Jurassic stratigraphy and correlation in New Mexico

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Abstract

We review Jurassic stratigraphy and correlation throughout New Mexico. All Jurassic strata exposed in the state belong to the Entrada, Todilto, Summerville, and Morrison Formations and are of Middle (Callovian) to Late (Tithonian) Jurassic age. The J-2 unconformity separates the base of the Jurassic section from underlying Upper Triassic strata. The base of the Todilto Formation correlates to the J-3 unconformity, and the base of the Salt Wash Member of the Morrison Formation is the J-5 unconformity.

Introduction

Jurassic strata are widely exposed across northern New Mexico (Fig. 1) and are almost entirely of nonmarine origin. These strata have been of great economic significance. Essentially all of New Mexico's gypsum resources are in Jurassic strata, and much of the nation's uranium ore was extracted from Jurassic strata in New Mexico. Jurassic strata also are important sources of building stone and regionally significant aquifers across northern New Mexico. Furthermore, New Mexico's Jurassic strata record significant environmental (especially climatic) changes and contain a sparse, but important fossil record of dinosaurs and fishes.

Because of its significance, Jurassic stratigraphy has long been studied in New Mexico, beginning with the work of Marcou (1858) and Dutton (1885). Recent studies of New Mexico's Jurassic stratigraphy have substantially modified and augmented stratigraphic knowledge that impacts in a major way the interpretation of Jurassic patterns of sedimentation in the state (Fig. 2). We present a summary of the results of our research on the stratigraphy and correlation of Jurassic rocks in New Mexico and highlight areas in which additional work is needed.

Stratigraphy

Jurassic exposures in New Mexico are here divided into seven major outcrop belts (Figs. 1, 3) to facilitate discussion. However, all these outcrop belts expose strata that were deposited in the same depositional basins throughout Jurassic time, so there is much continuity of lithofacies between belts.

1. Chuska Mountains–Zuni Pueblo

This is a particularly important outcrop belt because it is closest geographically to the type sections of most of the Jurassic lithostratigraphic units recognized in New Mexico. For example, the type San Rafael Group is in east-central Utah; the type Bluff Sandstone is near Bluff, Utah; and the various Morrison Formation members that Gregory (1938) named have type areas in the Blanding-to-Bluff (Recapture Creek), Utah area. Direct correlation from the Bluff area is how Craig et al. (1955) and early AEC (Atomic Energy Commission) workers extended Morrison Formation member nomenclature into northwest New Mexico.

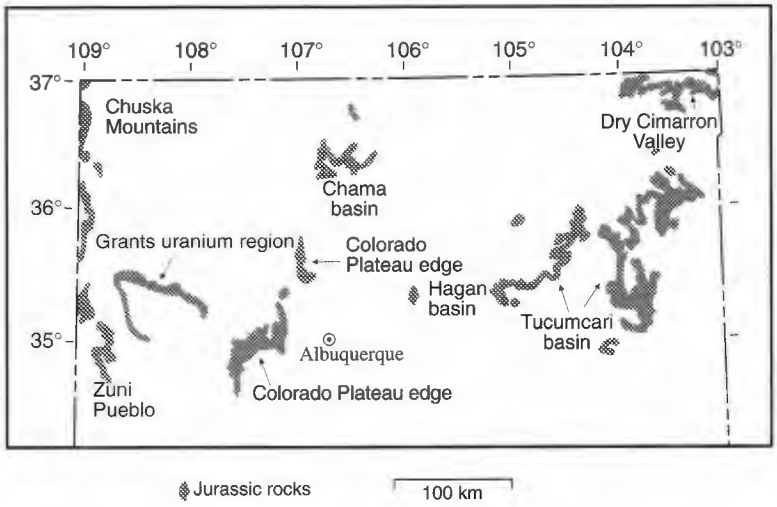

FIGURE 1—Distribution of Jurassic outcrops in New Mexico.

U.S. Geological Survey		Lucas and Anderson	
MORRISON FORMATION	Jackpile Sandstone Member	MORRISON FORMATION	Jackpile Member
	Brushy Basin Member		Brushy Basin Member
	Westwater Canyon Member		Salt Wash Member
	Recapture Member	BLUFF SANDSTONE	
BLUFF Ss.	Horse Mesa Member		
WANAKAH FORMATION	Beclabito Member	SUMMERVILLE FORMATION	
	Todilto Member	TODILTO FORMATION	
ENTRADA SANDSTONE	upper sandy member	ENTRADA SANDSTONE	Slick Rock Member
	medial silty member		Dewey Bridge Member
	Iyanbito Member		

FIGURE 2—Comparison of Jurassic stratigraphic nomenclature used in northwest New Mexico by workers of the U. S. Geological Survey with the nomenclature advocated here.

In stratigraphic order, the Jurassic units recognized in the Chuska Mountains–Four Corners region of New Mexico are (1) the San Rafael Group, consisting of Entrada Sandstone, a feather-edge of Todilto Formation, Summerville Formation, and Bluff Sandstone and (2) the Morrison Formation, consisting of a basal Salt Wash Member as thick as 200 m overlain by the soft shales and claystones and minor sandstones of the Brushy Basin Member

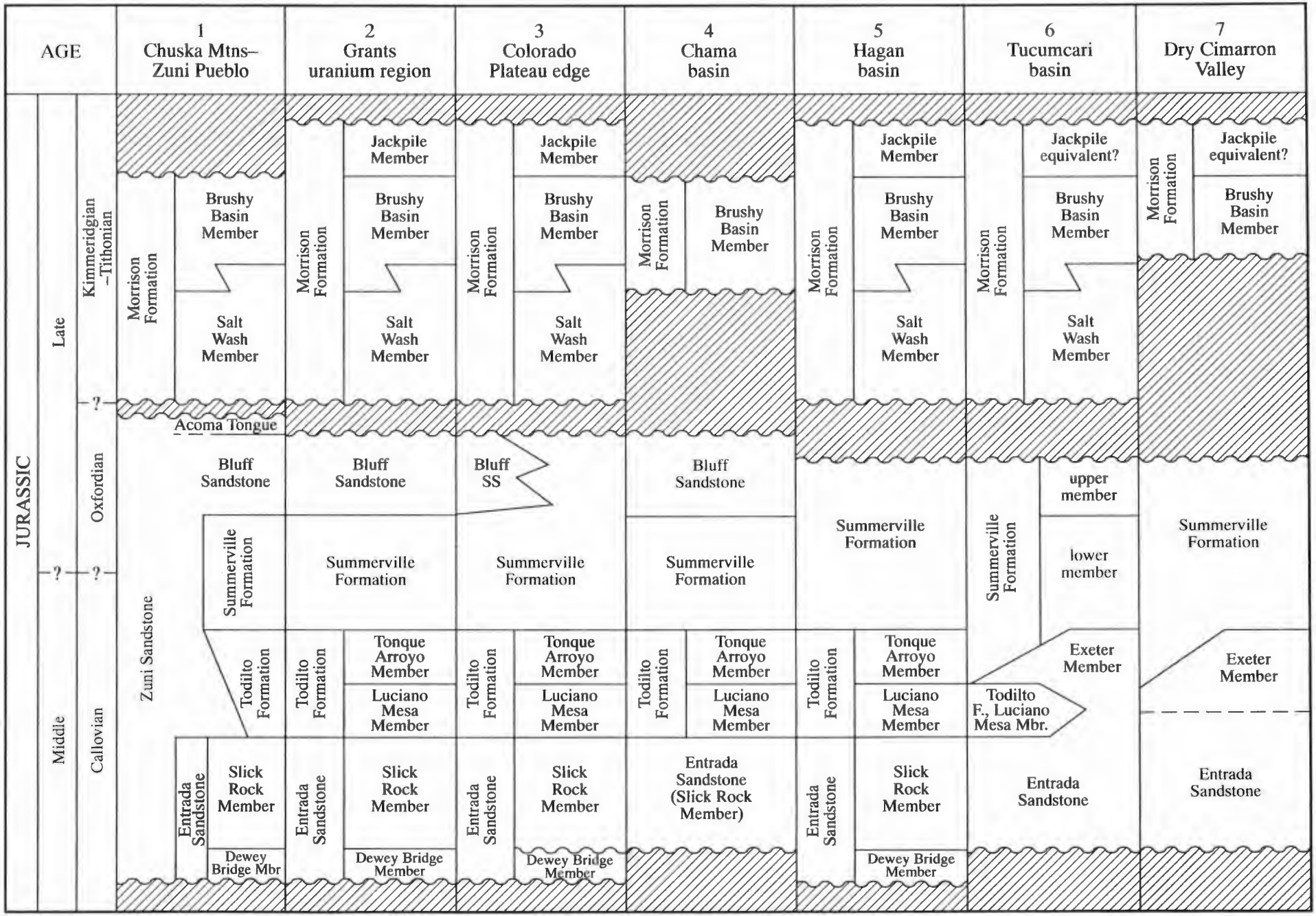

FIGURE 3—Correlation of Jurassic strata in New Mexico.

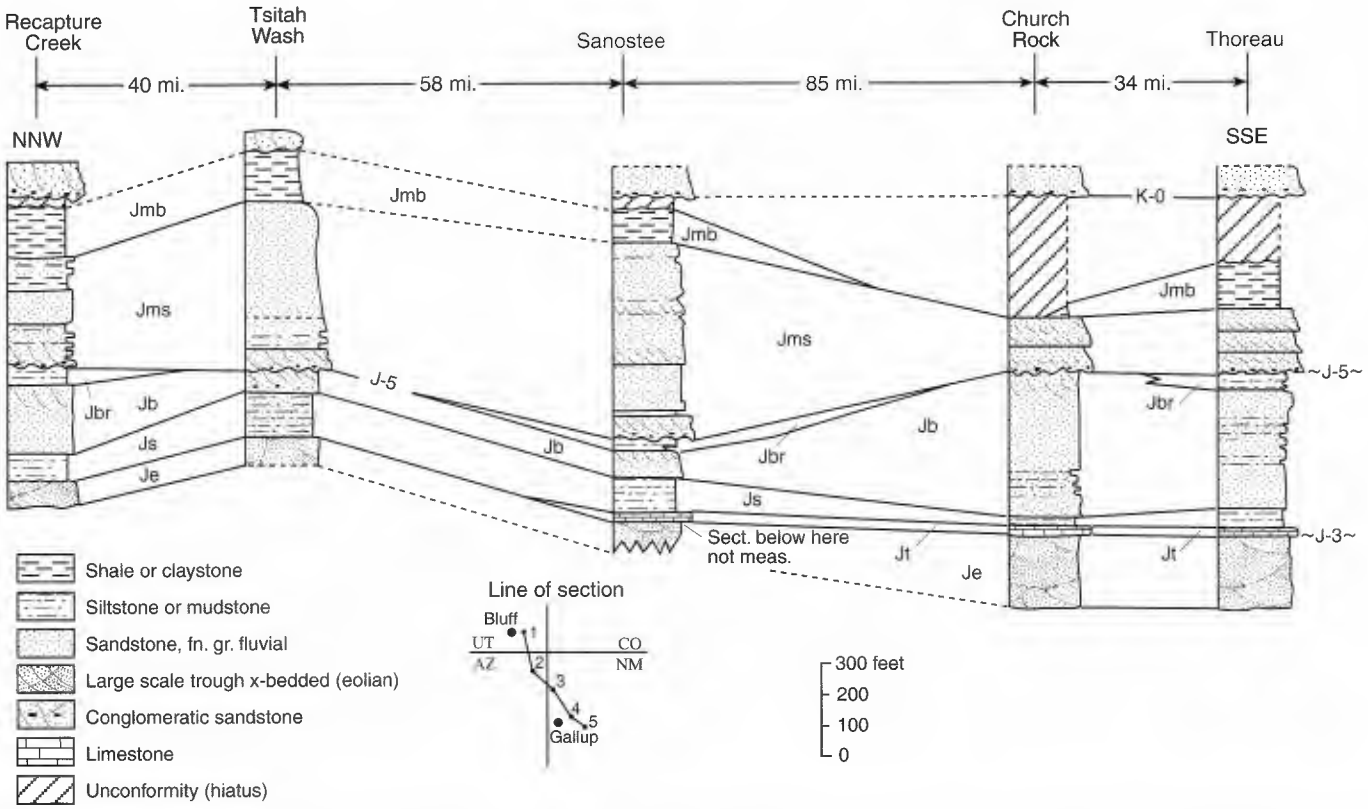

FIGURE 4—Stratigraphic correlation of Morrison Formation and San Rafael Group from the Four Corners into the San Juan Basin. Morrison units are **Jmb**, Brushy Basin Member, **Jms**, Salt Wash Member; San Rafael Group units are **Jb**, Bluff Sandstone (**Jbr**, Recapture Member), **Js**, Summerville Formation, **Jt**, Todilto Fm., **Je**, Entrada Sandstone. **K**, Middle or Upper Cretaceous rocks (Cedar Mountain or Dakota Formation). Jurassic unconformities numbered, e. g., **J-3**. **K-0,** basal Cretaceous unconformity. After Anderson and Lucas (1997) with additional data provided by W. Chenoweth.

(Anderson and Lucas, 1997; Lucas and Anderson, 1997). In the Chuska Mountains, the San Rafael Group is well exposed in the canyons of Sanostee Wash, approximately 10 km (6 mi) west of the village of Sanostee. A measured section of the post-Entrada section at this locality (Fig. 4) suggests the area lies on the west margin of the basin of Todilto deposition, as the Todilto is merely 0.1–0.2 m (1–2 ft) thick. The overlying Summerville Formation is dominantly fine-grained, horizontally bedded sandstone with the characteristic siltstone/maroon mudstone interbeds very thin to locally absent.

The Bluff Sandstone gradationally overlies the Summerville. Bluff rock types are very similar to Entrada rock types, but the similarity does not carry over into bedform. Lacking in the Bluff is the clear evidence of eolian processes in the form of thick sets of high-angle crossbeds with truncated upper boundaries (reactivation surfaces). The horizontal bedforms of the Bluff, commonly 0.5 to 5.0 m (1.5 to 15 ft) thick, contain indistinctly crossbedded facies, but overall the bedform and vertical facies zonation suggest fluvial reworking on a broad, arid coastal plain (sabkha) of very low relief.

Perhaps the most interesting feature of the upper San Rafael Group in northwest New Mexico is the presence of a fine-grained unit above the Bluff. This unit was first recognized as part of the San Rafael Group by Anderson and Lucas (1995) in the vicinity of Bluff, Utah, where it had previously been assigned by Gregory (1938) to the Morrison Formation. Recognition of this unit, designated the Recapture Member of the Bluff, confirms the regional extent of a non-eolian lithofacies at the top of the San Rafael Group. It has important implications for the correct placement of the San Rafael Group–Morrison Formation contact throughout the west half of the Colorado Plateau and eastward (Lucas and Anderson, 1997).

South of Gallup at Zuni Pueblo, the Todilto and Summerville Formations become thinner and disappear, and the entire San Rafael Group section is an unbroken succession of eolianites nearly 150 m thick. We refer to this succession as the Zuni Sandstone (Fig. 2) following Anderson (1993) and Anderson and Lucas (1994). The youngest, distinctive lithostratigraphic unit in this succession is the Acoma Tongue of Anderson (1993).

2. Grants uranium region

Jurassic strata have been intensively studied in the uranium-producing region of west-central New Mexico. The easily accessible Jurassic sections here, especially the ones at Red Rock State Park, Thoreau, Ambrosia Lake, and Mesa Gigante, make west-central New Mexico the Jurassic section in the state most familiar to geologists.

Condon and Peterson (1986; also see Condon and Huffman, 1984; Condon, 1989) interpreted and named these Jurassic strata very differently than we do (Fig 2; see Anderson and Lucas, 1997; Lucas and Anderson, 1997 for explanations of the difference and justification of the stratigraphic relationships and nomenclature used here). The differences largely reflect differences between the correlation from the Four Corners into west-central New Mexico that we advocate (Fig. 4) and the correlation Condon and Peterson (1986) accepted.

The base of the Jurassic section in west-central New Mexico remains an unresolved problem. The oldest Jurassic strata at Red Rock State Park near Fort Wingate (McKinley County) were named Wingate Sandstone by Dutton (1885). Gilluly and Reeside (1928) named the same lithosome Entrada Sandstone in Utah and, from west-central New Mexico westward into Arizona, miscorrelated most of the type Wingate with older rocks now included in the Glen Canyon Group. The result has been that Dutton's type Wingate has long been termed Entrada, and the name Wingate is applied to a rock unit much older (stratigraphically lower) than the type section!

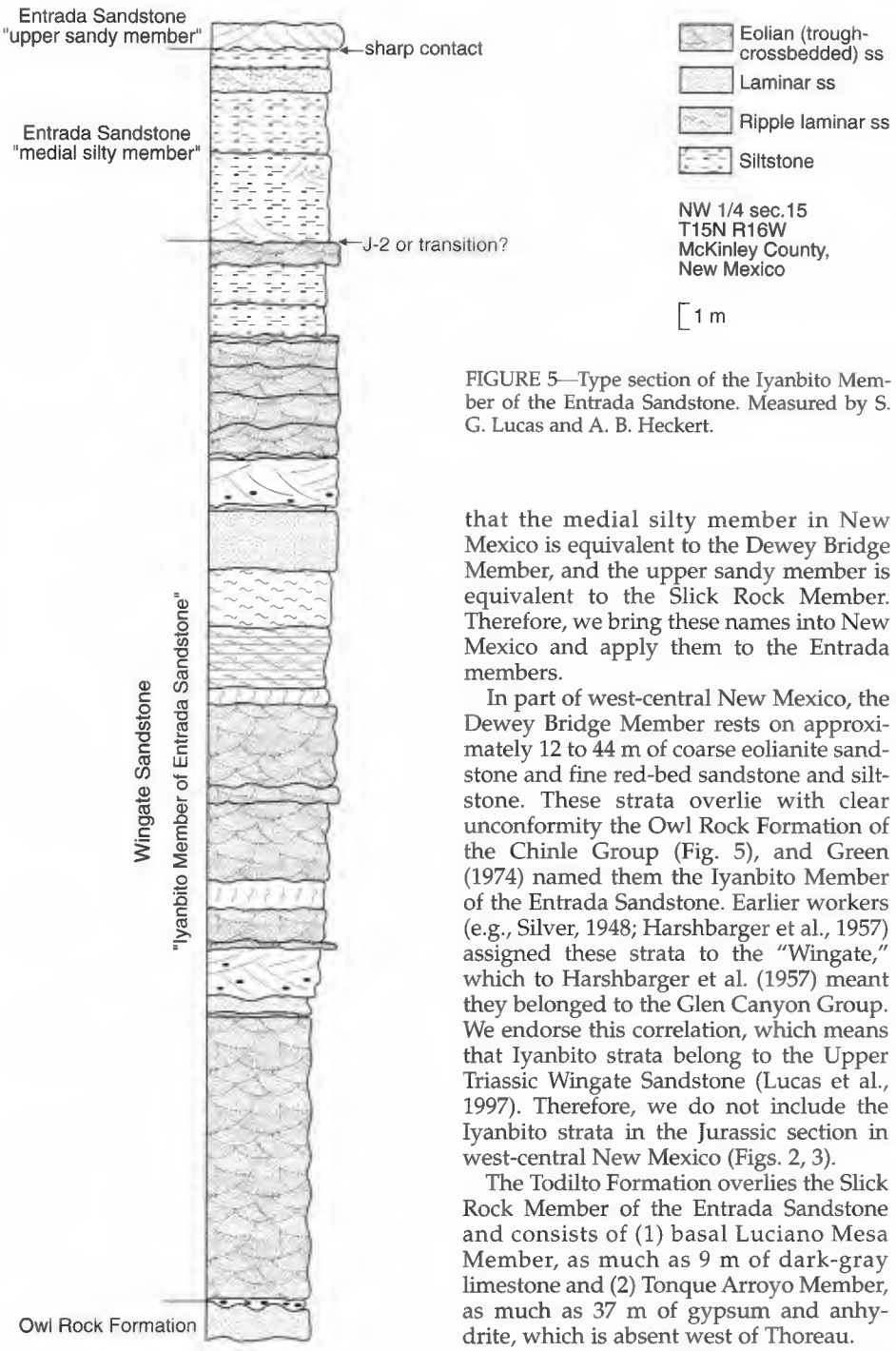

FIGURE 5—Type section of the Iyanbito Member of the Entrada Sandstone. Measured by S. G. Lucas and A. B. Heckert.

Current understanding of Entrada stratigraphy in west-central New Mexico, well summarized by Condon and Peterson (1986), recognizes a tripartite formation (ascending): Iyanbito, medial silty, and upper sandy members. Wright et al. (1962) ably demonstrated that the Entrada in Utah–Colorado consists of a basal Dewey Bridge, medial Slick Rock, and upper Moab Members, the Moab being an eolianite intertongued with the Summerville. Regional mapping by Cooley et al. (1969; also see Allen and Balk, 1954) and our own recent stratigraphic studies (in collaboration with A. B. Heckert) indicate that the medial silty member in New Mexico is equivalent to the Dewey Bridge Member, and the upper sandy member is equivalent to the Slick Rock Member. Therefore, we bring these names into New Mexico and apply them to the Entrada members.

In part of west-central New Mexico, the Dewey Bridge Member rests on approximately 12 to 44 m of coarse eolianite sandstone and fine red-bed sandstone and siltstone. These strata overlie with clear unconformity the Owl Rock Formation of the Chinle Group (Fig. 5), and Green (1974) named them the Iyanbito Member of the Entrada Sandstone. Earlier workers (e.g., Silver, 1948; Harshbarger et al., 1957) assigned these strata to the "Wingate," which to Harshbarger et al. (1957) meant they belonged to the Glen Canyon Group. We endorse this correlation, which means that Iyanbito strata belong to the Upper Triassic Wingate Sandstone (Lucas et al., 1997). Therefore, we do not include the Iyanbito strata in the Jurassic section in west-central New Mexico (Figs. 2, 3).

The Todilto Formation overlies the Slick Rock Member of the Entrada Sandstone and consists of (1) basal Luciano Mesa Member, as much as 9 m of dark-gray limestone and (2) Tonque Arroyo Member, as much as 37 m of gypsum and anhydrite, which is absent west of Thoreau.

As much as 49 m of red, thinly bedded sandstones and siltstones of the Summerville Formation (equivalent to Beclabito Member of Wanakah Formation of Condon and Peterson, 1986) overlie the Todilto. The Bluff Sandstone (includes the Horse Mesa Member of the Wanakah and "sandstone at Mesita" of Condon and Peterson, 1986) overlies the Summerville and is as much as 18 m of laminated and trough-crossbedded sandstone.

The Morrison Formation disconformably overlies the Bluff and consists of three members: (1) Salt Wash Member (equivalent to the Westwater Canyon Member of previous workers, see Anderson and Lucas, 1995, 1997), beds of sandstone and conglomerate and minor interbeds of mudstone as thick as 135 m; (2) Brushy Basin Member, mostly variegated smectitic claystones as thick as 107 m; and (3) Jackpile Member, as much as 28 m of kaolinitic sandstone, mostly present on the east side of Mt. Taylor.

3. Colorado Plateau edge

Anderson and Lucas (1996) revised Jurassic stratigraphy along the Colorado Plateau edge in the southeast San Juan Basin. The section exposed here is very similar to that in the Grants uranium region (Fig. 3) with the following exceptions:

1. The "Iyanbito Member" is not present in the southeast San Juan Basin, nor is the Acoma Tongue of the Zuni Sandstone.

2. The Bluff Sandstone is not everywhere a mappable unit distinct from the Summerville Formation in the southeast San Juan Basin. Eolian sandstones are common in the upper Summerville here, but they do not form a distinctive coalesced sandstone body readily recognized as the Bluff Sandstone.

Most previous workers in the southeast San Juan Basin included all Jurassic strata between the Todilto and Dakota in the Morrison Formation (e.g., Kelley and Wood, 1946; Woodward and Schumacher, 1973; Woodward and Ruetschilling, 1976; Manley et al., 1987). However, like Flesch (1974), Anderson and Lucas (1996) assigned the 70–80 m of horizontally bedded, fine sandstones and siltstones above the Todilto to the Summerville Formation.

4. Chama Basin

Anderson (1995) and Anderson and Lucas (1996) presented some new data on the Jurassic section in the Chama Basin and interpreted the section somewhat differently than previous workers (e.g., Smith et al., 1961; Manley et al., 1987; Crouse et al., 1992). The base of the Jurassic section here is the Slick Rock Member of the Entrada Sandstone, as much as 76 m of yellowish-gray and red, trough-crossbedded eolianite sandstone that rests disconformably on the Rock Point Formation of the Chinle Group (Lucas and Hunt, 1992).

The overlying Todilto Formation consists of the Luciano Mesa Member (as much as 6 m of dark gray, kerogenic limestone) and overlying gypsum-anhydrite (as much as 30 m) of the Tonque Arroyo Member. Overlying strata were long assigned to the Morrison Formation. However, as Anderson (1995) pointed out, the lower 80 m of these "Morrison" strata are color-banded, parallel-bedded, silty mudstones and minor thinly bedded, very fine grained sandstones (Fig. 6). The succeeding 58 m of strata are trough-crossbedded, very well sorted, fine-grained

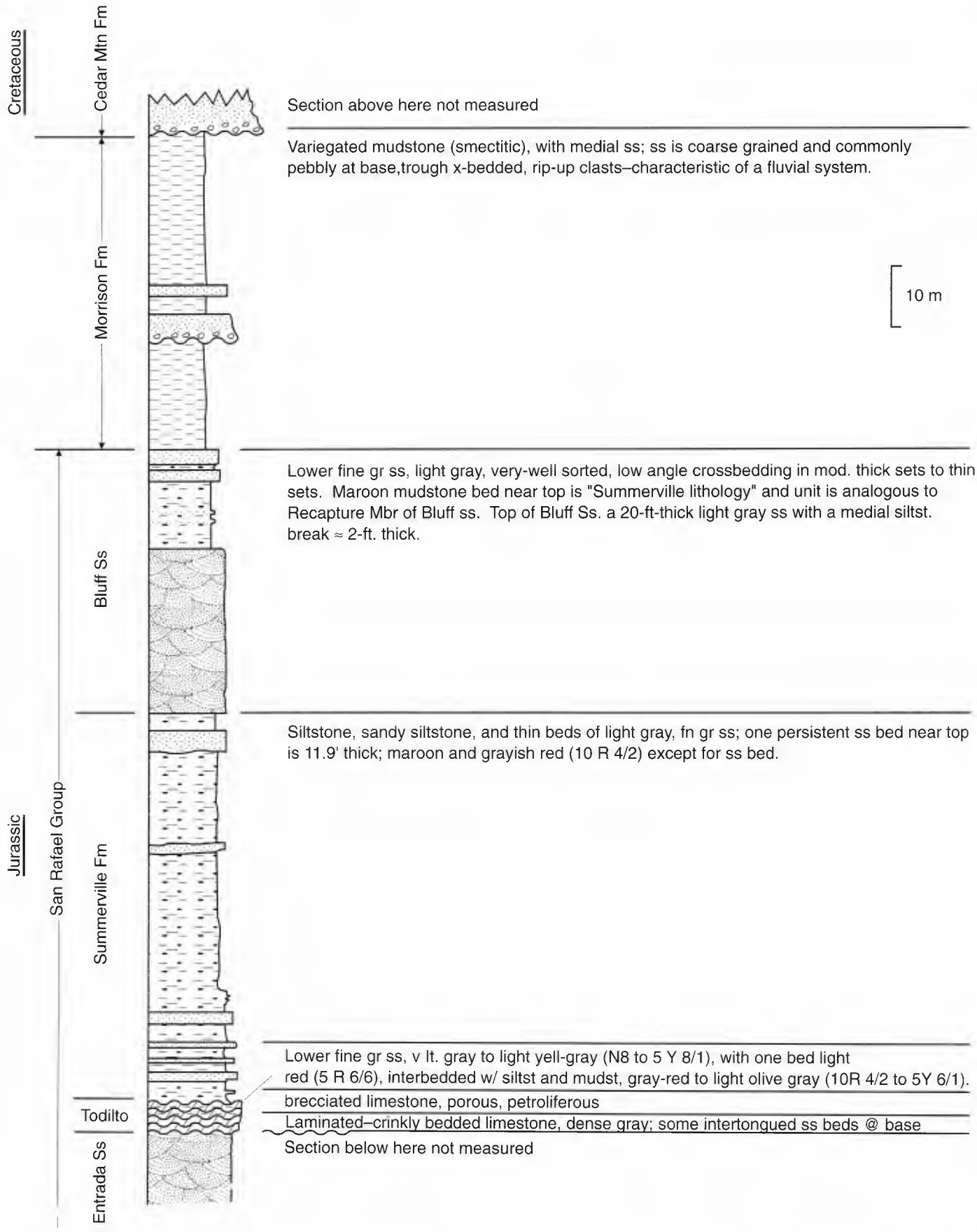

FIGURE 6—Jurassic stratigraphic section at Ghost Ranch, Rio Arriba County. Measured by O. J. Anderson in the NW¼ sec. 2 T24N R4E, Rio Arriba County.

sandstones. At the top of these sandstones is a manganese oxide-stained horizon 10–15 cm thick overlain by 64 m of green smectitic claystones. Rather than assign the entire post-Todilto Jurassic section here to the Morrison Formation, we follow Anderson (1995) in recognizing Summerville, Bluff, and Morrison (Brushy Basin Member) strata in the Chama Basin (Fig. 6). Evidently, the Salt Wash Member is not present in the Chama Basin, so the Brushy Basin Member rests directly on the Bluff Sandstone, a substantial unconformity (Fig. 6).

5. Hagan Basin

Lucas et al. (1995) detailed the Jurassic stratigraphy in the Hagan Basin (Fig. 3), and we provide a brief synopsis. The base of the Jurassic section is the Entrada Sandstone, which disconformably overlies the Upper Triassic Chinle Group. The lower, Dewey Bridge Member of the Entrada is as much as 20 m of mostly reddish-brown sandstone and siltstone overlain by the Slick Rock Member, as much as 29 m of mostly yellowish-gray trough-crossbedded sandstone. The Todilto Formation disconformably overlies the Entrada Sandstone and consists of two members: (1) Luciano Mesa Member, as much as 6 m of mostly dark-gray kerogenic limestone, overlain by the (2) Tonque Arroyo Member, as much as 61 m of mostly white gypsum/anhydrite. The Summerville Formation conformably(?) overlies the Tonque Arroyo Member of the Todilto Formation and is as much as 57 m of cyclically bedded, red and gray sandstone, mudstone, and siltstone. Locally, these strata include eolianite sandstones, but a regionally mappable Bluff Sandstone cannot be recognized here. These strata were formerly termed Recapture Member of the Morrison Formation by Picha (1982) and Pigman and Lucas (1989).

The Salt Wash Member of the Morrison Formation disconformably overlies the Summerville Formation and is as much as 75 m of mostly grayish-yellow sheets of fluvial sandstone and conglomerate with some interbeds of olive and brown mudstone. Picha (1982) and Pigman and Lucas (1989) formerly referred these strata to the Westwater Canyon (Sandstone) Member of the Morrison Formation.

The Salt Wash Member grades upward into and intertongues with the Brushy Basin Member of the Morrison Formation, as much as 128 m of mostly variegated olive, gray, and brown bentonitic mudstone/siltstone.

The Jackpile Member of the Morrison Formation overlies the Brushy Basin Member and is as much as 62 m of mostly light gray and pale orange, trough-crossbedded sandstone. Cretaceous strata of the Dakota Formation disconformably overlie the Jackpile Member in the Hagan Basin.

6. Tucumcari Basin

The Jurassic section exposed in the drainages of the Canadian and Pecos Rivers in east-central New Mexico (Figs. 1, 3) has been reviewed by Lucas et al. (1985) and Lucas and Kietzke (1986). In ascending order, these strata are the Entrada Sandstone, Todilto Formation, Exeter Member of the Entrada Sandstone, Summerville Formation, and Morrison Formation.

The Entrada Sandstone rests disconformably on the Upper Triassic Redonda Formation of the Chinle Group. It is as much as 53 m of trough-crossbedded, yellowish-gray to pale reddish-brown eolian sandstone, here assigned to the Slick Rock Member.

The Luciano Mesa Member of the Todilto Formation is as much as 6 m of dark-gray kerogenic limestone. Its depositional pinchout between the Entrada main body (below) and Entrada Exeter Member (above) is well documented in Guadalupe County (T9N R26E) (Dobrovolny et al., 1946; Lucas et al., 1985; Lucas and Kietzke, 1986).

The Exeter Member of the Entrada above the Todilto is an eolianite that underlies or is laterally equivalent to part of the Summerville Formation in northeast New Mexico. It is 10–15 m thick (Lucas et al., 1985, 1987b). The Exeter Member is probably homotaxial to the Moab Tongue of the Entrada Sandstone in Colorado–Utah.

The Summerville Formation of our usage includes the units previously termed Bell Ranch Formation (Griggs and Read, 1959) and "lower member" of the Morrison Formation (e.g., Trauger and Bushman, 1964; Wanek, 1962). As Anderson and Lucas (1992) explained, these strata occupy the same stratigraphic position and are remarkably similar lithologically to Summerville strata farther west. Thus, Summerville strata in east-central New Mexico are as much as 30 m of thinly and repetitively bedded, fine-grained sandstone, gypsum, siltstone, and sandy mudstone. Indeed, a two-part Summerville Formation can be recognized in east-central New Mexico and is similar to the two-part Summerville on the Colorado Plateau (Lucas and Anderson, 1997). The lower part of the Summerville is cyclically bedded sandstones and siltstones, whereas the upper part is mudstones and siltstones with thin beds of bentonite. Our correlation equates the lower part with the Beclabito Member, and the upper part with the Tidwell Member of the Summerville on the Colorado Plateau (Lucas and Anderson, 1997).

The Morrison Formation disconformably overlies the Summerville Formation in east-central New Mexico. It consists of the lower Salt Wash Member, up to 30 m of sandstones and conglomerates (equivalent to medial sandstone member of Wanek, 1962), overlain by as much as 150 m of green and variegated smectitic claystone of the Brushy Basin Member (equivalent to green shale member of Wanek, 1962).

7. Dry Cimarron Valley

Jurassic strata exposed in the canyons of the Dry Cimarron Valley in Union County (Figs. 1, 3) were most recently reviewed by Lucas et al. (1987a), Hunt and Lucas (1987) and Neuhauser et al. (1987). Eolianites of the Entrada Sandstone are at the base of the Jurassic section, where they rest unconformably on Upper Triassic strata of the Chinle Group (also see Baldwin and Muehlberger, 1959; Lucas et al., 1987b). These Entrada strata are as thick as 30 m and include the Exeter Member resting directly on the Entrada main body (the Todilto Formation is absent in the Dry Cimarron Valley).

The Summerville Formation is 20–25 m thick and similar to Summerville strata farther south. The Morrison Formation is a relatively fine grained smectitic mudstone- and limestone-dominated unit as thick as 140 m that we assign to the Brushy Basin Member.

Paleontology

Relatively few fossils are known from Jurassic strata in New Mexico, much less than are known from Triassic or Cretaceous strata. Moreover, most of the fossils known from Jurassic rocks in the state are of little or no biochronologic significance.

The oldest Jurassic fossils from New Mexico are dasyclad algae, an ostracod, insects (mostly Hemiptera) and three species of fishes from the Todilto Formation (e.g., Lucas et al., 1985; Kietzke, 1992; Kirkland et al., 1995; Armstrong, 1995). One of the species of fossil fishes—*Hulettia americana* (Eastman)—is also known from the Canyon Springs Sandstone and Stockade Beaver Shale Members of the Sundance Formation of South Dakota/Wyoming, units of Bathonian age (Schaeffer and Patterson, 1984). On face value, this could be used to argue for a Bathonian age of the Todilto Formation. However, the Todilto must be younger than the underlying, early Callovian Entrada Sandstone. The age discrepancy created by the temporally disjunct distribution of *Hulettia americana* must mean it has a longer temporal range (Bathonian–Callovian) than is recorded in either South Dakota/Wyoming or New Mexico.

Dinosaur footprints of the theropod ichnogenera *"Grallator"* and *Megalosauripus* and bones of the sauropod *Camarasaurus* are known from the Summerville Formation in New Mexico (Lucas et al., 1990, 1995; Anderson and Lucas, 1996; Lockley et al., 1996). Similar fossils are

known from Utah and suggest a Late Jurassic age, though the possibility of a late Middle Jurassic age cannot be excluded (Lucas and Anderson, 1997). Charophytes and ostracods from the uppermost Summerville Formation (Tidwell Member) in Utah–Colorado suggest an Oxfordian age (Schudack, 1996), as does an Ar/Ar age of 154.9 ± 1.5 Ma from a Tidwell Member ash bed in Utah (Peterson et al., 1993).

The Morrison Formation in New Mexico has produced identifiable dinosaurs from the Brushy Basin Member—*Allosaurus, Camarasaurus, Diplodocus, Seismosaurus,* and *Stegosaurus* (see reviews by Hunt and Lucas, 1993; Lucas et al., 1996)—and unionid bivalves from the Brushy Basin Member (Lucas, 1996). The dinosaurs are generally considered to be of Late Jurassic (Kimmeridgian–Tithonian) age (Lucas, 1993).

Sequence stratigraphy

Pipiringos and O'Sullivan (1978) proposed a succession of Jurassic unconformities that delimit sequences throughout part or all of the Jurassic Western Interior basin. Four of these regional unconformities can be identified in New Mexico's Jurassic section (Fig. 7).

The J-2 unconformity separates Middle Jurassic strata of the Entrada Sandstone from underlying Upper Triassic strata of the Chinle Group. This striking unconformity is unambiguously identified across all the Jurassic outcrop belts in New Mexico.

The J-3 unconformity of Pipiringos and O'Sullivan is the basal transgressive unconformity that separates the Entrada Sandstone from the overlying Curtis Formation. We correlate the Curtis with the Todilto, which suggests that the Todilto base either is the J-3 unconformity or a correlative conformity. Local stratigraphic relief, rip-up clasts, and floating pebbles, as well as sharp lithologic contrast—kerogenic limestone on eolianite sandstone—suggest the base of the Todilto Formation is the J-3 unconformity.

The base of the Morrison Formation was identified by Pipiringos and O'Sullivan (1978) as the J-5 unconformity. We also recognize this unconformity at the base of the Salt Wash Member across the state. The K-0 unconformity of Pipiringos and O'Sullivan (1978) separates Cretaceous strata (no older than late Albian) from underlying Jurassic strata across New Mexico.

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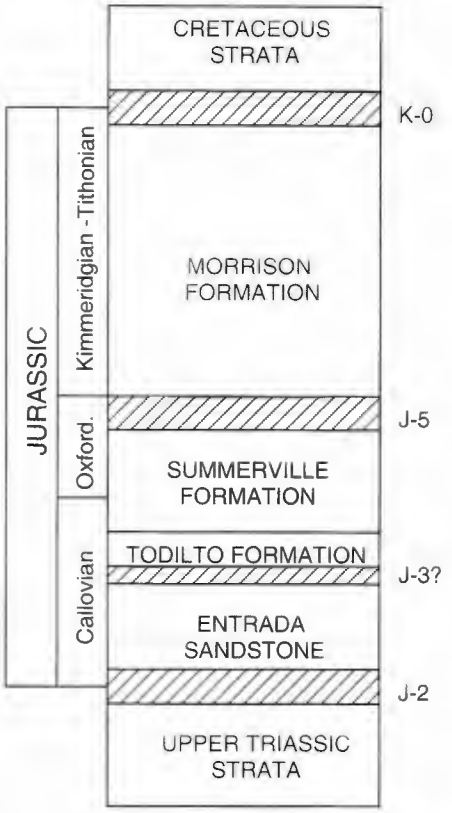

FIGURE 7—Unconformities that bound Jurassic sequences in New Mexico.

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Stratigraphy correlation is the basis of study on oilfield reservoir characterization. According to region study results, marine environments correlation pattern were used in EPC Oilfield, stratigraphic sequence were summarized, based on the feature of lithology and responding of core data and wired logging data, correlation markers were summarized in each sequence, formation distribution were described based on the zonation, geology model were summarized for the main oil bearing formation. Following study on reservoir were based on these results. The stratigraphic correlation of Jurassic sediments of the Irkutsk Coal Basin with the sedimentary basins of Western Siberia has been carried out based on paleobotanical data.Â Publishing on IntechOpen allows authors to earn citations and find new collaborators, meaning more people see your work not only from your own field of study, but from other related fields too. Content Alerts. Brief introduction to this section that descibes Open Access especially from an IntechOpen perspective.Â Open access peer-reviewed chapter. Stratigraphy of Jurassic Sediments of the Southern Siberian Platform (Russia) Studied through Lithologic and Paleobotanical Data. By Andrey Olegovich Frolov, Nikolay Ivanovich Akulov and Irina Mikhailovna Mashchuk. International Subcommission on Jurassic Stratigraphy: 612-624.Â Global correlation of the radiolarian faunal change across the Triassic-Jurassic boundary. Canadian Journal of Earth Science, 42: 777-790. Carter, e. s., orchard, M. j., tozer, e. t. 1989.Â The age of the Triassic/Jurassic boundary: new data and their implications for the extinction and recovery. Volumina Jurassica 4, p. 294. Pavia, g., enay, r. 1997.