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By R.B. O'Sullivan, M.A. Carey, and S.C. Good¹

Abstract

The Middle Jurassic Wanakah Formation averages about 30 m in thickness in Colorado. Fossils are sparse and include fish, ostracodes, and trace fossils. A thin (0.03–0.45 m) fossil bed near the middle of the formation extends for some 48 km along the northeast flank of the Uncompahgre Plateau near Delta. The fossil bed at one locality contains one pelecypod identified possibly as *Modiolus* cf. *M. subimbricatus* (Meek), as well as other specimens too poorly preserved for identification. Previously, *Mytilus* was found in the same fossil bed at another locality by C.N. Holmes. The Wanakah Formation is primarily of terrestrial origin, but the fossil bed represents a shallow-marine incursion.

Introduction

The Middle Jurassic Wanakah Formation is widespread in Colorado and the adjacent States of Utah, Arizona, and New Mexico (fig. 1A). Only a few fossils have been reported from the formation, so its origin is still somewhat speculative. Near Delta in western Colorado, the recovery of a single bivalve mollusk, together with associated fossils, contributes to understanding the local depositional environments of the formation.

The Wanakah Formation was named for strata that overlie the Middle Jurassic Entrada Sandstone and underlie the Upper Jurassic Morrison Formation. The name is derived from the Wanakah base and precious metals mine 1.6 km north of Ouray and 85 km south of Delta (Burbank, 1930). The Wanakah has been mapped in the Grand Junction area, just to the north of the study area (Scott and others, 2001), and has been traced from Bridgeport (fig. 1B) southward to Ouray (fig. 1A; O'Sullivan, 2004). The formation consists of a thin basal limestone member overlain by a thicker and more extensive sequence of sandstone and siltstone. The basal limestone member is termed Pony Express in Colorado and Todilto in New Mexico and Arizona.

Near Ouray, the Wanakah Formation is 27–38 m thick and consists of three units—in ascending order, the Pony Express Limestone Member, the Bilk Creek Sandstone Member, and the beds at Sawpit. The Pony Express Limestone Member is a dark-gray limestone generally 0–6 m thick within Colorado. However, near Ouray, where the upper part locally contains a thick lens of gypsum, the member is about 18 m thick. North of Ouray the Pony Express dips northward beneath younger rocks, and where the Wanakah reappears at the surface along Dry Creek 20 km southeast of Olathe (fig. 1B), the Pony Express Limestone Member is absent (see O'Sullivan, 2004). The Bilk Creek Sandstone Member, 4.5–9 m thick, is a fine-grained, flat-bedded sandstone capped by a distinctive carnelian sandstone marker bed. This marker bed, generally 0.3–0.6 m thick, is a poorly sorted, fine-grained sandstone containing sparse to abundant, rounded, coarse quartz grains. The beds at Sawpit at the top of the formation are mostly interbedded red sandstone and siltstone in units that are generally less than 0.9 m thick.

Previous Work

Holmes (1960, fig. 30), in his study of Jurassic stratigraphy in Colorado, assigned the strata above the Entrada Sandstone to the Summerville Formation, the type section of which is in Utah about 215 km west of Delta. In our study area (fig. 1), however, we consider the name Wanakah Formation to take precedence, following the definition of Burbank (1930, p. 171–177) for exposures near Ouray (fig. 1A). Furthermore, regional correlations, shown in figure 2, indicate the Summerville—which is separated from the Entrada by the Curtis Formation (a marine sandstone about 61 m thick) at the type locality—to be younger than the Wanakah.

Some of the strata we now recognize as Wanakah Formation were incorrectly assigned to the basal Morrison Formation in the area extending from Bridgeport (fig. 1B) west to Dewey Bridge in Utah by O'Sullivan and Pipiringos (1983). However, the stratigraphic relationships were clarified in a more recent report by O'Sullivan (2004).

The few fossils reported for the Wanakah Formation are mostly from the basal limestone member—the Pony Express in Colorado and the Todilto in New Mexico and Arizona.

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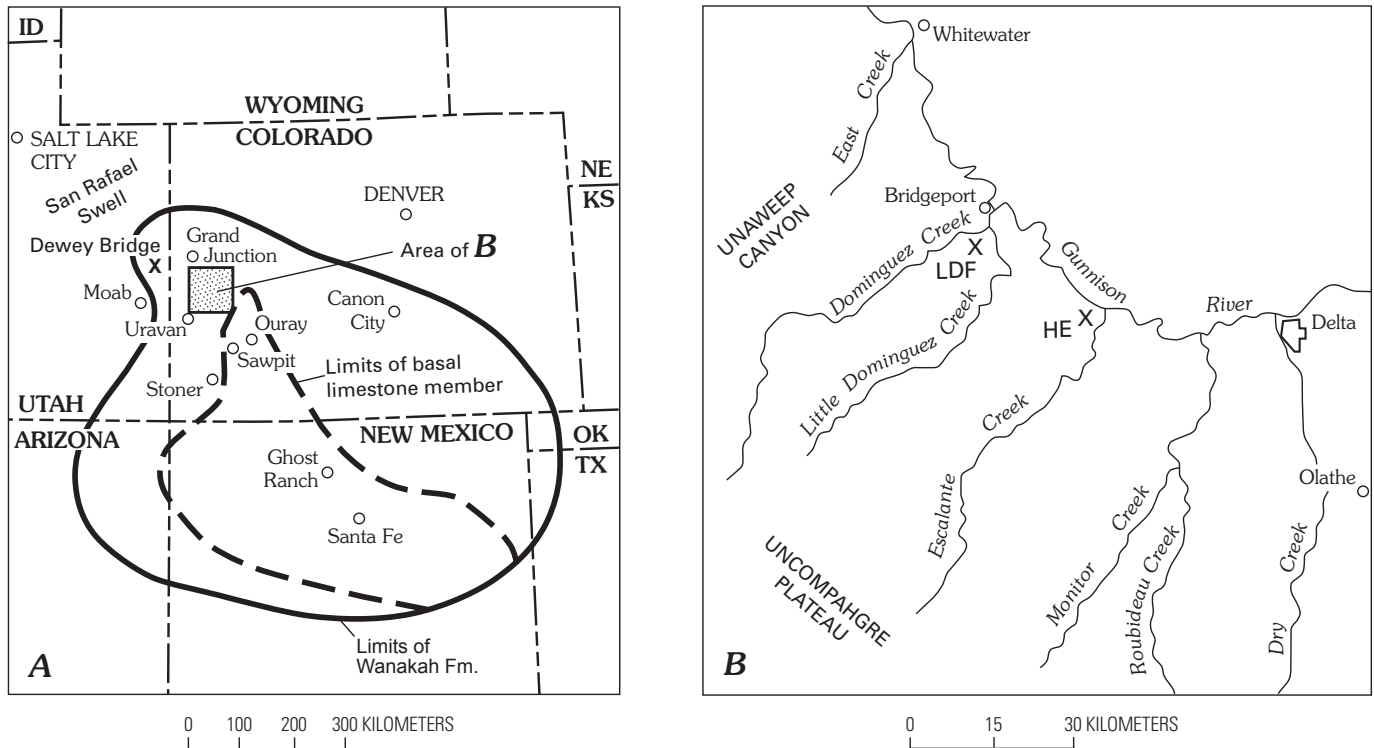


Figure 1. Distribution of Wanakah Formation and the Delta-Bridgeport area. *A*, Distribution of Wanakah Formation, modified from Schaeffer and Patterson (1984, fig. 1); limits of the basal limestone member of the Wanakah Formation from Ridgley (1989, fig. 10). *B*, Map of Delta–Uncompahgre Plateau area. LDF, Little Dominguez fossil locality; HE, Escalante Creek fossil locality of Holmes (1960).

They include fish, ostracodes, and aquatic insects described by Schaeffer and Patterson (1984) and Lucas and others (1985). Lucas and others (1985, p. 220–227) and Kirkland and others (1995, p. 33) concluded that the basal limestone of the Wanakah is of saline lake origin, whereas Harshbarger and others (1957, p. 46) interpreted the Todilto Limestone Member to be of marine origin. Work on sulfur-isotope compositions by Adler (1974, p. 630) and whole-rock carbon-, oxygen-, and sulfur-isotope studies by Ridgley and Goldhaber (1983, p. 414) suggested to them a marine rather than a lacustrine origin for the basal limestone.

The following fossils have been reported above the Pony Express and Todilto Limestone Members of the Wanakah Formation:

1. Lockley (1991, p. 59–65) documented abundant dinosaur footprints at a locality north of Moab, Utah.
2. Steele (1985, p. 9, 11) reported ostracodes (no distinction as to marine or freshwater forms) from the Bilk Creek Sandstone Member near Sawpit and Stoner (fig. 1A) in southwest Colorado and from the upper part of the Wanakah (beds at Sawpit) at an unspecified locality in the area between Uravan and Stoner (fig. 1A).
3. Trace fossils and the nonmarine mollusk *Vetulonia* were reported from the upper member of the Wanakah, above

the Todilto Limestone Member, near Ghost Ranch in northwestern New Mexico (fig. 1A), and were considered to be of shallow-lacustrine origin by Ridgley (1989).

4. Fish and plants were described by Schultze and Enciso (1983) from strata assigned to the Wanakah Formation by Schaeffer and Patterson (1984, p. 10–12) near Canon City in eastern Colorado. Lucas and others (1985, fig. 7) regarded the strata near Canon City as being part of the lacustrine facies of the Todilto Limestone Member.

Present Investigation

South and west of Delta (fig. 1B), the Wanakah Formation crops out in several places on the northeast side of the Uncompahgre Plateau, where the ground surface rises from an elevation of 1,443 m at a benchmark near Bridgeport to more than 2,987 m at the crest of the plateau. Deep canyons, trending northeast, reveal Cretaceous and Upper Jurassic rocks including the Wanakah Formation as well as underlying formations. These canyons include Little Dominguez, Escalante, Roubideau, and Dry Creeks, which flow into the Gunnison River south and east of Bridgeport (fig. 1B).

Series	Stage	San Rafael Swell	Study area
Younger rocks			
Upper Jurassic	Tithonian	unconformity	
	Kimmeridgian	Morrison Formation	
	Oxfordian		
Middle Jurassic	Callovian	San Rafael Group	Summerville Formation
			Curtis Formation
			J-3 unconformity
			Entrada Sandstone
			Carmel Formation
	Bathonian		
	Bajocian (part)		Page Sandstone
Older rocks			

Figure 2. Nomenclature of Middle and Upper Jurassic rocks in the San Rafael Swell and study area. Labeled unconformities discussed in Pipirigos and O'Sullivan (1978).

During our study, a fossil locality was found, by O'Sullivan, along Little Dominguez Creek about 3.2 km south of Bridgeport in a unit near the middle of the Wanakah referred to as the fossil bed. The fossil collection consisted of a single mollusk with associated poorly preserved and as-yet-unidentified fossils. Another pelecypod locality, described previously by Holmes (1960), is in the same bed along Escalante Creek (fig. 1B). The fossil bed is a thin gray sandstone extending from Bridgeport southeast to Dry Creek; it is overlain by a thin red claystone throughout the area.

The following stratigraphic section shows the thickness and lithologies of the Wanakah Formation at the fossil locality (section measured along Little Dominguez Creek 3.2 km south of Bridgeport, Colo., in NE $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 30, T. 14 S., R. 98 W.; Triangle Mesa 7.5-minute quadrangle, 1969):

*Thickness
(meters)*

Jurassic System:

Upper Jurassic Series:

Morrison Formation:

Tidwell Member (part):

Bed A:

- Sandstone, yellowish-gray, flat-bedded and ripple-marked; coarse to very coarse

grains; forms ledge; base is J-5

unconformity 2.16

Thickness of bed A 2.16

Middle Jurassic Series:

Wanakah Formation:

Beds at Sawpit:

- Siltstone; forms a slope; poorly exposed beneath a hard layer of rubble; reddish-tan and olive-drab siltstones occur at various levels; a 0.15-m-thick, yellowish-gray, very fine grained sandstone makes a slight ledge at base of unit; sparse, thin, dove-gray limestone nodules are present 7.31
 - Siltstone, reddish-brown; forms a slope; poorly exposed beneath a hard veneer of rubble; red siltstone exposed at several horizons 4.02
 - Claystone, reddish-brown; flaky, silty 0.24
 - Fossil bed; sandstone, gray, fine-grained; forms square-faced ledge 0.09
 - Siltstone, reddish-brown; forms small slope 0.73
 - Sandstone, gray, flat-bedded; forms conspicuous ledge that overhangs underlying units 0.33
 - Sandstone, reddish-tan, mottled and streaked gray; sparse medium-sized quartz grains; thin reddish-brown siltstone layers make deep reentrants 4.05 m above base and at top of unit 5.57
- Thickness of beds at Sawpit 18.29

Bilk Creek Sandstone Member:

- Carnelian sandstone marker bed; sandstone, moderate-orange-pink, crossbedded; abundant rounded, medium-size quartz grains; forms ledge that overhangs underlying unit 0.6
- Siltstone, reddish-brown, mottled gray; sandy; forms conspicuous reentrant beneath unit 4 0.97
- Sandstone, reddish-tan, mottled gray; sparse medium-size grains; forms gentle slope 3.44
- Sandstone, gray; lower 0.3 m is reddish-tan, flat-bedded; conspicuous nick at base 1.52

Thickness Bilk Creek Sandstone

Member 6.53

Total thickness Wanakah

Formation 24.82

Entrada Sandstone (not described)

The single bivalve mollusk collected at the Little Dominguez Creek locality was from the top of the fossil bed (unit 8 of the measured section). Although poorly preserved (fig. 3B–C), it can most reliably be identified, by Good, as *Modiolus* cf. *M. subimbricatus* (Meek). The specimen has a length of 17 mm, a growth axis of 19 mm, and a width of 11 mm. *Modiolus* is common in Jurassic rocks in Utah (Imlay, 1964) and is indicative of a shallow-marine environment. We noted possible sponge spicules at several localities in the fossil bed, and we found other fossils of uncertain classification (fig. 3D–E) at several different places in the fossil bed.

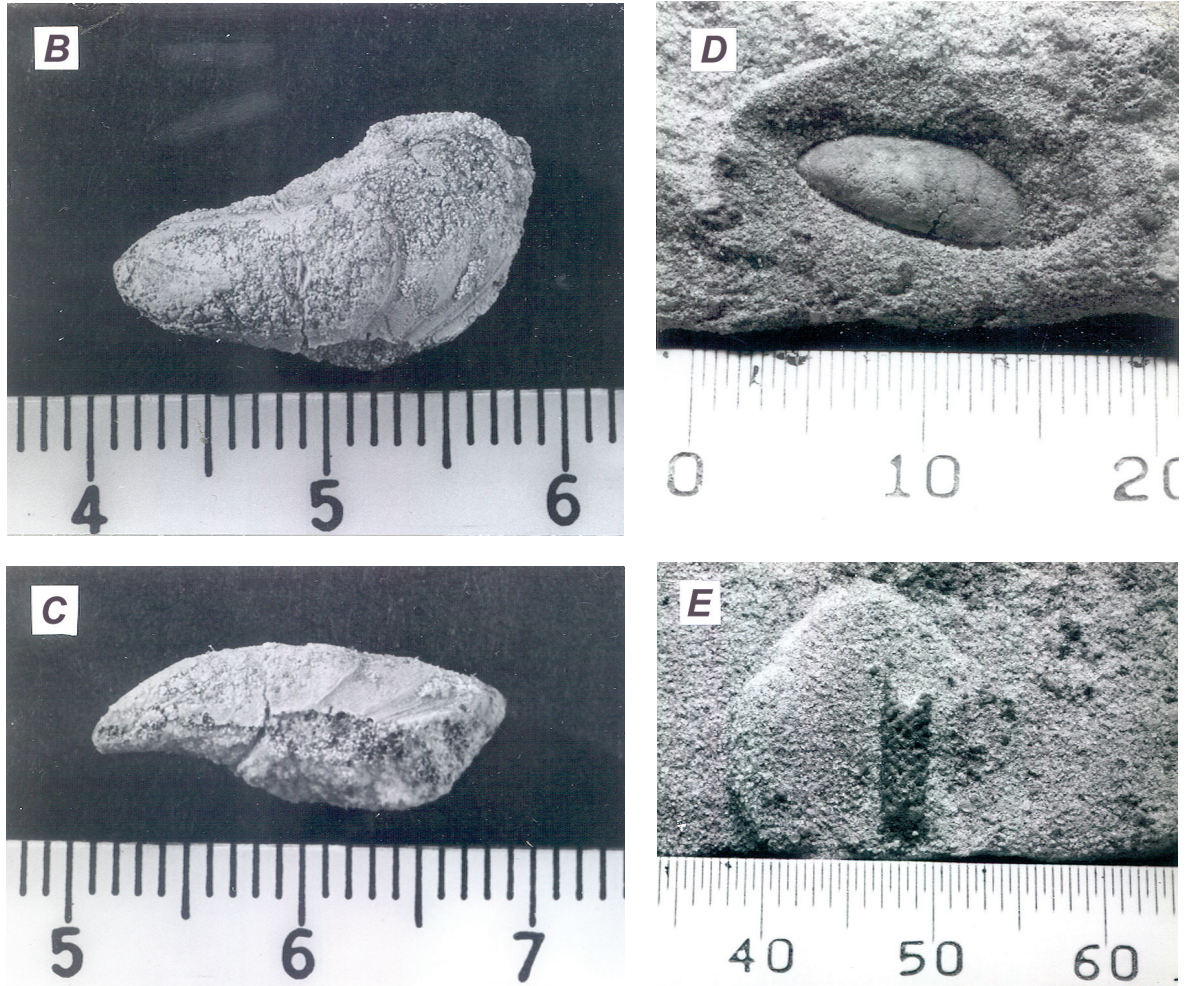
Pelecypod fossils collected near the mouth of Escalante Creek by Holmes (1960, p. 107) were examined by J.B. Reeside, Jr. (U.S. Geological Survey) and identified as an unnamed species of *Mytilus* of marine origin. Small calcareous tubes possibly formed by serpulid worms are also present at the same locality (Holmes, 1960, p. 107). A comparison of the section measured by Holmes (1960, fig. 30) with sections measured by O'Sullivan (2004) along Escalante Creek indicates that the fossil horizon described by Holmes is the fossil bed of the Wanakah Formation.

Conclusion

The Wanakah Formation is probably mostly of terrestrial origin. The red in the beds at Sawpit suggests a subaerial environment of deposition, but trace fossils at localities in New Mexico indicate that some beds are of lacustrine origin. The flat, thin, uniform bedding and lack of scour surfaces may reflect deposition in quiet waters. Some beds are widely distributed; the fossil bed, for example, is found from Bridgeport to Dry Creek, a distance of some 48 km, and the carnelian sandstone marker bed can be traced from Little Dominguez Creek to Ouray, a distance of 113 km. The various bedding features suggest a deltaic environment of deposition, as was interpreted by Wright (1959, p. 63), and the fossil bed represents a local incursion of the sea. During our investigation, the fossil bed was inspected only in a reconnaissance fashion, so future, more careful examinations of the fossil bed may reveal new forms that will add to a better understanding of the conditions of deposition of the Wanakah Formation.



Figure 3 (above and following page). Fossil bed and some fossil forms. *A*, Fossil bed (FB) on Escalante Creek; arrows indicate top and bottom of fossil bed. Dark band above fossil bed is claystone. View is to northwest in SE¼ sec. 30, T. 15 S., R. 97 W. Length of hammer handle is 28 cm for scale. *B*, Lateral view of right valve of *Modiolus* from the Little Dominguez fossil locality. *C*, Posterior view of *Modiolus*. *D*, Shell impression from fossil bed on Little Dominguez Creek. *E*, Fragment resembling a bryozoan matrix from fossil bed at Bridgeport. Scales in millimeters.



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