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Hilde L. Schwartz and Kim Manley

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Geology and stratigraphy of the *Seismosaurus* locality, Sandoval County, New Mexico

by *Hilde L. Schwartz*, P. O. Box 156, Dixon, New Mexico, 87527
and *Kim Manley*, 4691 Ridgeway Dr., Los Alamos, New Mexico 87544

Abstract

The Brushy Basin Member of the Morrison Formation (Upper Jurassic) is widely exposed in western North America and is well known for its diverse and abundant dinosaur fauna. Before 1985, however, the Brushy Basin in central New Mexico had yielded few fossils and was thought to be relatively barren of dinosaur remains. A group of new fossil sites reverses this view. They contain the remains of several different dinosaur taxa, including the supergiant sauropod *Seismosaurus*. The new localities are in the southeastern San Juan Basin, in an area that is both structurally and sedimentologically complex. Mapping shows that the fossil sites do not occur along a single horizon but are distributed through at least 65 meters of section, occurring in a variety of facies.

Introduction

Since 1985, several important paleontological sites have been discovered in the Morrison Formation approximately 50 km northwest of Albuquerque, New Mexico. The general location of the sites is shown in Fig. 1; precise locality data is not shown, in the interest of fossil protection, but is on file at the New Mexico Museum of Natural History (NMMNH). These sites have yielded dinosaur remains, including those of a supergiant sauropod, *Seismosaurus* (Gillette et al., 1985, 1990; Gillette, 1986, 1991; Gillette and Bechtel, 1989; Schwartz et al., 1989). The fossil localities are near the southwest flank of the southern end of the Nacimiento uplift, where it terminates in a southward-plunging anticline. The badlands in this region delineate the southeastern margin of the San Juan Basin. Stratigraphic units exposed in the area include the Upper Triassic Chinle Formation, the Jurassic Entrada Sandstone, Todilto [considered by some authors part of the Wanakah Formation (Condon, 1989)], and Morrison Formations, and the Cretaceous Dakota Formation and Mancos Shale (Woodward and Ruetschilling, 1976). Prior to the work of Gillette and numerous volunteers, the only significant dinosaur remains reported from this region were a partial (20%) skeleton of a *Camarasaurus* and several *Allosaurus* teeth (Rigby, 1982). Indeed, the Morrison Formation was thought by some to be relatively barren throughout New Mexico (Hunt and Lucas, 1984; Lucas and Hunt, 1985).

Our work was undertaken to provide a geological and paleoenvironmental framework for these new paleontological sites. Local stratigraphy and the sedimentology and petrography of the Seismosaurus I site were studied by Schwartz; Manley mapped the regional geology and established a stratigraphic framework for the network of fossil localities. ☞

FIGURE 1—The study area in the San Juan Basin of northwestern New Mexico. Limits of the San Juan Basin after Aubrey, 1987.

Also in this issue

Coming soon

Geologic hazards in New Mexico—part 2
New fusulinid data and ancestral Rocky Mountain deformation in the Joyita Hills, Socorro County
Hiking to the top of New Mexico—Wheeler Peak

General stratigraphy, age, and structure

The Upper Jurassic Morrison Formation of the Western Interior is a complex, widespread sequence of continental fluvatile and lacustrine sedimentary rocks that is well known for its abundant dinosaur fauna (e.g. Ostrom and McIntosh, 1966; Dodson et al., 1980). In central New Mexico, the Morrison is approximately 230 m thick and consists of four members, in ascending order: the Recapture, the Westwater Canyon, the Brushy Basin, and the Jackpile Sandstone Members (Flesch, 1974, 1975; Owen et al., 1984). These units were mapped by Santos (1975) and are well described in Flesch (1974, 1975) and Flesch and Wilson (1974).

Most of the fossil sites discussed below are in the Brushy Basin Member, the most widely exposed and fossiliferous unit of the Morrison Formation; one site is in the uppermost portion of the underlying Westwater Canyon Member. The Brushy Basin in this part of New Mexico is exposed in broad canyons whose slopes are commonly covered by an overburden of sandstone rubble and rotated, landslid blocks of well-indurated sandstone.

Near the *Seismosaurus* site, the Brushy Basin consists of approximately 80 m of variegated claystones, siltstones, sandstones, and rare limestones, punctuated by resistant ledges of well-indurated sandstone (Fig. 2). Many of the claystones are altered volcanic ash beds, as indicated by relict shard textures in beds that have been altered to clinoptilolite or by their bentonitic clay composition. The ledge-forming sandstones beds in the Brushy Basin range in thickness from several centimeters to several meters and are dominantly coarse-grained arkosic arenites. They are cemented for the most part by siliceous minerals (mainly chalcedony) and minor calcite. Authigenic clays are also present in many horizons. Individual sandstone beds are lenticular, but some extend far enough to be useful as local marker horizons. Highly polished, subangular to subrounded pebbles and cobbles (ranging from 1 cm to 15 cm), of exotic lithologies, also occur in the Brushy Basin. Their origin and significance is currently being studied by Manley (1989, 1991a,b; Johnston et al., 1990). Overall, the Brushy Basin deposits in the study area represent fluvial channel, floodplain, pond, and playa lake facies (Flesch, 1974; Bell, 1986; Turner and Fishman, 1991).

Preliminary K/Ar dates from the Brushy Basin Member near the *Seismosaurus* locality indicate a minimum age of sedimentation of 154 ± 2.4 Ma (Woldegabriel and Hagan, in press). $^{40}Ar/^{39}Ar$ ages for the Morrison Formation at Montezuma Creek, Utah and Dinosaur National Monument, Utah range from 153–145 Ma (Kowallis et al., 1991), and it is unknown to what extent the Morrison Formation may be time-transgressive.

Structurally, the Brushy Basin and Westwater Canyon Members exposed in the study area are dominated by low westerly and southwesterly dips (<10°) and are cut by several NNW- to ENE-trending faults that are predominantly down to the southwest. These faults are high angle and have offsets of as much as 60 m. Sandstone lenses in the Brushy Basin Member contain numerous small fractures with slickenside surfaces, along which net motion has been negligible.

Fossil sites

All the fossil sites described are in T15N, R1W and R1E. To date, more than a dozen dinosaur bone sites have been discovered in the area; of these, nine have been documented and studied. The latter are designated Seismosaurus I (SSI), Seismosaurus II (SSII), Seismosaurus III (SSIII), McConnell I (MCI), McConnell II (MCII), Martini I (MTI), Cary–Kim I (CKI), Cary I (CI), and Lat I (LI). Other localities within a 5 km radius from the main, Seismosaurus I, site have yet to be mapped and studied.

The nine sites discussed below are separated by a maximum distance of 2.8 km, with five of them located within a radius of 1 km. The stratigraphic interrelationships of all the sites could not be directly measured because of erosion and faulting; one group of sites, SSI, SSII, SSIII, MTI, CKI, CI, and LI, is closely spaced and not separated by faulting. Faults separate this group from the MCI and MCII sites, however. The relative stratigraphic positions of these two groups of sites were determined by establishing the irrelationship to the base of the overlying Jackpile Member. Because the Brushy Basin and Jackpile Sandstone may be intertonguing over several meters of vertical section and because the basal contact of the Jackpile Sandstone is locally channeled into the Brushy Basin, these measurements allow for only an approximate correlation.

Fig. 2 illustrates the stratigraphy of the Brushy Basin and uppermost Westwater Canyon Members in the study area and the stratigraphic positions of the fossil sites. The "Seismosaurus" localities: SSI, SSII, and SSIII are, respectively, 26, 31, and 35 meters below the Jackpile Sandstone. McConnell I is approximately 18 m below the base of the Jackpile Sandstone and McConnell II 5 m below the base. The Martini I site is 46 m below SSI and 72 m below the Jackpile Sandstone. Sites CKI and LI occur at about the same stratigraphic level, approximately 32 m below the Jackpile Sandstone. Locality CI lies approximately 39 m below the Jackpile Sandstone. The contact between the Brushy Basin Member and underlying Westwater Canyon Member is not sharp but vertically interfingers through a stratigraphic interval of approximately 20 m. The lower boundary of the Brushy Basin is placed at the top of the highest thick, continuous sandstone unit, in accordance with Flesch (1974).

Site descriptions

Seismosaurus I (SSI)

The largest excavated site and main source of *Seismosaurus* remains thus far is locality SSI. It is near the top of a peninsular mesa that rises 40m above the surrounding valley floor and is capped by a thick, well-indurated sandstone bed. SSI has yielded

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the articulated remains of a single *Seismosaurus* individual, including vertebrae, ribs, chevrons, parts of the inominate bone, and gastroliths (Gillette, 1986, 1991). The bones trend into a hillside and excavation is continuing in search of more. Three of the caudal vertebrae have been prepared and are on display at the NMMNH. Because of its paleontological significance and accessibility, SSI has been studied in greater detail than the other seven sites in the area.

The bones at SSI are enclosed in several different horizons of moderately indurated, buff to grey, arkosic arenite. The sandstone is coarse grained and moderately sorted; its constituent framework grains consist mainly of quartz (80–85%) and feldspar (pla-

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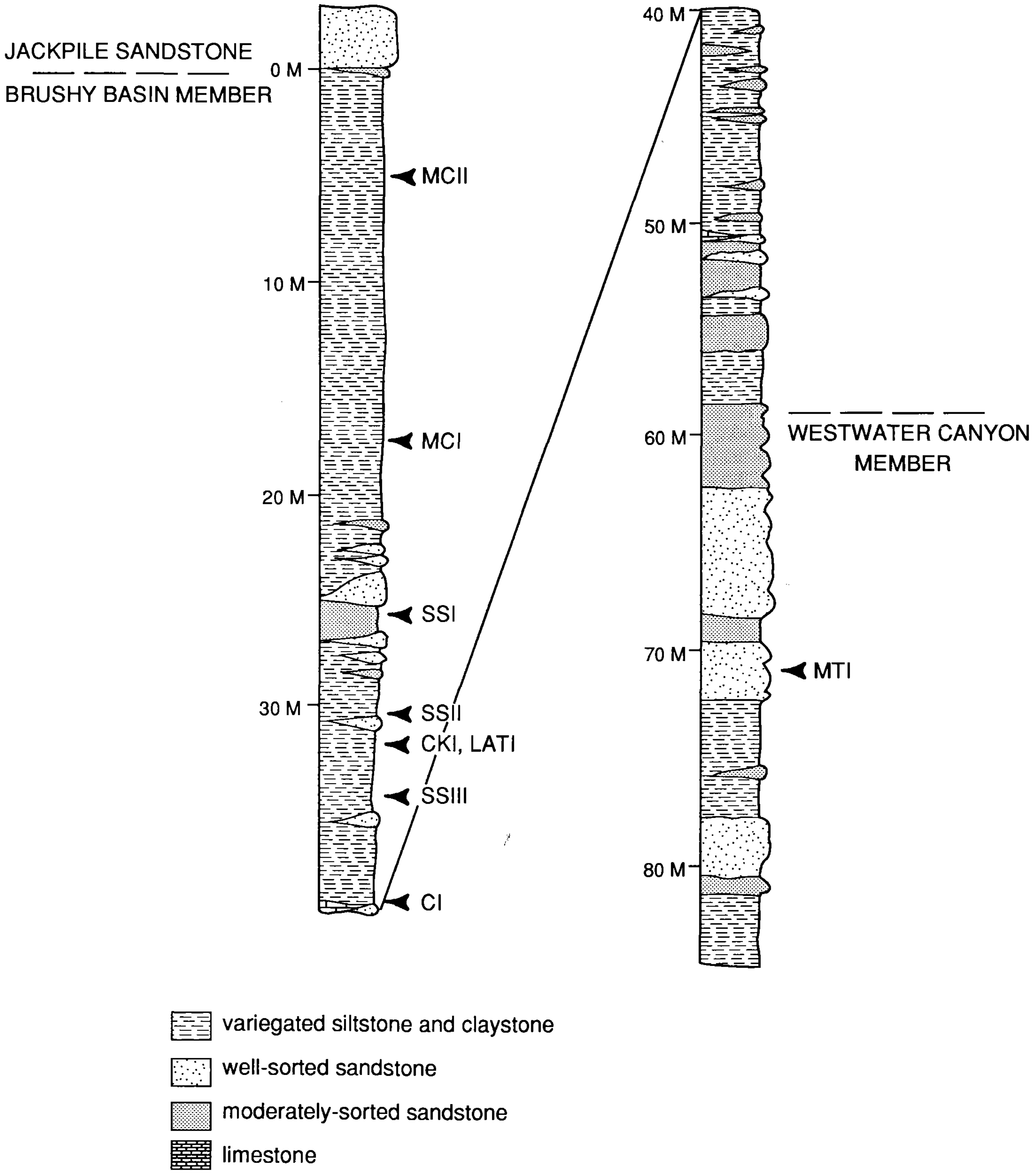

FIGURE 2—Stratigraphy of the Jackpile Sandstone, Brushy Basin, and Westwater Canyon Members of the Morrison Formation in the study area. Arrows on right side of section show the stratigraphic locations of the fossil localities discussed. Meter measurements indicate distance of fossil sites below the Jackpile Sandstone–Brushy Basin contact.

gioclase, microcline, and orthoclase, 15–20%). The quartz grains are subrounded to subangular and contain abundant inclusions. Quartz overgrowths and clay rims are common. Feldspar grains are generally subangular and range in preservation from nearly pristine to completely altered. Both fresh and altered grains commonly exhibit twinning, zoning, or perthitic texture.

Minor detrital grains in the SSI sandstone include heavy minerals (predominantly zircon) and rock fragments. The rock fragments are mainly volcanic materials, consisting of feldspar laths and quartz phenocrysts in a dark, fine-grained matrix. Light-colored mottling in the matrix of some of the fragments suggests relict shard textures. Rare sedimentary rock fragments (chert and silicified siltstone) and igneous rock fragments (polycrystalline quartz with muscovite) also occur in the sandstone. Bone fragments make up a significant percentage of the detrital grains in the SSI sandstone near the contacts between dinosaur bone and matrix as well as in sediment-filled cracks in larger bones.

Diagenetic alterations in bone and matrix at SSI were recognized using petrographic and scanning electron microscopes. Cementation is prevalent, occurring as grain coatings, void fillings, and overgrowths. Clay (smectite) rims are common around detrital grains, pore spaces, and voids in both sandstone and bone, and fill in approximately 45–85% of the sandstone porosity. Locally, a second generation of chalcedony cement and quartz overgrowths is volumetrically important in pore space reduction (approximately 15–55%). The largest pore spaces in the bone are the haversian canals, which are tubes that lie parallel to the long axis of a bone. In living bone, the canals are filled with blood vessels, connective tissue, and nerve filaments, but these organic materials decay and wash out of bone with time and burial. Haversian canals in the interior, spongy parts of *Seismosaurus* bone are cemented exclusively by chalcedony. Variable sorting of the sandstone accounts for discrete, concretionary lenses (pore spaces largely filled with chalcedony) in the quarry area, some of which are associated with fossil bone. A later generation calcite cement is also present locally in the sandstone and bone; its distribution is related to the location of large (to several centimeters thick) root and caliche-filled cracks that criss-cross the sandstone at the SSI quarry (Fig. 3).

A microstratigraphic section of the quarry wall at SSI (Fig. 3) shows the internal structure of the *Seismosaurus*-bearing sandstone. Planar laminations, trough cross-stratification, scour and fill, and repeated fining-upwards sequences predominate, suggesting that the deposit represents a fluvial channel sandstone bed (Fisk, 1944; Folk and Ward, 1957; McGowen and Garner, 1970). Crossbedding at the quarry site shows that current directions were generally to the east and northeast. Scroll bars, representing parts of the point bars of large rivers (Fisk, 1944; Sundborg, 1956), are selectively cemented and weathering out across the upper surface of the *Seismosaurus* mesa, several meters strati-

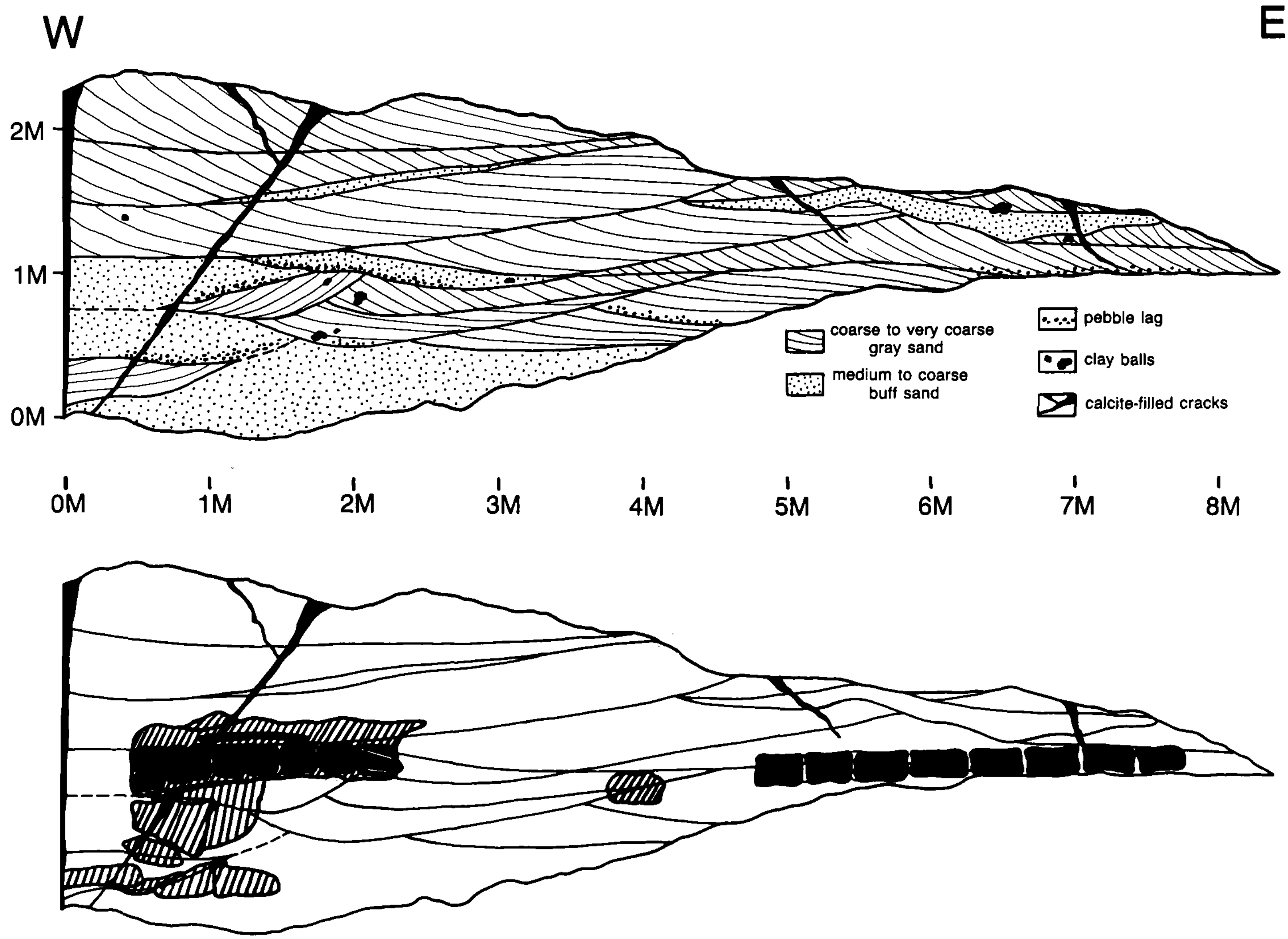

FIGURE 3—Stratigraphy of the SSI quarry: top, lithology and bedding in the northern quarry wall; bottom, position of *Seismosaurus* remains exposed in the south end of the quarry. Bones are colored solid black; bone-bearing, plastered blocks are indicated by diagonal lines. The plastered blocks have not yet been fully prepared and thus the precise positions and shapes of the bones in them is not known. Both bones and blocks are shown superimposed upon a vertical surface. Vertical positions of the bones and blocks were measured by sighting from an established benchmark.

graphically above SSI. They also have an overall east-west orientation and are part of a resistant sandstone that is continuous across several kilometers. Trough cross-bedding, scroll bars, and the sheet-like geometry of the sandstones at SSI all suggest that the *Seismosaurus* died on or near the banks of a large meandering river.

Seismosaurus II (SSII)

SSII is 0.2 km southeast of, on the same mesa as, and 5 m stratigraphically below SSI. It consists of several piles of bone fragments. The fragments are parts of large bones that eroded (apparently in place) from a sandy shelf composed of poorly indurated, buff sandstone. The fossiliferous sandstone was deposited directly above a well-indurated, dark sandstone bed (with abundant 1-cm-sized calcite concretions), and is interpreted to be a paleochannel deposit.

Seismosaurus III (SSIII)

An isolated limb bone was excavated from the SSIII locality. The bone was found in situ in an olive-green claystone, approximately 4 m stratigraphically below SSII. The claystone lies between two channel sandstones and is itself an overbank deposit. SSIII is located approximately 0.2 km northeast of SSI, on a ledge on the north side of the same peninsular mesa.

McConnell I (MCI)

MCI consists of an accumulation of disarticulated skeletal elements, including ribs, teeth, vertebrae, one tooth, and one gastrolith in situ. The bones represent at least two individuals, a sauropod and a carnosaur (Gillette, 1991). They are at the base of a short, steep slope in a silty olive claystone that crops out 2.8 km southeast of SSI. The MCI stratum is part of a thick floodplain-overbank sequence that is near the top of the Brushy Basin Member.

McConnell II (MCII)

Only 0.1 km south-southeast of MCI, the MCII site is stratigraphically 13 m higher than its neighbor. One large bone and numerous bone flakes and fragments (unidentified to date) are exposed here. They are eroding from a dark reddish-brown siltstone bed that is part of the same floodplain-overbank complex as MCI.

Martini I (MTI)

The MTI site is 1.4 km east of SSI in a sandstone and small pebble conglomerate of locally derived clasts that is exposed in the middle of a long, steep, rubble-covered slope. The fossiliferous horizon is part of a channel-point bar facies. MTI is approximately 70 m below the base of the Jackpile Sandstone, in a zone of interfingering between the Brushy Basin and the Westwater Canyon Members. Several large dinosaur bone fragments have been collected from the site.

Cary–Kim I (CKI)

One large bone fragment, resting in float on a rubble-covered slope, was found at CKI. This bone was clearly not in situ, and thus only its lowest possible stratigraphic position is known. The hillslope at CKI is capped by a moderately well indurated sandstone considered equivalent to that capping the mesa at SSI, which provides some measure of control on the upper limit of the site's stratigraphic position.

Cary I (CI)

Various bones and bone fragments are exposed in situ at CI. They are eroding from an olive claystone that crops out 0.8 km south of SSI. Thin, discontinuous limestone outcrops near and stratigraphically just above CI also contain broken fragments of dinosaur bone. These beds represent floodplain deposits that interfinger with pond or lake-margin sediments.

Lat I (LI)

Site LI, about 0.3 km south-southeast of SSI, contains many large fragments of dinosaur bone. The fragments are along one horizon, along 25 m of hillside, but are not in situ; their depositional setting is thus indeterminate. Although one large bone fragment was found in a landslid sandstone block, the rest of the bones lie on a reddish claystone. The hillslope at LI is capped by a well-indurated buff sandstone; it lies between 5 and 8 m above the level at which most of the bones are found.

Conclusions

The Brushy Basin Member of the Morrison Formation in the southeastern San Juan Basin is much richer in dinosaur remains than was previously believed. Both sauropods (at least *Seismosaurus* and *Camarasaurus*, and possibly others) and a theropod have been identified. Nine documented fossil localities within the study area (approximately 2.24 km^2) occur over 65 m of vertical section. They are found in both fine-grained and sandy units, representing a range of paleoenvironments from distal floodplain and pond to fluvial channel and channel top; the fossiliferous sediments may have accumulated near the southern margin of a large alkaline, saline lake (LakeT'oo'dichi'), under semiarid to arid climatic conditions (Turner and Fishman, 1991).

For the most part, the dinosaur remains in the study area represent isolated partial skeletons (articulated and disarticulated) and isolated bones (both complete and broken). In the Morrison Formation to the north of New Mexico, isolated partial dinosaur skeletons and bones occur mainly in floodplain and overbank environments, while mass skeletal accumulations are found mainly in paleochannel deposits (Dodson, et al., 1980). The lack of mass accumulations of dinosaur bone in Morrison Formation paleochannels in the southeastern San Juan Basin suggests that paleoenvironmental conditions varied widely across the Morrison depositional basin (and Lake T'oo'dichi') during the Late Jurassic.

The local abundance of dinosaur bone in this area shows that the Morrison Formation in central New Mexico has great potential for further vertebrate paleontological studies, particularly with respect to taphonomy and paleoecology, and deserves further investigation.

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References

Aubrey, W. M., 1987, The nature of the Dakota–Morrison boundary, southeastern San Juan Basin; *in* Turner–Peterson, C. E., Santos, E. S., and Fishman, N. S. (eds.), A basin analysis case study: the Morrison Formation, Grants uranium region, New Mexico: American Association of Petroleum Geologists, Studies in Geology Series no. 22, pp. 93–104.

Bell, T. E., 1986, Deposition and diagenesis of the Brushy Basin Member and upper part of the Westwater Canyon Member of the Morrison Formation, San Juan Basin, New Mexico; *in* Turner–Peterson, C. E., Santos, E. S., and Fishman, N. S. (eds.), A basin analysis case study: the Morrison Formation, Grants uranium region, New Mexico: American Association of Petroleum Geologists, Studies in Geology Series no. 22, pp. 77–91.

Condon, S. M., 1989, Revisions of Middle Jurassic nomenclature in the southeastern San Juan Basin, New Mexico: U.S. Geological Survey, Bulletin 1808–E, pp. E1–E21.

Dodson, P., Behrensmeyer, A. K., and McIntosh, J. B., 1980, Taphonomy and paleoecology of the dinosaur beds of the Jurassic Morrison Formation: Paleobiology, v. 6, no. 2, pp. 208–232.

Fisk, H. N., 1944, Geological investigation of the alluvial valley of the lower Mississippi River: Mississippi River Commission, Vicksburg, Mississippi, 78 pp.

Flesch, G. A., 1974, Stratigraphy and sedimentology of the Morrison (Jurassic) Formation, Ojito Spring quadrangle, Sandoval County, New Mexico: a preliminary discussion: New Mexico Geological Society, Guidebook to 25th Field Conference, pp. 185–195.

Flesch, G. A., 1975, Stratigraphy, sedimentology, and environments of deposition of the Morrison (Upper Jurassic) Formation, Ojito Spring quadrangle, Sandoval County, New Mexico: MS thesis, Univ. of New Mexico, Albuquerque, New Mexico, 106 pp.

Flesch, G. A., and Wilson, M. D., 1974, Petrography of Morrison Formation (Jurassic) sandstone of the Ojito Spring quadrangle, Sandoval County, New Mexico: New Mexico Geological Society, Guidebook to 25th Field Conference, pp. 197–210.

Folk, R. L., and Ward, W., 1957, Brazos River bar: A study in the significance of grain-size parameters: Journal of Sedimentary Petrology, v. 27, pp. 3–26.

Gillette, D. D., 1986, A new giant sauropod from the Morrison Formation (Upper Jurassic) of New Mexico (abs.): 4th North American Paleontological Convention, Boulder, Colorado, August 12–15, 1986, Proc., v. 4, p. A18.

Gillette, D. D., 1991, *Seismosaurus halli*, gen. et sp. nov., a new sauropod dinosaur from the Morrison Formation (Upper Jurassic/Lower Cretaceous) of New Mexico, USA: Journal of Vertebrate Paleontology, v. 11, no. 4, pp. 417–433.

Gillette, D. D., and Bechtel, J. W., 1989, Pelvic and caudal anatomy of the giant sauropod dinosaur "Seismosaurus" (Morrison Formation, New Mexico) (abs.): Journal of Vertebrate Paleontology, Abstracts of Papers, 49th annual meeting, v. 9, no. 3, p. 22A.

Gillette, D. D., Bechtel, J. W., and Bechtel, P., 1990, Gastroliths of a sauropod dinosaur from New Mexico (abs.): Journal of Vertebrate Paleontology, Abstracts of Papers, 50th annual meeting, v. 10, no. 3, p. 24A.

Gillette, D. D., Gillette, J. L., and Thomas, D. A., 1985, A diplodocine dinosaur in the Morrison Formation of New Mexico (abs.): Annual Symposium of Southwest Geology and Paleontology, Museum of Northern Arizona, Flagstaff, p. 4.

Hunt, A. P., and Lucas, S. G., 1984, Rarity of dinosaurs in the Upper Jurassic Morrison Formation, New Mexico (abs.): Geological Society of America, Abstracts with Programs, v. 16, no. 4, p. 225.

Johnston, R. G., Manley, D., and Lemanski, C. L., 1990, Characterizing gastrolith surface roughness with light scattering: Optics Communications, v. 74, pp. 279–283.

Kowallis, B. J., Christiansen, E. H., and Deino, A. L., 1991, Age of the Brushy Basin Member of the Morrison Formation, Colorado Plateau, western USA: Cretaceous Research, v. 12, pp. 483–493.

Lucas, S. G., and Hunt, A. P., 1985, Dinosaurs from the Upper Jurassic Morrison Formation in New Mexico: New Mexico Journal of Science, v. 25, no. 1, pp. 1–15.

Manley, K., 1989, Technique for distinguishing bona fide and suspected gastroliths (abs.): Annual Symposium of Southwestern Geology and Paleontology, Museum of Northern Arizona, Flagstaff, p. 18.

Manley, K., 1991a, Gastrolith identification and sauropod dinosaur migration (abs.): Geological Society of America, Abstracts with Programs, v. 23, no. 4, p. 45.

Manley, K., 1991b, Two techniques for measuring surface polish as applied to gastroliths: Ichnos, v. 1, pp. 313–316.

McGowan, J. H., and Garner, L. E., 1970, Physiographic features and stratigraphic types of coarse-grained point bars: Modern and ancient environments: Sedimentology, v. 14, pp. 77–111.

Ostrom, J. H., and McIntosh, J. S., 1966, Marsh's Dinosaurs—the collections from Como Bluff: Yale University Press, New Haven, Connecticut, 388 pp.

Owen, D. E., Walters, L. J., Jr., and Beck, R. G., 1984, The Jackpile Sandstone Member of the Morrison Formation in west-central New Mexico—a formal definition: New Mexico Geology, v. 6, no. 3, pp. 45–52.

Rigby, J. K., Jr., 1982, *Camarasaurus* cf. *supremus* from the Morrison Formation near San Ysidro, New Mexico—the San Ysidro dinosaur: New Mexico Geological Society, Guidebook to the 33rd Field Conference, pp. 271–272.

Santos, E. S., 1975, Lithology and uranium potential of Jurassic formations in the San Ysidro–Cuba and Majors Ranch areas, northwestern New Mexico: U. S. Geological Survey, Bulletin 1329, 22 pp.

Schwartz, H. L., Gillette, D. D., and Manley, K., 1989, Taphonomy and paleoecology of the Upper Jurassic (?) "Seismosaurus" locality, San Ysidro, New Mexico: Journal of Vertebrate Paleontology, Abstracts of Papers, 49th annual meeting, v. 9, no. 3, p. 37A.

Sundborg, A., 1956, The river Klaralven: A study of fluvial processes: Geografica Annales, v. 38, pp. 125–316.

Turner, C. E., and Fishman, N. S., 1991, Jurassic Lake T'oo'dichi': A large alkaline, saline lake, Morrison Formation, eastern Colorado Plateau: Geological Society of America, Bulletin, v. 103, no. 4, pp. 538–558.

Woldegabriel, G., and Hagan, R., in press, Diagenetic processes and burial history of the Morrison formation in the southern San Juan Basin, New Mexico; *in* D. D. Gillette (ed.), Chemistry of preservation of dinosaur bone: Springer–Verlag, New York.

Woodward, L. A., and Ruetschilling, R. L., 1976, Geology of San Ysidro quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 37, scale 1:24,000. □

Upcoming geologic meetings

Conference title	Dates	Location	Contact for more information
Sixth Annual BLM Nationwide Natural Gas Policy Act Seminar	June 25	Ramada Hotel Classic Albuquerque	Allen F. Buckingham BLM, Alb. District 435 Montano Road NE Albuquerque, NM 87107 (505) 761-8765
GeoTech '92 Geocomputing Conference	Aug. 29-Sept. 1	Denver, CO	Mark Cramer, GeoTech C.S. 19, P.O. Box 207 Denver, CO 80231-4952 (303) 752-4951
Grant County Rolling Stones Gem and Mineral Society Show	Sept. 5-7	Municipal Recreation Center Silver City, NM	Maurice Williams 2017 Fir St. Silver City, NM 88061 (505) 538-2144
New Mexico Conference on the Environment	Sept. 13-15	Convention Center Albuquerque, NM	NM Environment Dept. 1190 St. Francis Drive P.O. Box 26110 Santa Fe, NM 87502
Denver Gem and Mineral Show	Sept. 18-20	Merchandise Mart Denver, CO	Denver Council Box 621444 Littleton, CO 80162 (303) 978-9926