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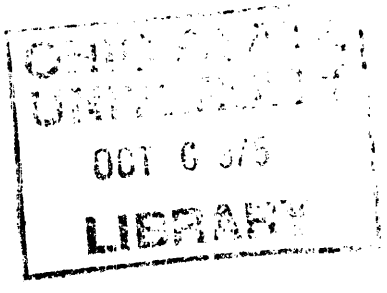

Marine Trace Fossils in the Upper Jurassic Bluff Sandstone, Southeastern Utah

By ROBERT B. O'SULLIVAN *and* JOHN O. MABERRY

CONTRIBUTIONS TO STRATIGRAPHY

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A description of newly discovered trace fossils and their significance

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MARINE TRACE FOSSILS IN THE UPPER JURASSIC BLUFF SANDSTONE, SOUTHEASTERN UTAH

By Robert B. O'Sullivan and John O. Maberry

ABSTRACT

The Bluff Sandstone, as much as 340 feet (104 metres) thick, is the uppermost formation of the San Rafael Group in southeastern Utah and extreme northeastern Arizona. Trace fossils, 4 to 9 millimetres across and of indeterminate length, are found as burrows in the lower part of the Bluff Sandstone. The depositional environment represented is the upper foreshore of a marine beach. The middle part of the Bluff is eolian but the upper part may be marine. The upper contact of the Bluff is almost certainly an unconformity.

INTRODUCTION

The Bluff Sandstone, of rather limited geographical extent (fig. 1) in southeastern Utah and northeastern Arizona, is the youngest formation in the San Rafael Group. Fossils have not heretofore been found in the Bluff Sandstone or, for that matter, in any other part of the San Rafael Group in southeastern Utah. Discussions of the age and depositional history of the San Rafael Group in this area have been based largely on regional relationships. Trace fossils described herein, although not diagnostic as to age, are helpful in interpreting the geologic history and depositional environment of the Bluff Sandstone and associated underlying parts of the San Rafael Group. This report briefly describes the Bluff Sandstone, describes the trace fossils, and discusses their significance.

This report is part of a continuing study of the geology of the Navajo Reservation and was done on behalf of the U.S. Bureau of Indian Affairs in cooperation with the Navajo Tribe.

SAN RAFAEL GROUP

The name San Rafael Group was applied (Baker and others, 1927, p. 787) to a sequence of rocks in the San Rafael Swell of central Utah where the group consists of, in ascending order, Carmel Formation, Entrada Sandstone, and the Curtis and Summerville

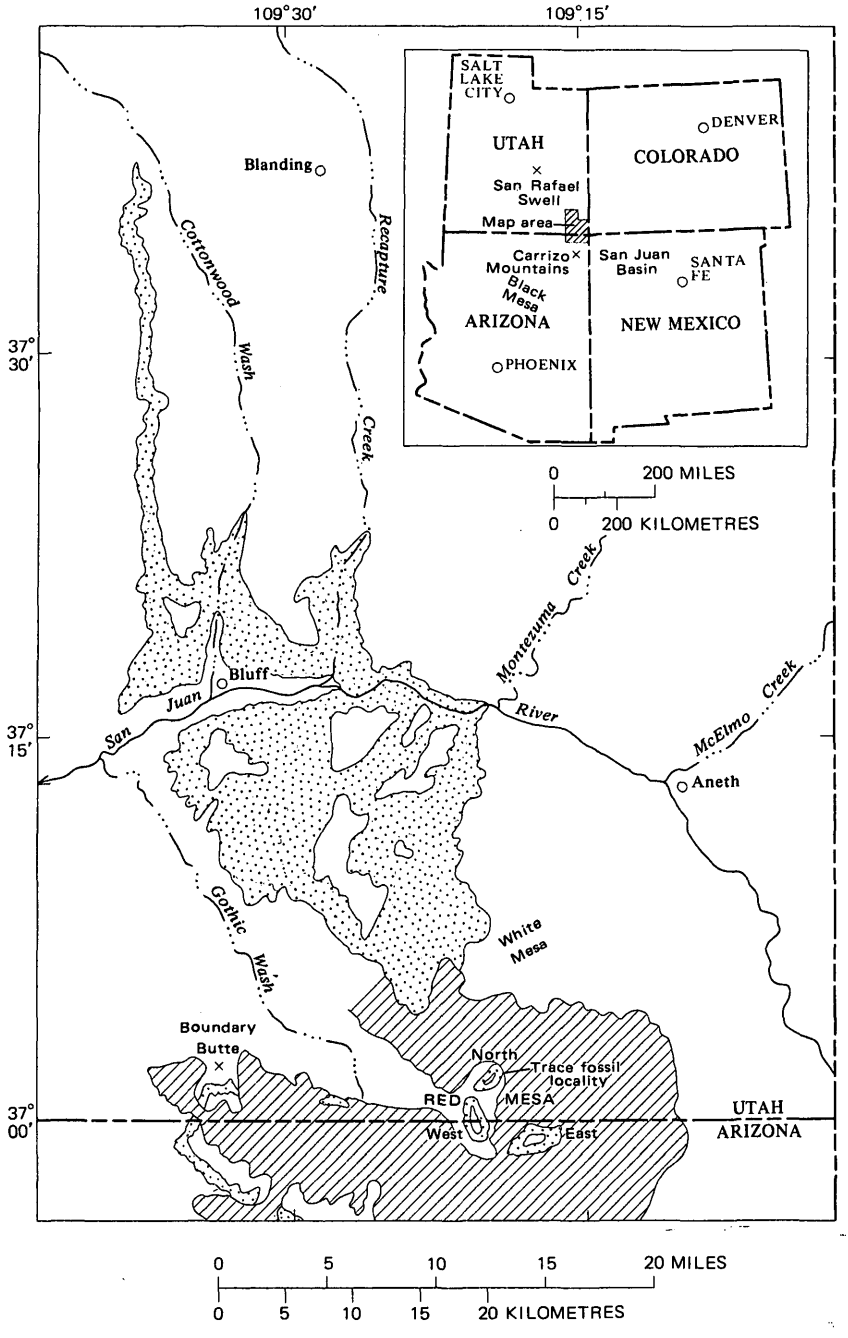

FIGURE 1.—Map showing generalized distribution of Bluff Sandstone (stippled) and the trace fossil locality. Quaternary alluvium and eolian sand (lined) shown in Red Mesa-Boundary Butte area, where they conceal the Bluff Sandstone. Compiled in part from Haynes, Vogel, and Wyant (1972).

Formations. The Curtis Formation grades southward from the Swell into the Summerville Formation and is not recognized in southeastern Utah. Instead, in that area, the Bluff Sandstone is at the top of the San Rafael Group.

Parts of the San Rafael Group are fossiliferous, particularly the Carmel Formation in southwestern and central Utah and the Curtis Formation in the San Rafael Swell. The fossils indicate that the lower part of the Carmel Formation is of Middle Jurassic age and the remainder of the group is of Late Jurassic age.

The San Rafael Group, in southeast Utah, is overlain by the Morrison Formation of Late Jurassic age and is underlain by the Navajo Sandstone of the Glen Canyon Group. The Glen Canyon Group is mostly of Late Triassic age, but its uppermost part is thought to include rocks of Jurassic age.

BLUFF SANDSTONE

The Bluff Sandstone was named formally by Gregory (1938, p. 58) for the excellent exposures about the settlement of Bluff, where the sandstone forms bold cliffs along the San Juan River. Gregory treated the Bluff Sandstone as a member of the Morrison Formation, as had been done previously by Baker, Dane, and Reeside (1936, p. 15). Later, the Bluff was recognized as a tongue (Craig and others, 1955, p. 133) of the Cow Springs Sandstone, a formation of eolian origin whose type locality lies about 50 miles (80 km) southwest of Bluff on Black Mesa in Arizona. At present the Bluff Sandstone is considered to be a separate formation at the top of the San Rafael Group (Sears, 1956, p. 202; Harshbarger and others, 1957, p. 42).

The Bluff Sandstone near the San Juan River forms prominent cliffs. North and south of the river the topographic expression of the Bluff Sandstone is more subdued, and over large areas the formation forms a rolling hummocky surface largely veneered by windblown sand. The Bluff is well displayed near the Arizona-Utah State line near the tops of the three mesas that are collectively referred to in this report as Red Mesa and are distinguished individually as North, West, and East Red Mesa (fig. 1). For a distance of 4 to 5 miles (6.4 to 8 km) to the north and south of Red Mesa, the Bluff Sandstone is almost completely obscured by windblown sand and alluvium of Quaternary age.

The Bluff Sandstone is thickest near the settlement of Bluff where it is 338 feet (103 m) thick in the cliffs just south of the San Juan River. The Bluff thins gradually northward and pinches out in the Summerville Formation about 24 miles (39 km) north of the San Juan River. Similarly, the Bluff thins gradually southward and is only 75 feet (22.8 m) thick at the north end of North Red

Mesa. The Bluff is 25 feet (7.6 m) thick near the north end of West Red Mesa and is only 7 feet (2.1 m) thick at the west end of East Red Mesa.

Near Bluff, the massive Bluff Sandstone is yellowish gray to very light gray and weathers tan or buff. Although cliff-forming, the Bluff Sandstone is friable. It is composed of well-sorted very fine to fine subrounded to rounded grains of quartz and has minor amounts of feldspar, varicolored chert, and dark accessory minerals. Well-rounded medium to coarse grains are either disseminated throughout the formation or concentrated along laminae.

The Bluff Sandstone is divided into four informal members, referred to as members A, B, C, and D, in ascending order (Cadigan, 1952; Craig and Cadigan, 1958). The distinguishing characteristics of each of these members are shown in figure 2. Members A and D have been interpreted as subaqueous deposits, member B as an eolian deposit, and member C as an eolian deposit that has been, in part, reworked by water.

The four members of the Bluff are all found together near the San Juan River; elsewhere one or more of the members is absent (Craig and Cadigan, 1958, p. 185). Only member A is recognized throughout the distribution area of the Bluff Sandstone. From the town of Bluff, members B and C both lose definition northward by internal thinning, and near the northern limits of the Bluff Sandstone, member D lies directly on member A. South of the San Juan River the overlying Morrison Formation progressively truncates member D and the thinning remnants of members B and C in the area near the south end of White Mesa. At Red Mesa the Morrison Formation lies on a southward-thinning wedge of member A.

TRACE FOSSILS

Trace fossils (fig. 3) are present in about the upper half of the Bluff Sandstone on the eastern side of North Red Mesa in the NE¼SE¼NE¼ sec. 25, T. 43 S., R. 23 E., and near the eastern boundary of the same township. At that locality only member A, about 68 feet (21 m) thick, is present. The trace fossils occur in two beds, each about 2.5 feet (75 cm) thick and separated from each other by a bed of gently crossbedded sandstone about 5.5 feet (1.7 m) thick. That part of member A below the lower trace fossil bed consists of 38 feet (11.6 m) of flat-bedded sandstone. The upper trace fossil bed is overlain by 20 feet (6.1 m) of sandstone that is mostly gently crossbedded but with some flat-bedded units. The lower trace fossil bed extends for a distance of about 100 feet (30 m) along the outcrop and is more persistent than the upper bed.

Formation and member		Columnar section	Thickness		Description
			Feet	Metres	
Morrison Formation			600–700	182.8–213.3	Light-gray and yellow sandstone and reddish-brown and green siltstone and shale
Bluff Sandstone	D		0–100	0–30.5	Mostly massive and structureless sandstone; some hoodoo weathering units and horizontally bedded units; medium grains sparse or absent
	C		0–50	0–15.2	Mostly small-scale low-angle crossbedded sandstone; numerous horizontal truncation planes; medium grains in moderate abundance
	B		0–150	0–45.7	Large-scale high-angle crossbedded sandstone; coarse and medium grains abundant particularly in lower part
	A		0–75	0–22.8	Contains flat-bedded and small-scale crossbedded sandstone units; numerous horizontal bedding planes; reddish-brown siltstone partings. Medium and coarse grains abundant
Summerville Formation			140–160	42.6–48.7	Dark-reddish-brown siltstone and shale with interbedded thin white and tan sandstone

FIGURE 2.—Diagram showing arrangement and distinguishing characteristics of the members of the Bluff Sandstone. In part from Craig and Cadigan (1958).

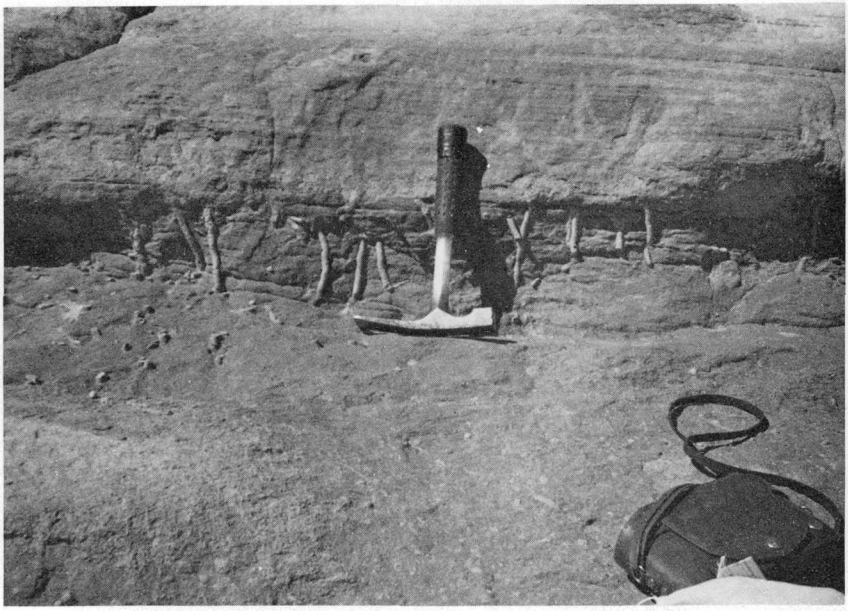

FIGURE 3.—Trace fossil burrows on North Red Mesa. Burrows at the top of the lower trace fossil bed have been etched out by weathering and truncated by overlying beds.

The most conspicuous trace fossils found to date in the Bluff Sandstone are burrows; there are no other extraneous tracks or trails. The sandstone surrounding the burrows contains abundant fecal material and aggregates of sand grains excavated from the burrows. The burrows are in a very fine to fine-grained sandstone consisting of well-rounded, clear smooth-surfaced quartz grains. All mud and other fine-grained particles have been removed, undoubtedly by the winnowing action of water. Bioturbation due to burrowing destroyed all bedding structures within the trace fossil beds prior to consolidation. The sandstone matrix, burrow filling, and burrow lining are all slightly calcareous and effervesce slowly in dilute hydrochloric acid.

The burrows range in diameter from 4 to 9 mm based on 63 separate measurements; most fall in the 7 to 8 mm range. Original lengths of the burrows are indeterminate because the structures have been weathered away in their upper parts or have been truncated by overlying beds. The burrows commonly terminate downward in a bulbous structure with a rounded bottom. The bulb ranges in size from 25 to 50 mm in length and 8 to 14 mm in maximum diameter. The bulb is filled with ovoid and spindle-shaped fecal pellets in random orientation, mixed with fine-grained sandstone.

The burrows at places are abundant. In two hand specimens (fig.

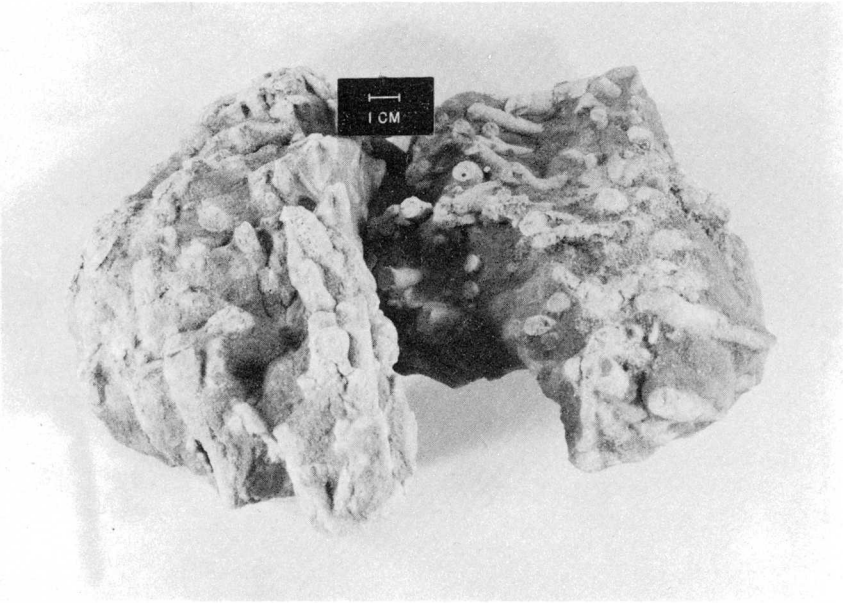

FIGURE 4.—Oblique photograph of hand specimen of trace fossils showing characteristics of burrow structure.

4) measuring 13 by 16 by 6 cm and 10 by 20 by 7.5 cm, there are 85 and 74 recognizable burrow structures, respectively. At one locality on the outcrop there is a small bench, approximately parallel to the bedding, near the top of the lower trace fossil bed. Numerous white circles packed no more than 12 mm apart are exposed on the bench. Each white circle is a cross section of a burrow. Due to variations in animal behavior relative to burrow habitation and construction, however, it is impossible to estimate animal density during occupation of the substrate by organisms.

The burrows are straight, nontapering, unbranched, nonintersecting shafts lined with quartz grains firmly bound by calcite cement; phosphate cement has not been detected (G.A. Desborough, oral commun., 1974). The burrows are filled with homogeneous sand that is similar to the matrix rock. There is no evidence of spreiten, which are linear sediment traces indicative of sequential excavation and backfilling in response to some external stimulus such as sedimentation rates.

Most of the burrows have an internal canal near the circumference but separate from the burrow wall (fig. 5). The canal is 1 to 2 mm across, and commonly is poorly preserved. In weathered specimens where the burrow wall is partially worn away, the canal is preserved as a U-shaped structure, convex toward the center of the burrow.

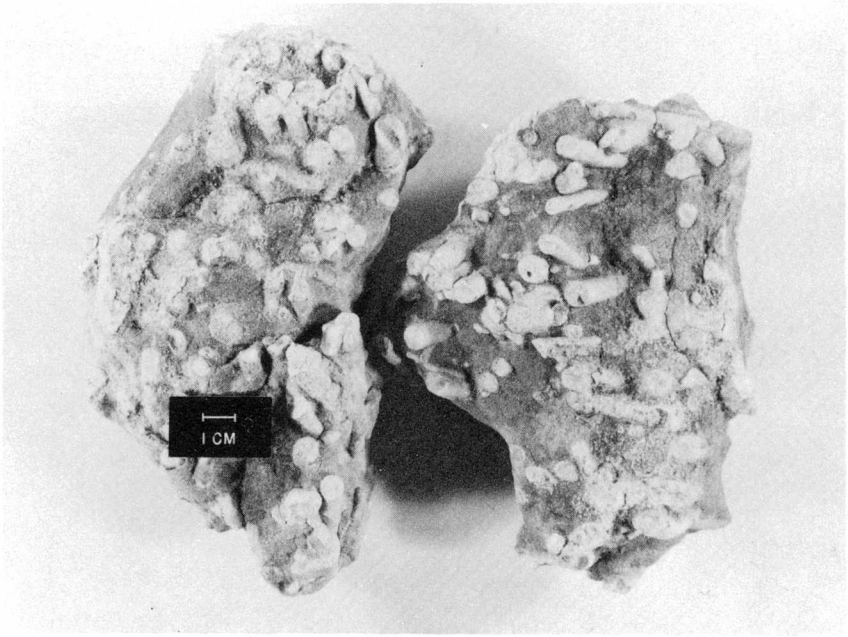

FIGURE 5.—Vertical photograph of hand specimen of trace fossil showing morphology and burrow density.

The burrows are very conspicuous on the weathered outcrop because the burrow tubes and fillings are bleached white in a matrix of brownish-gray sandstone. The burrows are much less conspicuous lower down in fresh white sandstone. Preservation is much better in the weathered zone than in fresh rock.

The full-relief trace fossils are oriented vertically to steeply inclined to the surface. Although the inclined burrows appear to have a random orientation, many of them have an inclination to the south or southwest. Modern burrows generally are inclined away from the dominant wave action. The inclination to the south and southwest of many of the trace fossil burrows suggests an ancient beach in that direction.

The burrows were undoubtedly domichnia (Seilacher, 1964) of decapod crustaceans and are similar to burrows of living crustacea such as shrimp and crabs. Such decapod crustaceans are suspension feeders, which feed on particulate organic matter suspended in the water and do not burrow within the substrate for nourishment.

The environment of the burrows is in the upper foreshore of a marine beach. Lined small burrows are accepted by ichnologists as indicating a zone of relatively high water-energy. Burrows in quiet water rarely have linings, and either have random orientation relative to the sediment-water interface or are mostly horizontal or in-

clined at low angles. Fauna who feed within the sediment usually have branching burrows, which have linings of organic-rich mud to delineate them from their matrix. Also, quiet waters commonly have a more diverse fauna. If the environment had been subaerial, the burrows probably would not be lined; if lined, the lining would not be likely to be as thick as these. Also, in a subaerial environment, population density would not be as high as in these rocks. If the environment had been a lake, there would be more mud, a more diverse fauna, and structures with thin walls or uncemented walls. Marine microenvironments other than upper foreshore have different fauna, different types of structures, and different lithologies than do the burrows described here.

SIGNIFICANCE

The trace fossils described in this report are helpful in interpreting the environment of deposition of the Bluff Sandstone. Member A, characterized by both flat-bedding and crossbedding and containing marine trace fossils, was probably deposited near the shore of an oscillating sea that reworked dunes which formed at the end of Summerville time. Member B contains high-angle crossbeds and is undoubtedly of eolian origin; it is perhaps akin to similar sandstone bodies in the Entrada Sandstone, which probably represent deposition under subaerial conditions on a beach near a sea. Member C, with low-angle crossbeds and numerous truncation planes, records the return of water which reworked dune sand. Bedding structures and the decrease in grain size and increase in carbonate cement compared to the underlying members show that member D was a subaqueous deposit (Craig and Cadigan, 1958, p. 185).

The waters in which member D was deposited and which reworked the dune sands of member C may indicate a return of the sea in which member A was deposited. Certain bedding features support this conception of deposition in marine waters although it is unsupported by fossil data. Member D locally weathers to rounded spheroidal weathering features termed hoodoos. Similar hoodoos in the underlying Entrada Sandstone are found in parts of the formation that are of marine origin (Harshbarger and others, 1957, p. 44). In addition, the bedding features and general aspect of member D, at places (fig. 6), are strikingly similar to the Summerville, a formation also regarded as marine or marginal marine in origin.

The entire San Rafael Group in southeastern Utah is characterized by marine, marginal marine, and associated eolian deposits, which contrast sharply with the lithofacies of the underlying and overlying formations. The overlying Morrison Formation is dominantly a fluviatile and flood-plain deposit. The underlying formations of the Glen Canyon Group are dominantly eolian deposits

FIGURE 6.—Member D of Bluff Sandstone southeast of the town of Bluff. Exposures are in the NE¼ sec. 8, T. 41 S., R. 23 E., located 8.5 miles (13.7 km) southeast of Bluff. A basal channeling sandstone of the Morrison Formation caps the cliff.

having minor fluviatile deposits. The Glen Canyon Group represents a long period of continental deposition and is everywhere separated from the marine deposits of the San Rafael Group by a great regional unconformity.

The contact between the San Rafael Group and the Morrison Formation also marks an important and widespread break in deposition. In the Red Mesa area of southeastern Utah, the contact separates the terrestrial fluviatile Morrison Formation from the marine Bluff Sandstone and the contact is an unconformity. Elsewhere on the Colorado Plateau, the contact represents a depositional hiatus. According to Cadigan (1967, p. 109), a widespread uplift and consequent withdrawal of marine waters brought to an end the tectonically quiescent environment of San Rafael time. After the uplift, erosion of the uppermost part of the San Rafael Group provided the

initial fluviatile deposits of the Morrison Formation. R. A. Cadigan (written commun., 1968) further stated that "* * * the sequence of tectonic events which occurred after the deposition of the Bluff Sandstone and before deposition of the Morrison and which produced major correlated changes in lithology and sedimentary structures throughout the * * * Colorado Plateau regions very definitely did represent a considerable amount of geologic time."

The relationships described in this report suggest that the Bluff Sandstone did not extend very far into Arizona. The Bluff Sandstone, as previously discussed, thins markedly southward to a thickness of only 7 feet (2.1 m) at the west end of East Red Mesa. Furthermore, the inclination of the trace fossil burrows indicates a nearby ancient beach in Arizona beyond which the marine part of the Bluff Sandstone could not have extended. The Bluff, however, has been widely recognized in Arizona in the Carrizo Mountains area (Strobell, 1956) and in Black Mesa (Harshbarger and others, 1957; Craig, 1959). It has also been recognized in New Mexico in the southern part of the San Juan Basin (Freeman and Hilpert, 1956; Green and Pierson, 1971; Moench and Schlee, 1967; Thaden and Ostling, 1967). The relationship of the type Bluff Sandstone in southeastern Utah to these other sandstone bodies in Arizona and New Mexico called Bluff is as yet incompletely understood.

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