

Upper Jurassic bonebeds around Ten Sleep, Wyoming, USA: overview and stratigraphy

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The Morrison Formation is an Upper Jurassic lithostratigraphic unit cropping out in Western United States (Colorado, Wyoming, Utah, Montana, Idaho, North Dakota South Dakota, Arizona, New Mexico, Texas, Oklahoma, Kansas, and Nebraska). Its lithology varies between continental sandstones and mudstones and lacustrine limestones (Dodson *et al.*, 1980), dating mostly from the Kimmeridgian to the late Tithonian (154.7 to 147.82±0.63 Ma) (Kowallis *et al.*, 1998). The Morrison Fm. is well known for its rich and diverse vertebrate fauna, comprised of several fishes, amphibians, crocodyliforms, lepidosaurs, turtles, pterosaurs, dinosaurs, and mammals, as well as its complex ecosystems, including floodplains, wetlands, coal marshes, eolian and marine environments (Foster, 2003; Turner & Peterson, 2004). In Wyoming, sediments of the Morrison Fm. surface at the Bighorn Basin, with the underlaid marine sediments of the Upper Jurassic Sundance Fm., and the overlaid Early Cretaceous sediments of the Cloverly Fm. It should be noted that it is difficult to distinguish the different members of the Morrison Fm. in this basin due to a lack use of such distinction in this region, as most of these members are described based outcrops from the southern part of this formation.

The most complete and recent work on the Morrison Fm. around Ten Sleep is presented by Galiano & Albersdörfer (2010), based on the fieldwork started in 2006 by The Dinosauria International LLC at Dana Quarry, a bonebed locality on a private farmland, belonging to the Tan-

ner family, Northwest of the Ten Sleep. The fossil-bearing layers of the quarry are comprised mostly of soft yellow-ochre sandstones and lenses of grey mudstones, with gypsum inclusions commonly associated, representative of a single depositional event, preserving both animal, and plant remains. These layers are approximately six to nine meters above the Sundance Fm., with the contact between the two formations being at the base of lenticular green shales or mudstones, visible on the Eastern slope of the quarry. The most of fossils found at Dana Quarry are nearly complete and articulated, being mainly representative of the Upper Jurassic dinosaur fauna from North America, but with a lack of fish, and mammal remains. According to Galiano & Albersdörfer (2010), dinosaur taxa found at Dana Quarry are: *Allosaurus jimmadse-ni* Chure, 2000; *Amphicoelias* “*brontodiplodocus*” Galiano & Albersdörfer, 2010; *Brachiosaurus* sp. Riggs, 1903; *Camarasaurus* sp. Cope, 1877; *Camptosaurus* sp. Marsh, 1885; *Ceratosaurus* sp. Marsh, 1884; cf. *Coelurus* sp. Marsh, 1879; *Diplodocus* sp. Marsh, 1878; *Hesperosaurus mjosii* Carpenter *et al.*, 2001; *Ornitholestes* n. sp. Osborn, 1903; *Othnielosaurus consors* (Marsh, 1878); and *Torvosaurus* sp. Galton & Jensen, 1979. A nearly complete skeleton of an unidentified turtle has been recovered from this bonebed, as well as plant remains representative of horsetails, ferns, cycads, and several families of conifers, plus an assortment of fossilized seeds and cones. The fossils found in Dana are now scattered across the world in countries such as Denmark, Qatar, Mexico, Singapore, and the United Arab Emirates as result of being in private land, therefore marketable.

From August 29th to September 15th 2016, an expedition to the Late Jurassic of Ten Sleep area was lead by one of us (OM) for the AMNH (American Museum of Natural History, New York). Most of the fieldwork was performed on a multispecific bonebed from the Morrison Fm. located in a highly fossiliferous lenticular sandstone layer. As bones were exposed and collected, they were given field numbers, photographed, and their relative position recorded on a dig site map. From recovered dinosaur remains was possible to identify several theropods, sauropods, and possibly ornithopods. The degree of preservation ranges from fragmentary (with some bones almost complete, bearing minor fractures, to loosen fragments floating in the sediment) to partially articulated; no complete specimen was found during the 2016's season. On some occasions, gypsum was found to fill the gap between the fractures

or covering the surface of the bone.

At the area of Bobcat Hill, around 78 meters of Morrison Fm. sediments are visible (Figure 1) and they overlay the upper part of the Sundance Fm.: the contact happens after 15 meters of greenish-grey sandstone (lower part of Morrison Fm.) and yellowish to brown carbonated sandstones filled with bivalves and belemnites (upper part of Sundance Fm.). Overlaying the lowermost sandstone of the Morrison Fm. there are 48 meters of reddish and gray-purple claystones and light grey sandstones, followed by 16 final meters of yellowish-grey sandstones (upper part of Morrison Fm.). Atop the latter sediments, grey to orange sandstones of the Cloverly Fm. overlay disconformably.

Fieldwork took place at the lowermost layers of the above-mentioned yellowish sandstones of the Morrison Fm. either alternating with dark conglomerates, bearing bone fragments, or with greenish mudstones, bearing greyish mud clasts. The least eroded sandstones preserve crossbedding as evidence of deposition by a meandering river with enough power to carry a large amount of vertebrate remains. Moreover, the dug area is also very rich of plant material, with several thin dark layers (up to few centimeters thick) preserving trunks, branches, cones, and leaves, sometimes in direct contact with the bone surface.

The 2016 expedition represents the return of large AMNH digging activity to Wyoming, since the 1930's, with an expedition lead by Barnum Brown to a sauropod dominated quarry in private land that, 60 years after being closed, came to be known as Howe Ranch Quarry after its reopening by Hans-Jakob "Kirby" Siber (Sauriermuseum Aathal). Further taxonomic, stratigraphic, and taphonomic studying is required for a better understanding of the two above-mentioned bonebeds of Ten Sleep and other Morrison Fm. localities in the area.

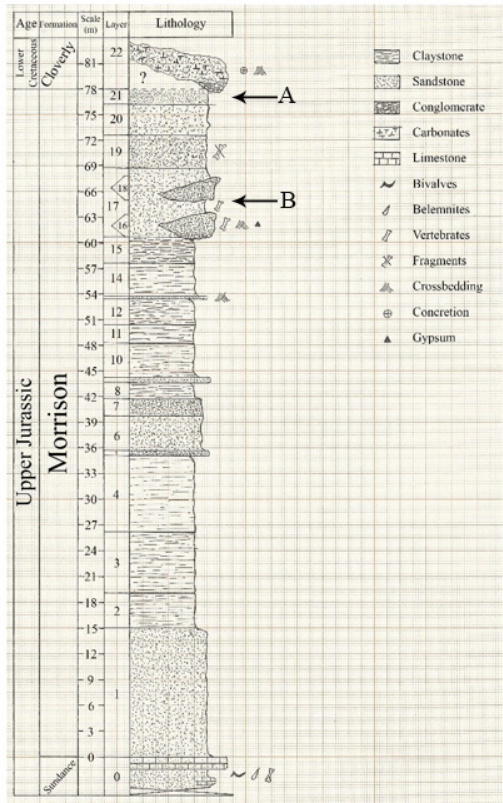
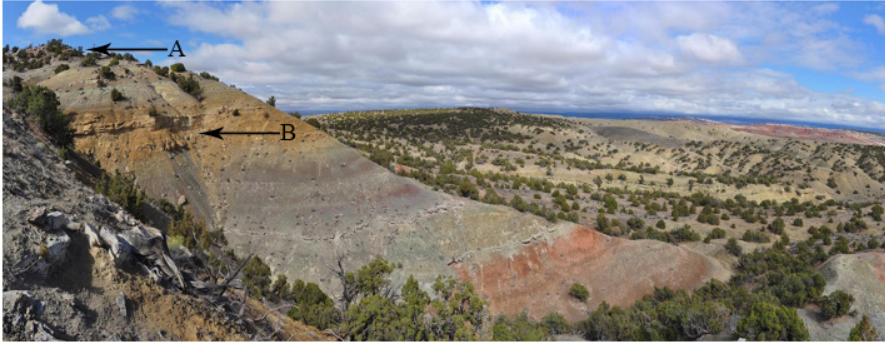


Figure 1. Panoramic view and stratigraphic log of the Sundance, Morrison, and Cloverly Fms. cropping out at Bobcat Hill, near Ten Sleep. A: Contact between the last Morrison Fm. and the first Cloverly Fm. layers exposed in the pictured outcrop. B: Yellowish sandstone layers (L16, L17, and L18) that form the exposed face of the quarry where last year's expedition fieldwork took place.

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