.....20 — 6

12. Sandstone, dark-brown, medium- to coarse-grained, contains 3 inch (8 cm) limestone nodules and iron concretions; forms ledge; meandering stream deposit with basal lag.....2 — 0.6

11. Sandstone, white- to yellow-orange, calcareous, very coarse grained with 1.5 inch (4 cm) diameter pebbles and iron concretions; bedding indistinct, horizontal, very thin; forms cliff; meandering stream.....12 — 3.6

10. Siltstone, and fine- to medium-grained sandstone; calcareous clay matrix, and very thin horizontal bedding; forms small ledge; meandering stream.....3 — 1

9. Mudstone, medium-gray, bentonitic, forms "popcorn"-like weathered surface; marginal lacustrine.....7 — 2.1

8. Mudstone, medium-gray, very slightly bentonitic, contains scattered fine-grained sand, forms very steep slope; marginal lacustrine	10	3
7. Sandstone, white, very coarse grained, thin-bedded; laterally grades into limestone, and into sandstone containing limestone nodule intraclasts; forms ledge; marginal lacustrine	1	0.3
6. Mudstone, black to medium-gray, mottled purple, silty, has faint very thin horizontal laminations; weathers to gray slope, lacustrine-marsh	5	1.5
5. Mudstone, black to gray, silty, very thin horizontally laminated; weathers to gray slope; lacustrine-marsh	8	2.4
4. Mudstone, black, very thinly laminated, organic-rich, contains conchostracan branchiopods; forms gray slope; lacustrine-marsh	8	2.4
3. Siltstone, gray, very thin horizontally laminated; forms ledge; lacustrine-marsh	1	0.3
2. Mudstone, gray, silty, with small carbonized organic bits, forms slope; lacustrine-marsh	3	1
Total Monitor Butte Member	237	72.2
Total Chinle Formation (part)	237	72.2

Unconformity, based on regional studies, contact indistinct, but with color change from red below to gray above.

Moenkopi Formation (part):

1. Siltstone, red-brown, thin-bedded, forms ledgy slope; regional studies suggest mudflat deposit		Not Measured

Section 13.--Blue Notch Gap

[Section is in lower, very narrow part of Blue Notch Canyon formed by large bench of the Moss Back sandstone in NE1/4 NW1/4 sec. 16, T. 35 S., R. 14 E., San Juan County, Utah. Section begins in small reentrant on south wall of narrow gap and continues directly up slope to top of the Moss Back Member]

	Thickness	
	Feet	Meters
Chinle Formation (part):		
Moss Back Member:		
10. Sandstone, medium-yellow-brown, medium-grained, thick-bedded, trough-crossbeds and overturned trough-crossbeds; forms steep cliff; braided stream	18	5.4
9. Sandstone, medium-yellow-brown, medium-grained, thick-bedded, with large-scale low-angle trough crossbeds and horizontal laminations; quartz-pebble lag at base; forms steep cliff; braided stream	25	7.5
8. Siltstone, gray, with very fine grained sand; horizontal laminations; weathers to form recesses in of sandstone cliff; deposited in ponded water, deposit as channel fill in braided stream	2	0.6
7. Sandstone, medium-yellow-brown, medium-grained, thick-bedded, with large-scale low-angle trough- crossbeds (current direction approximately N 60° W); forms steep cliff; braided stream	20	6
6. Sandstone, yellow-brown, medium-grained, massive to shallow trough-crossbedded with quartz-pebble lag at the base; forms steep cliff; braided stream	33	10
5. Sandstone, yellow-brown, very calcareous, very coarse grained with abundant black chert and quartz pebbles in lag at base; edge of channel sandstone pinchout trends NW; forms steep cliff; braided stream	8	2.4
Total Moss Back Member	106	32.1
Monitor Butte Member:		
4. Siltstone, gray; bedding structure obscured by covered slope; nearshore lacustrine	24	7.2

3. Sandstone, white to yellow-white, calcareous, very fine to fine-grained, thin- to medium-bedded, with horizontal laminations and shallow trough crossbeds; forms rounded cliff; meandering stream.....34 10.3

2. Siltstone, greenish-gray to green and gray, muddy, massive to laminated; unit is sandier at base and contains plant fragments; weathers to gray slope; lacustrine; on north side of gap in Blue Notch Canyon the top 30 feet (10 m) of this unit is cut out by a channel of unit 3.....66 20

Total Monitor Butte Member.....124 37.5

Total Chinle Formation (part).....230 69.6

Unconformity, based on regional studies, contact sharp and distinct.

Moenkopi Formation (part):

1. Siltstone, reddish-brown, very thin bedded, and very fine grained, sandstone forms ledgy slope, regional studies suggest mudflat.....Not Measured

Section 14.--Blue Notch Canyon-North Wall

[Section is on north wall of Blue Notch Canyon on large promontory directly south of the easternmost of two gaps in the Wingate Sandstone, in NW1/4 SW1/4 sec. 2, T. 35 S., R. 14 E., San Juan County, Utah. Section begins at base of promontory and continues directly up slope to white sandstone unit in the Petrified Forest Member]

	Thickness	
	Feet	Meters
Petrified Forest Member (part):		
12. Sandstone, white, medium-grained, thin-bedded, with tabular-planar crossbeds; forms rounded ledges	15+	4.5+
Total Petrified Forest Member (part)	15+	4.5+
Monitor Butte Member:		
11. Mudstone, reddish-purple; contains very fine grained sand, weathers to light-purple slope; overbank	12	3.6

10.	Sandstone, yellow-brown, medium- to very coarse grained with limestone nodule conglomerate at base; thin-bedded with faint trough crossbeds (NW); forms ledge; braided stream	3	1
9.	Mudstone, reddish-brown to light-purple; contains very fine grained sand, forms slope; overbank	18	5.4
8.	Mudstone, reddish-brown, massive, with limestone nodules increasing in abundance to top; forms slope with ledgy top; overbank	15	4.5
7.	Sandstone, medium-gray, bentonitic, very fine grained, thin-bedded, with horizontal laminations, climbing ripple cross-laminations, and faint, shallow trough-crossbeds; weathers to "popcorn"-like soil-covered slope; meandering stream	20	6
6.	Mudstone, medium-gray, bentonitic; forms "popcorn"-like soil-covered slope; lacustrine	20	6
5.	Sandstone, greenish-gray, medium- to coarse-grained, thin- to thick-bedded, with low-angle trough crossbeds and climbing-ripple cross-laminations; forms small cliff; meandering stream	25	7.5
4.	Mudstone, medium-gray, silty, bentonitic; weathers to "popcorn" soil-covered slope; lacustrine	105	31.8
3.	Sandstone, gray, very fine grained, thick-bedded, structureless; contains carbonized plant fragments; forms rounded cliff; lacustrine	9	2.7
2.	Sandstone, yellow-white, medium- to coarse-grained, thick-bedded, burrowed and bioturbated; contains burrows 2 inch (5 cm) by 2 feet (0.6 m), and carbonized plant fragments and sticks; weathers to blocky cliff; marginal lacustrine	21	6.3
Total Monitor Butte Member		255	77.1

Unconformity, based on regional studies, contact sharp and distinct.

	forms steep cliff and steep slope with ledges; river-dominated deltaic distributary mouth bars.....50	15
8.	Sandstone, greenish-gray, micaceous, calcareous, fine- to medium-grained, medium- to thin-bedded, with lunate climbing-ripple cross-laminations; iron-stained, case-hardened outcrop surfaces; forms steep cliff; deltaic distributary mouth bars.....10	3
7.	Sandstone, light-greenish-gray, micaceous, fine-grained, thin-bedded, with faint crossbeds and faint horizontal laminations; iron-stained, case-hardened, lenticular bedded; forms steep knobby-weathered cliff; deltaic distributary mouth bars.....10	3
6.	Mudstone, light- to medium-gray, bentonitic, silty, oil(?) stained; has faint horizontal laminations, up to 3 inch (8 cm) diameter calcareous nodules, and small carbonized plant fragments; forms steep slope; lacustrine, ...7	2.1
5.	Sandstone, gray, fine- to medium-grained, and dark-gray, sandy siltstone; contains numerous, scattered, rounded, very coarse quartz grains, and small, carbonized plant fragments; forms steep slope; marginal lacustrine.....17	5.1
4.	Sandstone, white with mottled yellow stains, coarse- to fine-grained, structureless, bioturbated and burrowed; small carbonized plant fragments; forms ledgy slope; marginal lacustrine.....8	2.4
3.	Mudstone, gray, slightly bentonitic, and very fine grained sandstone; faint horizontal laminations, carbonized plant fragments and leaves; contains beds of white clay, orange stain, and veinlets of secondary gypsum; forms slope; lacustrine.....8	2.4
2.	Siltstone, red-brown, micaceous, slightly calcareous; base of unit has two gray, very coarse grained, well-rounded, poorly sorted, thin sandstone beds; sandstone contains carbon fragments; forms slope; lacustrine.....16	4.8
Total Monitor Butte Member.....		224 68.2
Total Chinle Formation (part).....		224 68.2

Moenkopi Formation (part):

1. Siltstone, reddish-brown, thin-bedded, regional studies suggest mudflat.....Not Measured

Section 15.--Apollo North

[Section is in Blue Notch Canyon on dirt road leading from Blue Notch to Lake Powell, in NW1/4 NW1/4 sec.1, T. 35 S., R. 14 E., San Juan County, Utah. Section begins on south wall of small reentrant 0.4 mile (0.65 km) northwest of Apollo Claim adit, continues up slope to left, then up right to a white sandstone bed in the Petrified Forest Member]

	Thickness	
	Feet	Meters
Petrified Forest Member (part):		
14. Sandstone, white, medium- to fine-grained, with white clayey matrix, thin-bedded with tabular-planar crossbeds	12+	3.6+
Total Petrified Forest Member (part)	12+	3.6+
Monitor Butte Member:		
13. Sandstone, reddish-brown, fine-grained, thin-bedded, alternately bedded with mudstone beds that weather back; forms slope with thin rounded ledges; unit can be traced along the north wall of Blue Notch Canyon, can be seen to grade into thick fluvial sandstone of the Moss Back Member at the lower end of Blue Notch Canyon; overbank	28	8.4
12. Mudstone, gray, and light-gray to white sandstone that forms very thin rounded ledges in slope; lacustrine	30	9
11. Mudstone, greenish-gray, contains very fine grained sand; forms slope; lacustrine	20	6
10. Mudstone, medium-red, contains very fine grained sand; forms slope; lacustrine	20	6
9. Sandstone, greenish-gray, micaceous, calcareous, fine- to medium-grained, medium- to thick-bedded, with wavy parallel bedding, climbing-ripple cross-laminations indicate current direction approximately west; top of unit has lunate climbing ripples at upper part of beds; bedding planes exhibit disc-like impressions, 2 inch (5 cm) in diameter, possibly the tops of burrows;		

Unconformity, based on regional studies, contact distinct.

Moenkopi Formation (part):

1. Siltstone, reddish-brown, micaceous, slightly calcareous; thin malachite veinlets present; forms ledgy slope; regional studies suggest mudflat.....Not Measured

Section 16.--Apollo Claim

[Section is at head of Blue Notch Canyon, 0.7 mile (1.1 km) due west of Blue Notch on dirt road leading from Blue Notch to Lake Powell, in SW1/4 NW1/4 sec. 6, T. 35 S., R. 15 E., San Juan County, Utah. Section begins at Apollo Claim adit, just NE of prominent knoll, and continues directly up slope to top of a distinctive greenish-gray cyclically bedded sandstone unit that correlates with top of unit 8, section 15. Upper part of section is identical to section 15]

	Thickness	
	Feet	Meters
Chinle Formation (part):		
Monitor Butte Member (part):		
9. Sandstone, greenish-gray, micaceous, calcareous, fine-grained, medium- to thick-bedded, with climbing-ripple cross-laminations; cyclically bedded with upper bedding plane surfaces commonly exhibiting oscillation ripples; forms steep slope with numerous ledges; river-dominated delta distributary mouth bars (Dubiel, 1982; Miall, 1979), rate of deposition approximately equals rate of subsidence, resulting in a vertically accreting system (Curtis, 1970)	42	12.7
8. Sandstone, greenish-gray, micaceous, calcareous, fine-grained; thin-bedded, with rare climbing-ripple cross-lamination; cyclically bedded; forms steep cliff; river-dominated delta distributary mouth bars, farther offshore than unit 9	16	4.8
7. Mudstone, dark-gray, bentonitic, clayey, slightly silty, forms slope; lacustrine	4	1.2
6. Mudstone, medium-gray, silty, with carbonized plant fragments; forms steep slope, lacustrine	22	6.6

5. Sandstone, yellow-white, very fine to very coarse grained, well-rounded, poorly sorted, silicified, bioturbated and burrowed; burrows, vertical, 4 inch (10 cm) by 2 feet (0.6 m); forms blocky cliff; marginal lacustrine	16	4.8
4. Siltstone, gray, very thin horizontal laminations, forms slope; marginal lacustrine	3	1
3. Mudstone, dark-brown to gray and black, coaly in places; abundant conchostracans; forms dark-gray slope; lacustrine-marsh	11	3.3
2. Covered slope, probably mudstone as in unit 3	4	1.2
Total Monitor Butte Member (part)	118	35.7
Total Chinle Formation (part)	118	35.7

Unconformity, based on regional studies, contact obscured by covered slope in line of section, but is sharp and erosional where exposed.

Moenkopi Formation (part):

1. Siltstone, reddish-brown, micaceous, thin- to very thin bedded, rippled; forms ledgy slope, regional studies suggest mudflats	Not Measured	

REFERENCES CITED

Ash, S. R., 1978, ed., Geology, paleontology and paleoecology of a Late Triassic lake, western New Mexico: Brigham Young University Geology Studies, v. 25, part 2, 100 p.

Curtis, D. M., 1970, Miocene deltaic sedimentation, Louisiana Gulf Coast, in Morgan, J. P., (ed.) Deltaic sedimentation, modern and ancient: Society of Economic Paleontologists and Mineralogists, Special Publication no. 15, p. 293-308.

Dubiel, R. F., 1982, Measured sections of the Shinarump Monitor Butte and Moss Back Members of the Chinle Formation (Upper Triassic) in the White Canyon and Red Canyon area, southeastern Utah: U.S. Geological Survey Open-File Report 82-729, 25 p.

Finch, W. I., 1959, Geology of uranium deposits in Triassic rocks of the Colorado Plateau: U.S. Geological Survey Professional Paper 1074-D, p. 125-164.

Harms, J. C., Southard, J. B., Spearing, D. R., and Walker, R. G., 1975, Depositional environments as interpreted from primary sedimentary structures and stratification sequences: SEPM Short Course No. 2, Dallas, Texas, 161 p.

Lewis, R. Q., Sr., and Campbell, R. H., 1965, Geology and uranium deposits of Elk Ridge and vicinity, San Juan County, Utah: U.S. Geological Survey Professional Paper 474-B, 69 p.

Lupe, R., 1977, Depositional environments as a guide to uranium mineralization in the Chinle Formation, San Rafael Swell, Utah: U.S. Geological Survey Journal Research, v. 5, no. 3, p. 365-372.

McKee, E. D., and Weir, G. W., 1953, Terminology for stratification and cross-stratification in sedimentary rocks: Geological Society of America Bulletin, v. 64, no. 4, p. 381-389.

Miall, A. D., 1979, Facies Models: Walker, R. G., ed., Deltas in Facies Models: GeoScience of Canada, Reprint Series No. 1, p. 43-56.

Peterson, Fred, 1980, Sedimentology as a strategy for uranium exploration: concepts gained from analysis of a uranium-bearing depositional sequence in the Morrison Formation of south-central Utah, in Turner-Peterson, C. E., ed., Uranium in sedimentary rocks--application of the facies concept to exploration: Society of Economic Paleontologists and Mineralogists, short course notes, p. 65-126.

Reading, H. G., ed., 1978, Sedimentary environments and facies: New York, Elsevier, 569 p.

Reineck, H. E., and Singh, I. B., 1975, Depositional Sedimentary Environments: New York, Springer-Verlag, 439 p.

Reynolds, M. W., Ahlbrandt, T. W., Fox, J. E., and Lambert, P. W., 1975, Description of selected drill cores from Paleozoic rocks, Lost Soldier Oil Field, south-central Wyoming: U.S. Geological Survey Open-File Report 75-662, p. 1-34.

Smith, N. D., 1970, The braided stream depositional environment: comparison of the Platte River with some Silurian clastic rocks, north-central Appalachians: Geological Society of America Bulletin, v. 81, p. 2293-3014.

Stewart, J. H., Poole, F. G., and Wilson, R. F., 1972a, Stratigraphy and Origin of the Chinle Formation and related Upper Triassic strata in the Colorado Plateau region: U.S. Geological Survey Professional Paper 690, 366 p.

_____1972b, Stratigraphy and origin of the Triassic Moenkopi Formation and related strata in the Colorado Plateau region: U.S. Geological Survey Professional Paper 691, 195 p.

Tasch, Paul, 1978, Clam shrimps, in Ash, S. R., ed., Geology, paleontology, and paleoecology of a Late Triassic lake, western New Mexico: Brigham Young University Geology Series, v. 25. part 2, p. 61-65.

Thaden, R. E., Trites, A. F., Jr., and Finnell, T. L., 1964, Geology and ore deposits of the White Canyon area, San Juan and Garfield Counties, Utah: U.S. Geological Survey Bulletin 1125, 166 p.

Turner-Peterson, C. E., 1980, Sedimentology and uranium mineralization in the Triassic-Jurassic Newark basin, Pennsylvania and New Jersey, in Turner-Peterson, C. E., ed., Uranium in sedimentary rocks-application of the facies concept to exploration: Society of Economic Paleontologists and Mineralogists, short course notes, p. 149-175.