GEOLOGY OF THE INTERMOUNTAIN WEST

an open-access journal of the Utah Geological Association

ISSN 2380-7601

Volume 5 ***2018***

THE UPPER JURASSIC MORRISON FORMATION IN NORTH-CENTRAL NEW MEXICO—LINKING COLORADO PLATEAU STRATIGRAPHY TO THE STRATIGRAPHY OF THE HIGH PLAINS

Spencer G. Lucas

Theme Issue
An Ecosystem We Thought We Knew—
The Emerging Complexities of the Morrison Formation
SOCIETY OF VERTEBRATE PALEONTOLOGY
Annual Meeting, October 26 – 29, 2016
Grand America Hotel
Salt Lake City, Utah, USA

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View of upper part of Morrison Formation at Hub Canyon near Lamy in Santa Fe County, New Mexico. Pale green sandstone ledge in the foreground is Salt Wash Member overlain by greenish slopes of mudrock-dominated Brushy Basin Member capped by white-colored Jackpile Member at top of Morrison Formation. The Cretaceous Dakota Sandstone rests disconformably on the Jackpile Member and is seen as a brown sandstone at the top of the outcrop. Photograph by Spencer G. Lucas.

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The Upper Jurassic Morrison Formation in North-Central New Mexico–Linking Colorado Plateau Stratigraphy to the Stratigraphy of the High Plains

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ABSTRACT

Most study of the Upper Jurassic Morrison Formation has focused on its spectacular and extensive outcrops on the southern Colorado Plateau. Nevertheless, outcrops of the Morrison Formation extend far off the Colorado Plateau, onto the southern High Plains as far east as western Oklahoma. Outcrops of the Morrison Formation east of and along the eastern flank of the Rio Grande rift in north-central New Mexico (Sandoval, Bernalillo, and Santa Fe Counties) are geographically intermediate between the Morrison Formation outcrops on the southeastern Colorado Plateau in northwestern New Mexico and on the southern High Plains of eastern New Mexico. Previous lithostratigraphic correlations between the Colorado Plateau and High Plains Morrison Formation outcrops using the north-central New Mexico sections encompassed a geographic gap in outcrop data of about 100 km. New data on previously unstudied Morrison Formation outcrops at Placitas in Sandoval County and south of Lamy in Santa Fe County reduce that gap and significantly add to stratigraphic coverage. At Placitas, the Morrison Formation is about 141 m thick, in the Lamy area it is about 232 m thick, and, at both locations, it consists of the (ascending) sandstone-dominated Salt Wash Member, mudstone-dominated Brushy Basin Member, and sandstone-dominated Jackpile Member. Correlation of Morrison strata across northern New Mexico documents the continuity of the Morrison depositional systems from the Colorado Plateau eastward onto the southern High Plains. Along this transect, there is significant stratigraphic relief on the base of the Salt Wash Member (J-5 unconformity), the base of the Jackpile Member, and the base of the Cretaceous strata that overlie the Morrison Formation (K unconformity). Salt Wash Member deposition was generally by easterly-flowing rivers, and this river system continued well east of the Colorado Plateau. The continuity of the Brushy Basin Member, and its characteristic zeolite-rich clay facies, onto the High Plains suggests that localized depositional models (e.g., "Lake T'oo'dichi') need to be re-evaluated. Instead, envisioning Brushy Basin Member deposition on a vast muddy floodplain, with some localized lacustrine and palustrine depocenters, better interprets its distribution and facies.

INTRODUCTION

Jurassic strata of the Morrison Formation exposed in north-central New Mexico provide an important link between two extensive Morrison outcrop belts. To the west, Morrison strata of the southern Colorado Plateau have been studied intensively, particularly because of the uranium resources they contain (e.g., Kirk and Condon, 1986; Turner-Peterson and others, 1986; Anderson and Lucas, 1997). To the east, on the southern High Plains, the Morrison strata have not received such intensive study, but are clearly genetically related to Morrison strata on the southern Colorado Plateau (e.g., Lucas and others, 1985; Lucas and Woodward, 2001).

Citation for this article.
Lucas, S.G., 2018, The Upper Jurassic Morrison Formation in north-central New Mexico–linking Colorado Plateau stratigraphy to the stratigraphy of the High Plains: Geology of the Intermountain West, v. 5, p. 117–129.

Here, I review the Morrison Formation stratigraphy along a transect from the southern Colorado Plateau to the southern High Plains in north-central New Mexico (figure 1). My goal is to correlate the Morrison Formation strata between San Ysidro on the eastern Colorado Plateau edge, and at Romeroville on the western edge of the southern High Plains. This correlation has important implications for the extent and nature of Morrison unconformities, lithofacies and depositional systems.

Lucas and Anderson (1998) reviewed Jurassic stratigraphy in New Mexico; the stratigraphic nomenclature they advocated is on the current geologic map of New Mexico (NMBGMR, 2003) and is employed here. Lucas and others (1999) and Lucas and Woodward (2001) presented recent reviews of Jurassic stratigraphy along parts of the transect from the Colorado Plateau to the High Plains. The oldest Cretaceous strata above the Jurassic section are referred to the Dakota Sandstone/Formation in north-central New Mexico, though alternative names have been proposed elsewhere that may provide more appropriate nomenclature for this lithostratigraphic unit (e.g., Mateer, 1987; Carpenter, 2014). I can add new data here in the form of Morrison Formation stratigraphy at Placitas in Sandoval County (figure 2) and on the San Cristobal Ranch near Lamy in Santa Fe County (figures 3 to 6) that fill important gaps in earlier coverage of the regional Morrison Formation lithostratigraphy (figures 1 and 7).

STRATIGRAPHIC SECTIONS

Introduction

The correlation presented here is of six surface stratigraphic sections and one well log across an about 141 km transect of northern New Mexico (figures 1 and 7). Four of these Morrison sections and the well log have already been described in detail (see Lucas and others, 1999 and references cited therein and below), so they are only briefly reviewed here. Two of the surface sections of the Morrison Formation (Placitas, San Cristobal Ranch) have not been described previously, so they are new data presented here.

San Ysidro Section

Anderson and Lucas (1996; also see Woodward, 1987) reviewed Jurassic stratigraphy along the southeastern edge of the Colorado Plateau in the vicinity of San Ysidro. The Jurassic section there is approxi-

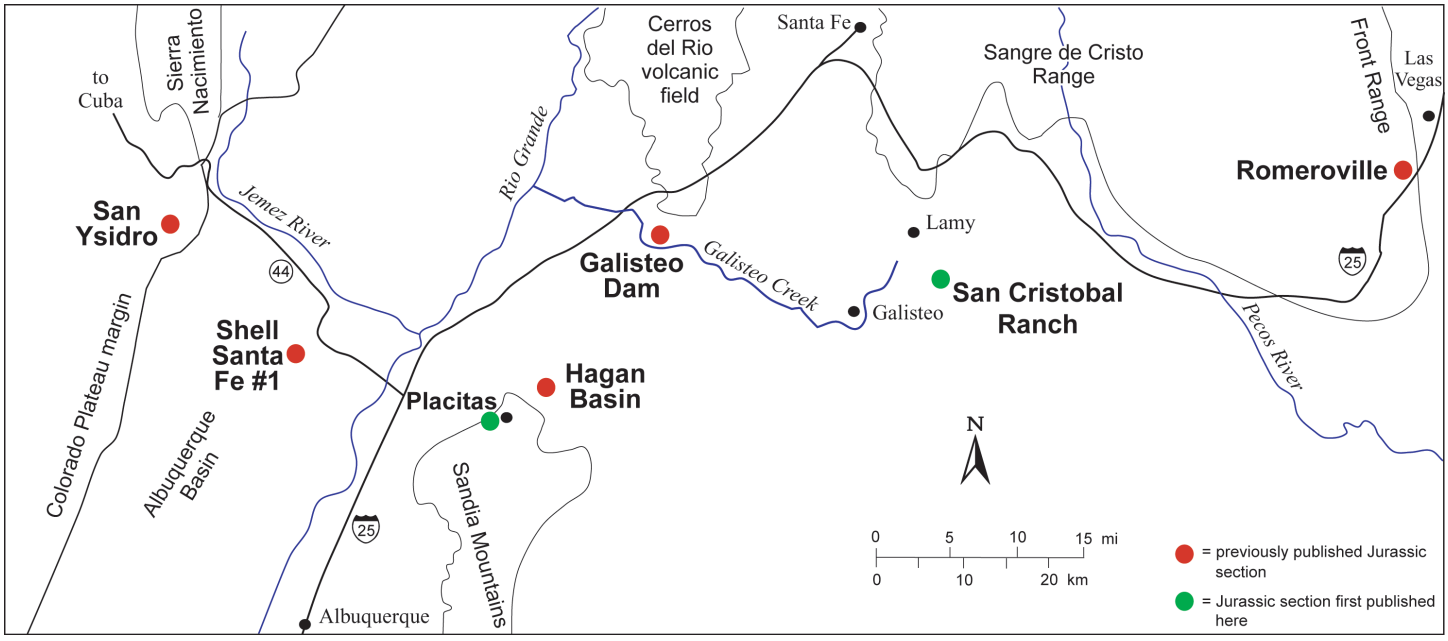

Figure 1. Map of part of north-central New Mexico, showing locations of the Jurassic sections discussed in this article. All sections are in shown in figure 7; the detailed section at Placitas is in figure 2; and the detailed sections on the San Cristobal Ranch are in figures 4 and 5.

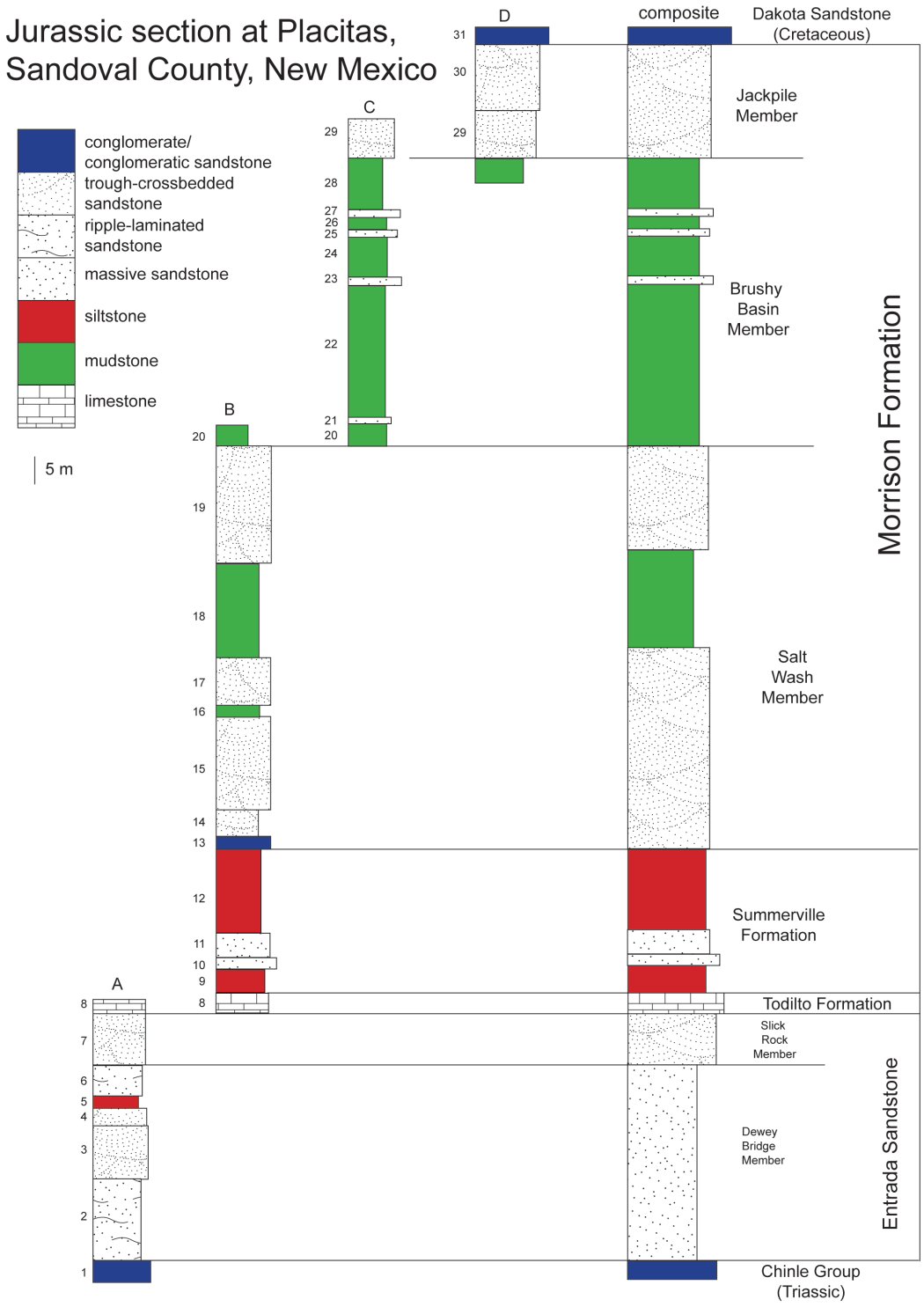

Figure 2. Stratigraphic sections of Jurassic strata measured at Placitas, Sandoval County, New Mexico. A, B, C and D are four overlapping sections measured on different fault blocks, and the column on the right is the composite Jurassic section. Locations of sections (GPS coordinates are UTM meters, zone 13, datum NAD 27). (A) Base of section is located at 367734E, 3906520N, top at 367750E, 3906646N; (B) Base of section is located at 366918E, 3906929N, top at 367034E, 3907157N; (C) Base of section is located at 369914E, 3907759N, top at 369933E, 3907813N; and (D) Section is located at 366307E, 3907103N. Member-level stratigraphic nomenclature of the Entrada Sandstone is based on Lucas and Heckert (2003).

Figure 3. Overview photographs of Morrison Formation sections at Hub Canyon (A) and Hub Mesa (B).

mately 300 m thick and is assigned to the (ascending) Entrada, Todilto, Summerville, and Morrison formations (figure 7). The Morrison Formation consists of the Salt Wash, Brushy Basin, and Jackpile members. The Salt Wash Member is up to 36 m thick and consists mostly of pale yellow, trough cross-bedded, fine to coarse-grained sandstone with chert-pebble conglomeratic zones (mainly in the basal part) interbedded with thinner units of siltstone and mudstone. The overlying Brushy Basin Member is as much as 80 m thick and mostly variegated, smectitic mudstone, and contains a few beds of lenticular, fine- and medium-grained sandstone. The Jackpile Member (Owen and others, 1984) is as much as 60 m thick and is mostly pale yellow to white, kaolinitic sandstone with some green mudstone interbeds. The Encinal Canyon Member of the Dakota Formation rests disconformably on the Jackpile Member at San Ysidro (Lucas and others, 1998).

Shell Oil Santa Fe No. 1

From the Jurassic outcrops on the eastern edge of the Colorado Plateau near San Ysidro to Jurassic outcrops on the eastern margins of the Rio Grande rift--at Placitas, in the Hagan basin and at Galisteo Dam—a distance of more than 50 km is covered by younger strata (figure 1). To aid in correlation across this gap, a subsurface section about midway between the Colorado Plateau edge and the Sandia uplift along

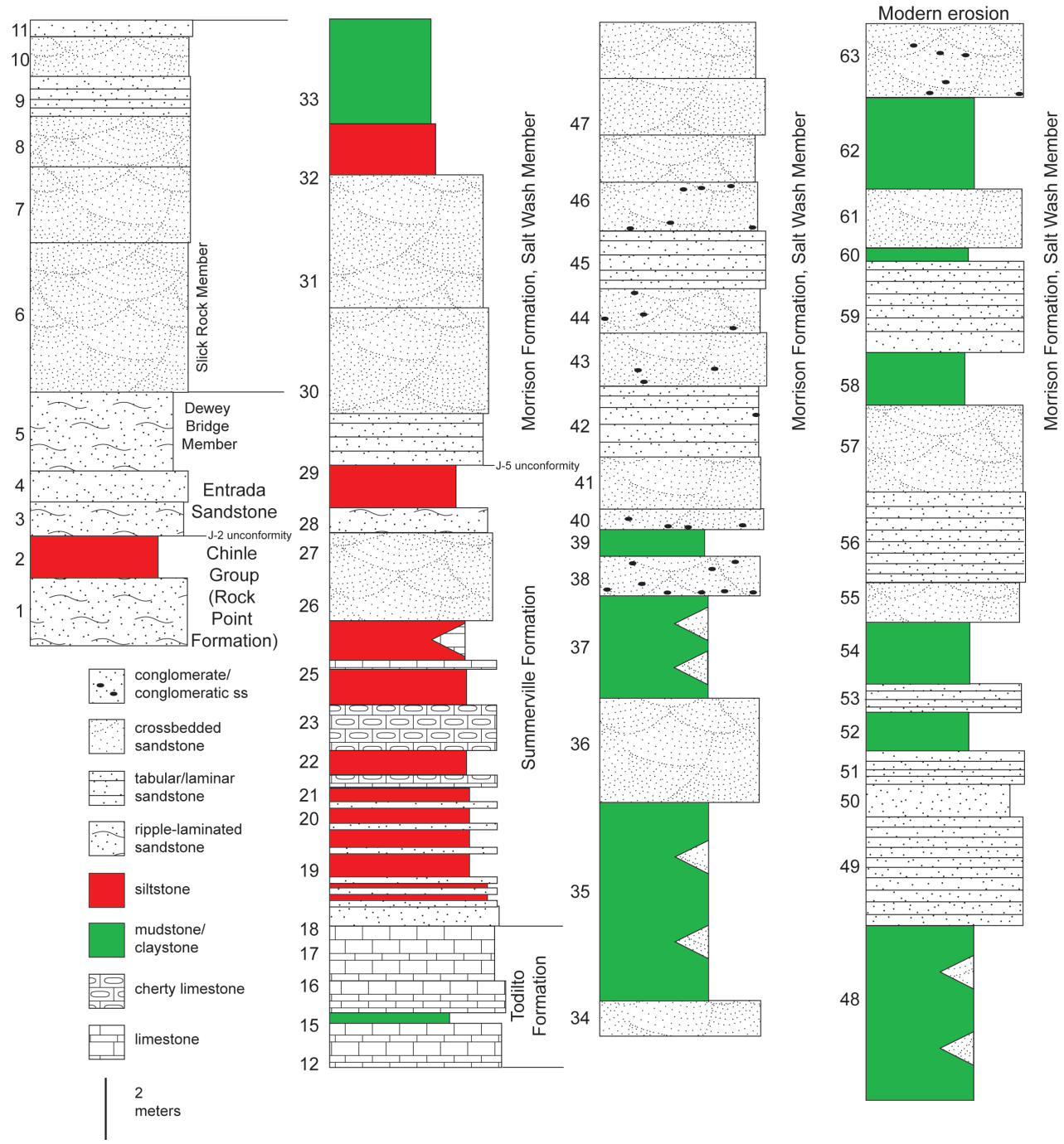

Figure 4. Stratigraphic section of Jurassic strata exposed at Hub Mesa on the San Cristobal Ranch, Santa Fe County, New Mexico. Location of section (GPS coordinates are UTM meters, zone 13, datum NAD 83): Base of section is located at 420858E, 3908188N, top at 420426E, 3908577N.

the eastern boundary of the Rio Grande rift is the geophysical log of the Shell Oil Santa Fe #1 well in section 18, T. l3 N., R. 3 E. (figure 7). Interpretation of this log by Black and Hiss (1974) and by Lucas and others (1999) indicates that the well penetrated the Entrada, Todilto, Summerville, and Morrison Formations in the subsurface.

Black and Hiss (1974) assigned the 145 m (642 ft) of Jurassic strata drilled by the well from 2210 to 2076 m (7252–6810 ft) to the Morrison Formation and at-

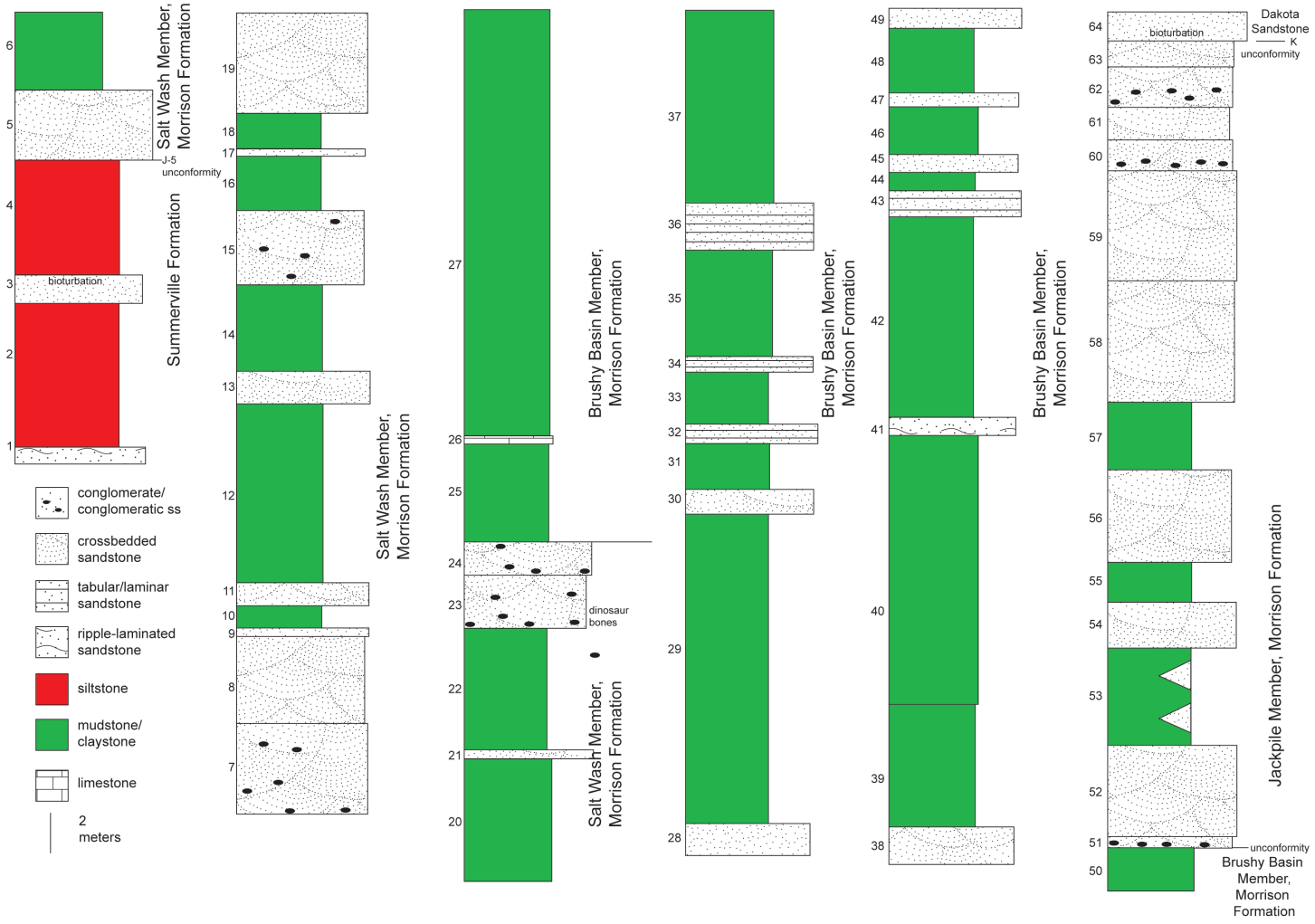

Figure 5. Stratigraphic section of the Morrison Formation at Hub Canyon on the San Cristobal Ranch, Santa Fe County, New Mexico. Location of section (GPS coordinates are UTM meters, zone 13, datum NAD 83). Base of section is located at 419981E, 3910395N, top at 419527E, 3911025N.

tempted no further subdivisions. However, Lucas and others (1999) concluded that the 79-m-thick (260-ft-thick) mudstone-dominated interval from 2106 to 2185 m (6910–7170 ft) is the Brushy Basin Member. If the underlying 33 m (110 ft) of strata belong to the Salt Wash Member (a thickness comparable to the outcrops at San Ysidro), then the base of the Salt Wash corresponds to the base of a prominent sandstone at 2220 m (7280 ft) (figure 7). All of the sandstone strata from 2106 to 2075 m (6910 to 6810 ft), about 31 m (about 102 ft), are assigned to the Jackpile Member of the Morrison Formation, though it is possible that a few meters of sandstone at the base of the Cretaceous Dakota Sandstone is included in this sandstone interval (figure 7).

Placitas

Placitas is located at the northern end of the Sandia Mountains in Sandoval County (figure 1). Here, Jurassic strata are exposed on fault blocks at the northern end of the Sandia uplift. Most of the published information on the Jurassic section at Placitas is on geologic maps (Kelley and Northrop, 1975; Menne, 1999; Connell and others, 1995). In 2000, a complete Jurassic section was measured as four overlapping sections on different fault blocks (figure 2). Anderson and Lucas (2000), in an ab-

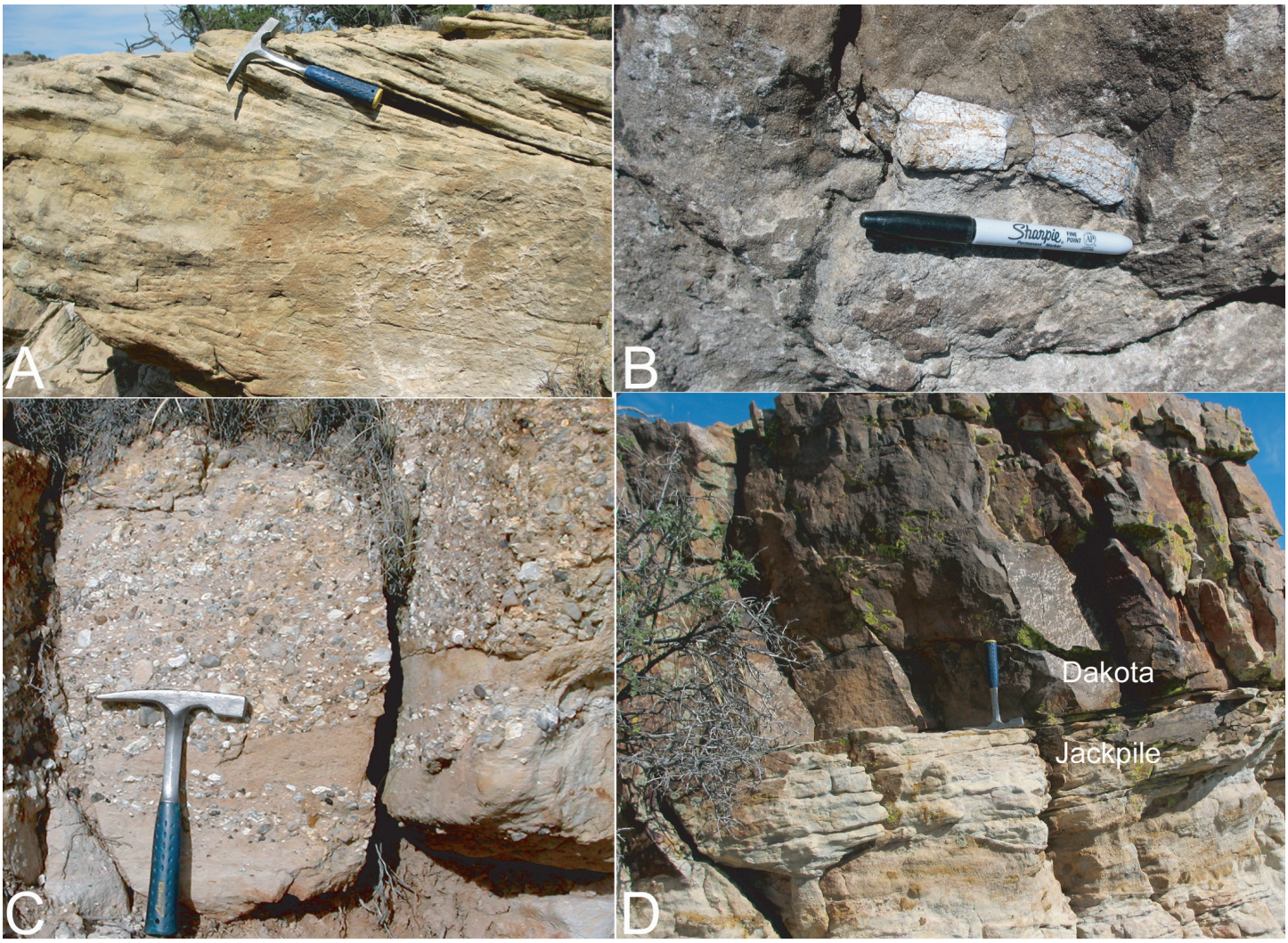

Figure 6. Photographs of selected outcrops of the Morrison Formation in the Hub Canyon section. (A) Cross-bedded sandstone in the Salt Wash Member (figure 5, unit 13). (B) Dinosaur limb-bone fragment in conglomeratic sandstone of the Salt Wash Member (figure 5, unit 23). (C) Silica-pebble conglomerate of the Jackpile Member (figure 5, unit 51). (D) Contact of Jackpile Member with overlying basal sandstone of the Oak Canyon Member of the Dakota Sandstone (figure 5, units 63 and 64).

stract, briefly reported on this section, which consists of the (ascending) Entrada, Todilto, Summerville, and Morrison Formations.

At Placitas, the basal member of the Morrison Formation, the Salt Wash Member, is as much as 71 m thick and consists of fine- to coarse-grained, feldspathic sandstone, with pebbly (conglomeratic) zones as much as several meters thick. In addition to the pebbly beds, other distinguishing features are trough cross-bedding, presence of clay clasts (rip-ups) and nonmarine bioturbation. The overlying Brushy Basin Member is as much as 49 m thick and consists of greenish, mostly smectitic claystone with thin interbeds of dark-weathering, fine-grained sandstone and nodular limestone. The uppermost member of the Morrison Formation, the Jackpile Member, is as much as 21 m thick locally and consists of trough and planar cross-bedded kaolinitic sandstone. The Cretaceous Oak Canyon Member of the Dakota Sandstone (Cretaceous) unconformably overlies the Jackpile Member at Placitas.

Hagan Basin

Lucas and others (1995a) described in detail the

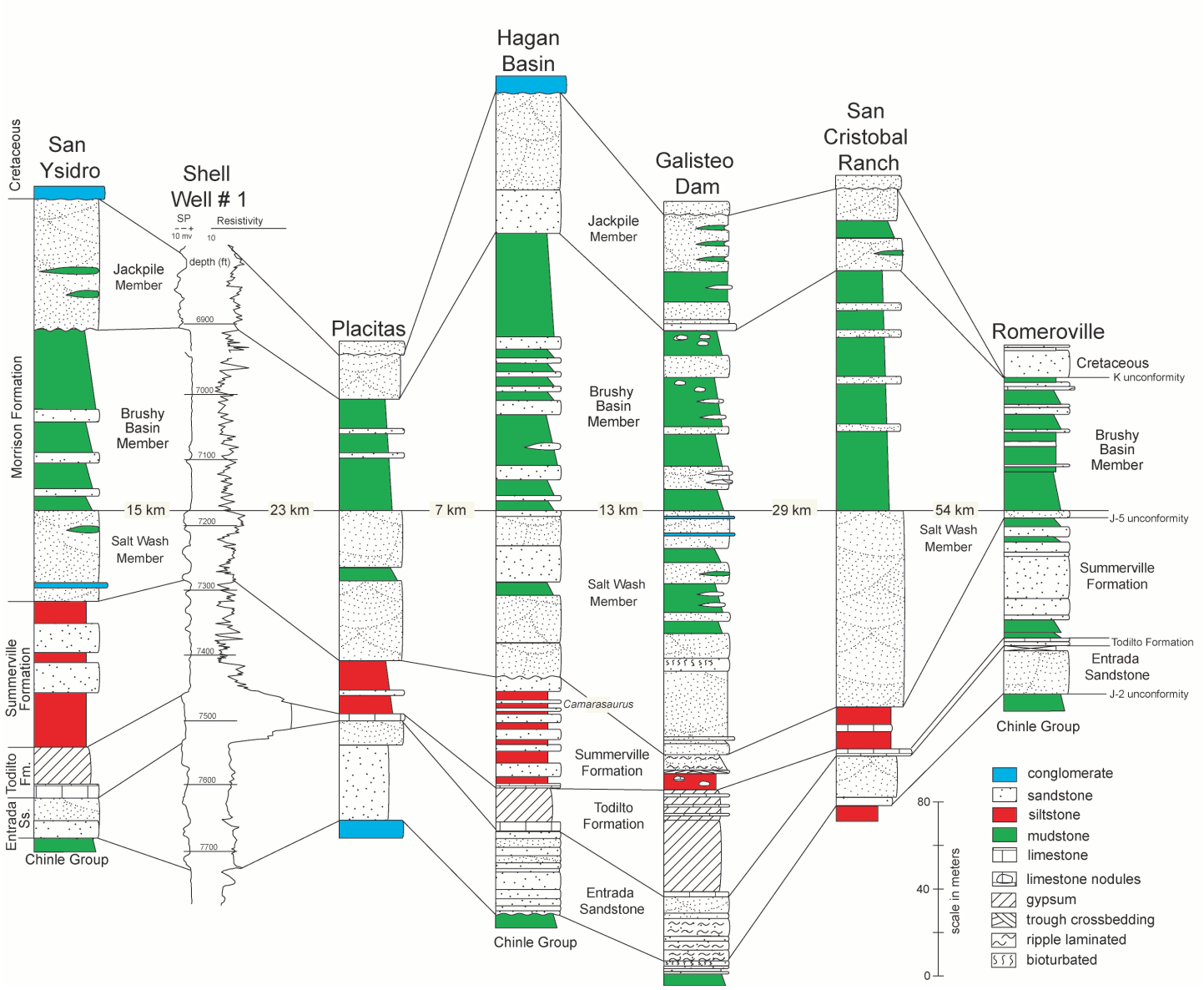

Figure 7. Lithostratigraphic correlation of Jurassic sections from San Ysidro on the southeastern edge of the Colorado Plateau to Romeroville, on the western edge of the southern High Plains, a transect of about 141 km. For location of sections see figure 1.

Jurassic section exposed in the Hagan basin (figure 1). The entire Jurassic section here is as much as 440 m thick and consists of the Entrada, Todilto, Summerville, and Morrison Formations. In the Hagan basin, the Salt Wash Member of the Morrison Formation disconformably overlies the Summerville 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. 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 disconformably overlies the Brushy Basin Member and

is as much as 62 m of mostly light gray and pale orange, trough-cross bedded kaolinitic sandstone. Cretaceous strata of the Dakota Sandstone (Encinal or Oak Canyon members) disconformably overlie the Jackpile Member in the Hagan basin (Lucas and others, 1998).

Galisteo Dam

The Jurassic section at Galisteo Dam (figure 1) is assigned to the (ascending) Entrada, Todilto, Summerville, and Morrison Formations (Lucas and others, 1999). At Galisteo Dam, the Salt Wash Member is 113 m thick and mostly consists of laterally extensive beds of yellow, gray, and brown arkosic sandstone and conglomerate. Green bentonitic mudstone lenses and beds appear in the upper half of the member and support the idea that the Salt Wash Member grades upward into the Brushy Basin Member.

At Galisteo Dam, the first laterally extensive, thick (9 to 10 m) bed of variegated green and brown smectitic mudstone is the base of the Brushy Basin Member, which is nearly 82 m thick. This type of mudstone is the dominant lithology of the Brushy Basin Member locally, which forms a gentle slope between the cliff- or cuesta-forming Salt Wash and Jackpile Members. Brushy Basin sandstone beds form thin ledges in that slope and are mostly dark brown, massive, lithic subarkoses. These sandstone beds are less extensive laterally than are sandstone intervals in the Salt Wash Member.

The Jackpile Member is 77 m thick at Galisteo Dam. It is mostly yellowish-gray and very pale orange, trough cross-bedded, kaolinitic, subarkosic sandstone with some interbeds of greenish-colored sandy mudstone. The base of the Dakota Sandstone (Oak Canyon Member; no Encinal Canyon Member is present at Galisteo Dam: Lucas and others, 1998) is a prominent disconformity at which clayey, carbonaceous litharenite of the Dakota Sandstone rests directly on kaolinitic subarkose of the Jackpile Member.

San Cristobal Ranch

South of Lamy, the San Cristobal Ranch is a large holding of patented land that encompasses most of the old San Cristobal Land Grant (figure 1). This land was largely inaccessible to geologists until the current owner of the ranch purchased it in 1985. Thus, the only information on the Jurassic stratigraphy of the San Cristobal Ranch previously published was geological mapping by Read and others (1944). I measured two sections of Jurassic strata on the San Cristobal Ranch, at Hub Mesa and at Hub Canyon (figures 3 to 6). The outcrops at Hub Mesa expose the entire local Jurassic section below the Morrison Formation (Entrada, Todilto, and Summerville Formations; Lucas and Cather, 2004) overlain by a nearly complete section of the Salt Wash Member of the Morrison Formation (figure 4). At Hub Canyon, a complete section of the Morrison Formation is exposed, between the underlying Jurassic Summerville Formation and below the overlying Cretaceous Dakota Sandstone (figure 5).

At Hub Mesa, the Salt Wash Member of the Morrison Formation is about 90 m thick, but this is an incomplete section of the unit (figure 4). However, the top of the Salt Wash Member should be a laterally persistent unit overlain by easily eroded Brushy Basin Member mudstone. Thus, the fact that the top of the Hub Canyon section is a mesa defended by Salt Wash sandstone beds (figure 3B) suggests that it may be very close to the top of the Salt Wash Member.

The Salt Wash Member at Hub Mesa (figure 5) is about two-thirds sandstone (68% of the section) and almost one third mudstone (31%). Conglomerate (1%) is a minor constituent of the measured section. Most sandstone beds are subarkosic and have trough cross-beds, but laminar beds are also present. Colors are mostly light gray, grayish yellow and yellowish brown. Mudstone beds that are mostly reddish and less often greenish in color form slopes between sandstone benches. These mudstone beds are not the swelling, smectite-rich clays found higher in the section (see below). Conglomerate beds are lenses in sandstone intervals of intraformational (mudstone, calcrete) rip-up clasts.

At Hub Canyon (figure 5), the Salt Wash Member is about 46 m thick. It is almost equally sandstone (46% of the section) and mudstone (49% of the section) with minor conglomerate (5%). Most of the sandstone beds have trough cross-beds, and some are bioturbated. Mudstone is mostly reddish colored with some greenish-colored bands. Conglomerate beds are pebbly lenses of intraformational (mudstone) pebbles, except for

bed 15, which has extraformational siliceous pebbles. Mudstone in the Salt Wash Member does not swell on outcrop when wet.

The Brushy Basin Member at Hub Canyon is about 108 m thick. It is mostly mudstone (89% of the measured section) with a minor amount of sandstone (11%). Mudstone colors are those characteristic of the Brushy Basin Member regionally—pale green, grayish red, reddish, and salmon. The stratigraphically lowest clay that swells on outcrop with the addition of water is bed 39 (figure 5), and this apparently is what has been called the "clay line" in the Morrison Formation section, at which the mineralogy changes from dominantly illitic to smectitic clay. However, I note that Trujillo (2006) pointed out that such outcrop observations can be misleading because smectitic clays with a high silt content may not swell when wet on outcrop.

At Hub Canyon, the Jackpile Member is about 35 m thick. It is mostly sandstone (63% of the measured section), about one-quarter mudstone (27%), and about 10% conglomerate. Sandstone is subarkosic and kaolinitic, and yellowish gray and white, as is characteristic of the Jackpile Member farther west.

Romeroville

The Jurassic section exposed at Romeroville Gap in San Miguel County (figure 1) was most recently described by Lucas and others (1995b, 1999). Here, the Jurassic section is approximately 85 m thick and is assigned to the Entrada, Todilto, Summerville, and Morrison Formations (figure 7).

Lucas and others (1999) placed the base of the Morrison Formation at Romeroville at a change from siltstone of the Summerville Formation to coarser, pebbly, trough cross-bedded sandstone that characterizes a 5-m-thick interval assigned to the Salt Wash Member (figure 7). Coarse grain size, the presence of clay clasts, and yellowish-brown color characterize the Salt Wash sandstone interval at Romeroville. Bentonitic mudstone beds that are variegated brownish, greenish, and grayish dominate the overlying Brushy Basin Member, which is 80 m thick. The Lower Cretaceous (upper Albian) Mesa Rica Sandstone of the Dakota Group rests disconformably on the Brushy Basin Member at Romeroville (Lucas and others, 1998).

LITHOSTRATIGRAPHIC CORRELATION

Correlation of Jurassic strata across the northern Rio Grande rift (figure 7) is a straightforward one based on lithostratigraphy. Thickness variation of the units in part reflects unconformities or facies changes and is discussed below. No paleontological control of the correlation is available, there are no radioisotopic ages from the sections, and magnetostratigraphy is only available for the Romeroville section (Steiner and others, 1994). Thus, the correlation presented here is purely lithostratigraphic, matching the member-level lithosomes across the transect (figures 7 and 8).

SOME IMPLICATIONS

The correlation presented here of Morrison strata across northern New Mexico improves our understanding of the nature and extent of regional Jurassic unconformities, and of deposition in the Jurassic paleobasin. It documents the continuity of the Morrison depositional systems from the Colorado Plateau eastward onto the southern High Plains.

The base of the Salt Wash Member of the Morrison Formation is here considered to be the regional J-5 unconformity (Anderson and Lucas, 1995, 1998; Lucas and Anderson, 1998). The varied thickness changes in the Salt Wash Member evident across northern New Mexico (figures 7 and 8) likely reflect paleotopography that developed during the hiatus preceding Morrison deposition. Indeed, the thickness trends of the Salt Wash Member across northern New Mexico may identify a large paleovalley in the Hagan Basin-Galisteo Dam-San Cristobal Ranch area that was filled during early Salt Wash Member deposition (figure 8).

Jurassic strata in northern New Mexico are overlain by Cretaceous strata at what Pipiringos and O'Sullivan (1978) termed the K unconformity. These are strata of the Dakota Group (Formation, Sandstone) of late Albian or middle Cenomanian age (Lucas and others, 1998). This unconformity (which represents as much as a 50 million-year-long hiatus) has substantial stratigraphic relief on top of the Morrison Formation, and the disappearance of the Jackpile Member between the San Cris-

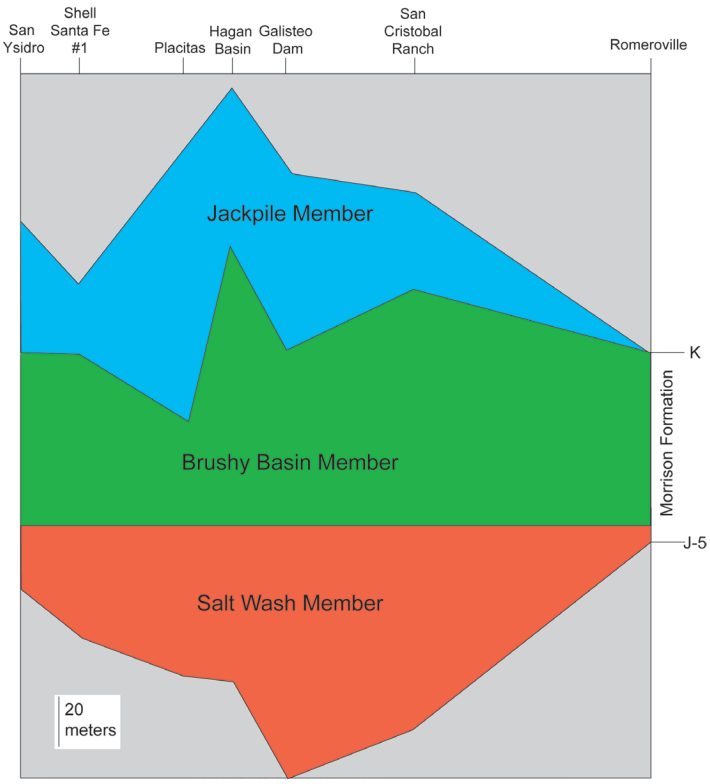

Figure 8. Restored cross section of Morrison Formation from San Ysidro on the southeastern edge of the Colorado Plateau to Romeroville, on the western edge of the southern High Plains, a transect of about 141 km. For location of sections see figure 1. Datum is base of Brushy Basin Member. J-5 and K unconformities are indicated on the right side of the diagram.

tobal Ranch and Romeroville may in large part be due to erosion at this unconformity (figure 8).

The base of the Jackpile Member also has substantial stratigraphic relief on top of the Brushy Basin Member (figure 8). This suggests that the regional (confined to northern New Mexico) low sinuosity river system that deposited the Jackpile Member (e.g., Schlee and Moench, 1961; Moench and Schlee, 1967; Flesch, 1974; Owen and others, 1984) was either (1) incised into the extensive muddy floodplain deposits of the Brushy Basin Member, or (2) there is a hiatus between the Brushy Basin and Jackpile Members during which an incised topography developed through erosion, to be later filled during Jackpile deposition. Unfortunately, there is insufficient age control on the Jackpile Member with which to evaluate these alternatives.

Reconstructions of Morrison depositional systems in the southern Western Interior have largely been confined to the Colorado Plateau (e.g., Peterson, 1994). These studies do not include the Morrison strata on the southern High Plains, and therefore do not encompass the southern or the eastern portion of the Morrison paleobasin. Thus, it is clear that Salt Wash Member deposition was generally by easterly-flowing rivers (Craig and others, 1955; Peterson, 1994; Anderson and Lucas, 1997), but this river system continued well east of the Colorado Plateau, and did not simply end in mudflats and dunes on the Colorado Plateau as depicted by Peterson (1994, figure 20). Salt Wash rivers flowed generally from west to east across the Morrison depositional basin, and clastic input to and subsidence of the basin was highly asymmetrical, with the greatest accumulations of Salt Wash Member in the western part of the basin (e.g., Craig and others, 1955; Anderson and Lucas, 1997).

Continuity of the Brushy Basin Member off the Colorado Plateau onto the High Plains also has particular significance for interpretation of depositional systems. Turner and Fishman (1991) argued that Brushy Basin Member deposition took place in a large, semi-arid lake centered in the Four Corners area with a maximum northwest-southeast dimension of 500 km. However, Brushy Basin Member outcrops off the Colorado Plateau were not included in this lake system, which was termed "Lake T'oo'dichi'" by Turner and Fishman (1991). Dunagan and Turner (2004) later revised this interpretation to recognize an extensive wetland (palustrine depositional system) instead of a lake centered in the Four Corners area.

However, the continuity of the Brushy Basin Member, and its characteristic zeolite-rich clay facies, onto the High Plains suggests that these localized depositional models need to be re-evaluated. Instead, Brushy Basin Member deposition on a vast muddy floodplain, with some localized lacustrine and palustrine depocenters, better encompasses the distribution and facies of the Brushy Basin Member (e.g., Anderson and Lucas, 1997; Galli, 2003, 2014; Tanner and others, 2014). Morrison depositional systems encompassed a significant area east of the Colorado Plateau and need to be interpreted across their entire outcrop area.

ACKNOWLEDGMENTS

Orin Anderson was instrumental in the fieldwork to obtain the stratigraphic data presented here. John Estep, Jess Hunley and Clarence Pigman assisted in the field. Will Singleton granted access to the San Cristobal Ranch, and Wesley Layman facilitated fieldwork there. John Foster, Ken Galli, and Kelli Trujillo provided helpful reviews of the manuscript.

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