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The Jackpile Sandstone Member of the Morrison Formation in west-central New Mexico—a formal definition

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The Jackpile Sandstone Member of the Morrison Formation (Upper Jurassic) in west-central New Mexico is named here formally from a stratotype near the Jackpile–Paguate uranium mine. The Jackpile Sandstone is typically a whitish, crossbedded subarkose with clay matrix and interbedded, variegated, pale-green to red, bentonitic mudstone lenses. Contacts with the underlying Brushy Basin Member of the Morrison Formation may be gradational, scoured, or interbedded. The Jackpile extends only a short distance south of the stratotype due to truncation along the basal Dakota unconformity. However, it extends northeast to Lamy, north to near Cuba, and a short distance west and a longer distance northwest into the subsurface of the San Juan Basin. Thickness of the Jackpile ranges from near zero to 300 ft (91 m); at the stratotype it is 100 ft (30 m) thick. Crossbedding indicates a regional easterly paleocurrent-flow direction for the braided-stream and distal alluvial-fan complexes in which the Jackpile was deposited. Source areas were to the west and southwest, south of Gallup, and in the Mogollon Highlands.

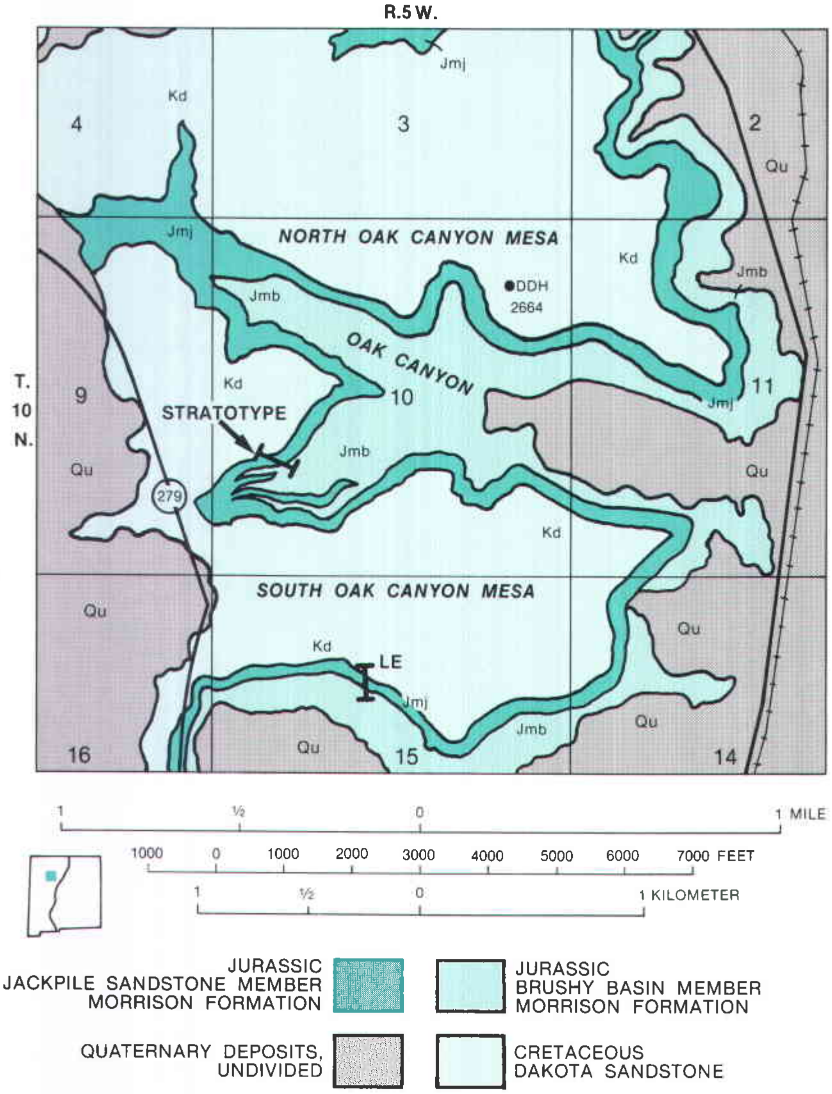

FIGURE 1—Geologic index map of the stratotype area of the Jackpile Sandstone Member (Morrison Formation). Note location of surface measured section illustrated in Fig. 2 and subsurface reference section (DDH 2664) illustrated in Fig. 3. **LE** is the location of an additional measured section. The map has been simplified and modified from Schlee and Moench (1963b); small igneous dikes and sills have been omitted.

Introduction

The Jackpile sandstone of economic usage has been employed informally in stratigraphic nomenclature for a distinctive bed in the uppermost part of the Brushy Basin Member of the Morrison Formation in west-central New Mexico since the Jackpile uranium body was discovered in that bed during 1951. The stratigraphic name Jackpile has ☞

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appeared in many publications in various forms since its first published use by Freeman and Hilpert (1956). The Jackpile sandstone appears on many geologic maps (e.g., Schlee and Moench, 1963a, b), in many government reports (e.g., Moench and Schlee, 1967; Santos, 1975), and in several correlation diagrams (e.g., Owen and Siemers, 1977; Maxwell, 1982). In spite of its use, the Jackpile sandstone has never been named formally. Nash (1968, p. 738) used the term Jackpile ". . . as if a Morrison member." The late Gary Flesch suggested that the Jackpile should be a formal member of the Morrison Formation and established two reference sections for it, but he did not actually formalize it (Flesch, 1974; 1975).

The purposes of this paper are to designate the Jackpile Sandstone Member of the Morrison Formation as a formal stratigraphic unit meeting the requirements of the new North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983) and to discuss the deposition of the Jackpile Sandstone.

Nomenclature and location

The Jackpile Sandstone is named for the Jackpile mine that was opened in the SE1/4 sec. 35, T. 11 N., R. 5 W., Cibola (formerly Valencia) County, New Mexico. The contiguous Jackpile–Paguate mine is the world's largest uranium mine; 24.1 million metric tons (26.51 million short tons) of uranium ore were shipped between 1954, when the mine opened, and 1982, when the mine closed (McLemore, 1982). The stratotype for the Jackpile Sandstone is a measured section of a surface outcrop in SE1/4 NW1/4 SW1/4 sec. 10, T. 10 N., R. 5 W., Mesita 71/2-min quadrangle (Fig. 1). This location is approximately 2.5 mi (4 km) southwest of the original mine opening. The section (Fig. 2; Table 1) was measured on a series of south-facing cliffs north of the south fork of Oak Canyon. These cliffs occur on the face of an unnamed triangular mesa between South Oak Canyon Mesa and North Oak Canyon Mesa at a point 0.3 mi (0.5 km) east of NM–279. A subsurface reference section (Fig. 3) also is provided from a core and log taken in Anaconda Diamond Drill Hole 2664 in SW1/4 NE1/4 NE1/4 of the same section, approximately 0.8 mi (1.3 km) northwest of the stratotype (Fig. 1). Flesch (1974, 1975) suggested two reference sections farther to the north that also are available for study. His 1975 section was published in Siemers et al. (1975, p. 30).

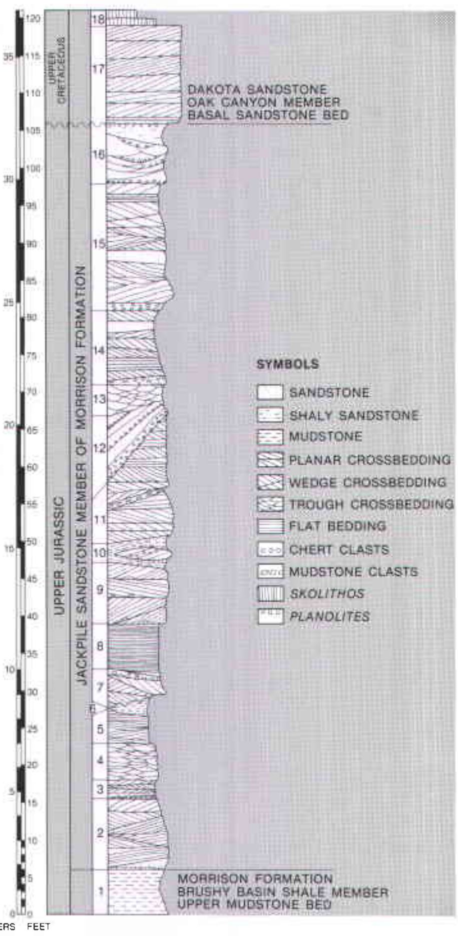

FIGURE 2—Graphic measured section of the Jackpile Sandstone Member (Morrison Formation) and adjacent units at the stratotype. See Table 1 for description of units and Fig. 1 for location of stratotype.

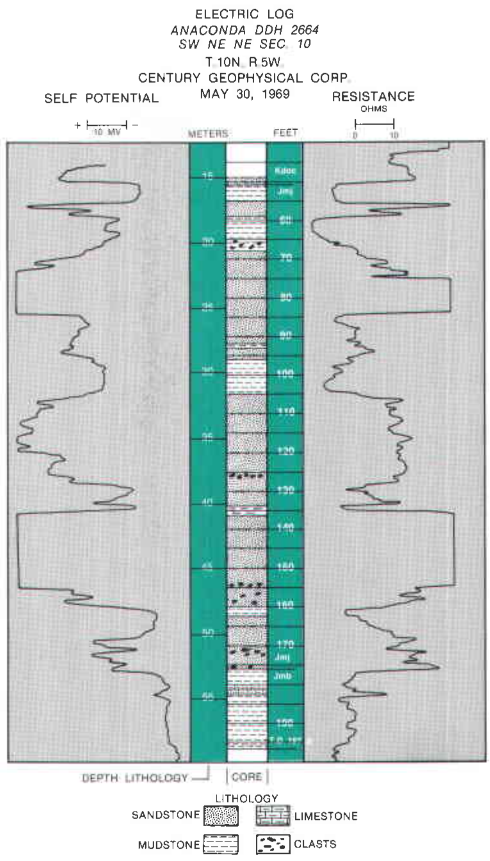

FIGURE 3—Electrical log and core log of the Jackpile Sandstone and adjacent units at the subsurface reference section. See Fig. 1 for location of DDH 2664. "Squared off" ends of spontaneous potential and resistance traces indicate off-scale readings. **Kdoc** is the Oak Canyon Member of Dakota Sandstone; **Jmj** is the Jackpile Sandstone Member of Morrison Formation; **Jmb** is the Brushy Basin Member of Morrison Formation.

Following established informal usage, the Jackpile Sandstone Member of the Morrison Formation is split from the underlying Brushy Basin Member. The Brushy Basin is the most extensive member of the Morrison, being present over nearly all of the Colorado Plateau (Craig et al., 1955, p. 155). At the stratotype, the Jackpile is overlain unconformably by the basal sandstone bed of the Oak Canyon Member of the Dakota Sandstone, which forms the rimrock in all of Oak Canyon (Fig. 4).

Description

LITHOLOGY

The Jackpile Sandstone varies considerably in detailed lithology. Typically, it is an off-white to yellowish-tan, crossbedded, friable, subarkosic sandstone with mostly medium and coarse, subangular to well-rounded, poorly to well-sorted grains in a white clay matrix. The white clay matrix, which is a distinctive feature of the Jackpile, is mostly kaolinite. Some beds are very coarse grained and a few, chiefly at the base of scour surfaces, contain a few pebbles, mostly of chert. Chert-pebble zones are more common in the southwest part of the Jackpile distribution, in the vicinity of the stratotype, than to the north and east. Some Jackpile beds are fine-grained sandstone, but very fine grained sandstone and siltstone beds are rare. Porosity ranges from near 0% to 20% or more and varies inversely with clay-matrix content. Most outcrops contain a few thin lenses and beds of variegated, pale-green to red,

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TABLE 1—LITHOLOGIC DESCRIPTION OF JACKPILE SANDSTONE STRATOTYPE. Unit numbers correspond to numbers in Fig. 2.

Unit	Description	Thickness
Dakota Sandstone: basal sandstone bed of Oak Canyon Member:		
18	Sandstone (quartz arenite), tan, weathers rusty brown; very fine to fine grained, well sorted, subangular to rounded; iron oxide and silica cement; thinly to poorly bedded (partially bioturbated); abundant *Skolithos* burrow fillings; sharp, planar lower contact; eroded back from canyon rim	2 ft (0.6 m)
17	Sandstone (quartz arenite), tan, weathers rusty brown; very fine to fine grained, well sorted, subangular to rounded; silica cement; carbonaceous; medium-scale planar crossbedding; abundant *Planolites* burrow fillings in lower 4 inches (10 cm) that extend into unit below; planar, unconformable lower contact; forms canyon rimrock	13 ft (4 m)
	Total thickness	15 ft (4.6 m)
Morrison Formation: Jackpile Sandstone Member:		
16	Sandstone (lithic subarkose), greenish-gray, fresh and weathered; medium to coarse grained, fines upward, poorly to very poorly sorted, subrounded to rounded; abundant clay matrix, especially in upper part; subrounded to rounded chert pebbles throughout, angular sandstone pebbles and cobbles in upper part, abundant kaolinized feldspar grains; medium-scale trough crossbedding, except in upper clayey part; gradational lower contact; recedes under canyon rimrock above	8 ft (2.4 m)
15	Sandstone (subarkose), off-white, weathers tan; medium to coarse grained, moderately to poorly sorted, angular to rounded; abundant clay matrix; planar and wedge crossbedding with some massive beds; one fining-upward sequence at base with basal chert pebbles and mudstone clasts; sharp, irregular lower contact; moderately resistant	17 ft (5.2 m)
14	Sandstone (subarkose), tan, fresh and weathered; fine to coarse grained, moderately to poorly sorted, subangular to rounded; clay matrix; mudstone clasts and chert pebbles in basal bed; small and medium-scale planar crossbedding and massive beds; one fining-upward sequence at base; sharp lower contact; moderately resistant	10 ft (3 m)
13	Sandstone (subarkose), off-white, weathers tan; fine to medium grained, moderately to poorly sorted, subangular to subrounded; clay matrix; small-scale trough crossbedding; sharp, uneven lower contact; moderately resistant	2–4 ft (0.6–1.2 m)
12	Sandstone (subarkose), off-white, weathers tan; fine to very coarse grained, poorly to moderately sorted, subangular to rounded; clay matrix; chert pebbles, especially in lower 3 ft (0.9 m); medium-scale planar crossbedding; sharp, planar lower contact; moderately resistant	2–9 ft (0.6–2.7 m)
11	Sandstone (subarkose), off-white, weathers tan; fine to coarse grained, well to poorly sorted, subrounded to rounded; clay matrix; mudstone cobble zone near middle; medium-scale planar crossbedding and laminated flat bedding; sharp lower contact; moderately resistant	8–16 ft (2.4–4.9 m)
10	Mudstone, grayish-green, fresh and weathered; silty, sandy, mudstone-clast conglomerate in part; sharp lower contact; non-resistant; with sandstone wedge (subarkose), light tan, weathers light brown; very fine to medium grained, well sorted, subrounded to rounded; clay matrix; few chert pebbles; composed of one set of wedge crossbedding; sharp lower contact; moderately resistant	2.5–4.5 ft (0.8–1.4 m)
9	Sandstone (arkose), light-tan, weathers dark tan; medium to coarse grained, several fining-upward sequences, moderately to poorly sorted, subangular to subrounded; clay matrix; few mudstone clasts; medium-scale wedge and planar crossbedding; sharp, planar lower contact; moderately resistant	8 ft (2.4 m)
8	Sandstone (subarkose), off-white, weathers tan; very fine to medium grained, well to moderately sorted, angular to rounded; clay matrix; thinly flat-bedded, changes to crossbedded to west; sharp, planar lower contact; weakly resistant	6.5 ft (2m)
7	Sandstone (lithic subarkose), off-white, weathers light brown; medium to very coarse grained, moderately to poorly sorted, angular to rounded; clay matrix; abundant mudstone clasts up to 6 inches (15 cm) diameter in bed near top; medium-scale, planar to wedge crossbedding; load casts on base with up to 1 ft (0.3 m) relief; sharp, very uneven lower contact	3–5 ft (0.9–1.5 m)
6	Mudstone, grayish-green, fresh and weathered; silty, sandy, feldspathic, common glass shards; thinly bedded; sharp, irregular lower contact; nonresistant	0–3 ft (0–0.9 m)
5	Sandstone (subarkose), yellowish-tan, weathers light brown; fine to coarse grained, poorly sorted, subangular to rounded; clay matrix; medium-scale planar crossbedding and flat bedding; sharp, flat lower contact; moderately resistant	3–5 ft (0.9–1.5 m)
4	Sandstone (arkose), very light tan, fresh and weathered; fine to very coarse grained, moderately to poorly sorted, subangular to subrounded; clay matrix; quartz overgrowths; small-scale trough crossbedding, gradational lower contact; moderately resistant	5 ft (1.5 m)
3	Sandstone (subarkose), light yellowish-tan, fresh and weathered; fine to coarse grained, several fining-upward sequences, well to poorly sorted, subrounded to rounded; clay matrix; chert pebbles near base; small-scale planar crossbedding; sharp, flat lower contact; weakly resistant	2.5 ft (0.8 m)
2	Sandstone (arkose), light yellowish-tan, fresh and weathered; fine to very coarse grained, moderately to poorly sorted, angular to rounded; clay matrix; basal chert pebble and mudstone clast zone; low-angle, medium-scale wedge crossbedding; sharp, uneven (scoured) lower contact changing to gradational to west; weakly resistant	9.5 ft (2.9 m)
	Total thickness	100 ft (30.5 m)
Morrison Formation: upper mudstone bed of Brushy Basin Member:		
1	Mudstone, grayish-green, weathers light grayish-green; silty, sandy; poorly bedded, fractured; lower contact concealed; non-resistant	6 ft (1.8 m)
	Total thickness	6 ft (1.8 m)

☞

FIGURE 4—View of the Jackpile Sandstone and adjacent units at the stratotype. Person is standing on upper part of Brushy Basin Member. Dark rimrock at skyline is basal Oak Canyon Member of Dakota Sandstone. Light-colored cliffs are Jackpile Sandstone Member (thickness: 100 ft; 30 m).

bentonitic mudstone. Locally, these may be thick and extensive. Mudstone clasts are fairly abundant in some sandstone beds and range from pebble to boulder size.

At the stratotype, Jackpile sandstones have an average composition of 58% quartz and chert, 16% feldspars, 5% rock fragments, and 21% clay matrix, based on point counts of 22 thin sections for major components (Table 2; Fig. 5). Significant minor components include very fine crystalline pyrite, organic carbonaceous material not recognized easily in hand specimens, iron oxide, and iron carbonate minerals. Of the 22 samples, 15 are subarkoses according to the classification of McBride (1963). Average porosity by point count is 10%.

Contacts

The contacts of the Jackpile Sandstone Member with adjacent stratigraphic units are distinct and easily recognized in outcrops and cores, but not so easily recognized on well logs. The basal contact with the Brushy Basin Member is well marked by a color and lithologic change from green and red mudstone to off-white to yellowish-tan sandstone (Fig. 6). At most localities this lithologic change is gradational through a few inches; at some localities the contact is sharp and scoured; and at a few localities, intertonguing of Brushy Basin mudstone and Jackpile sandstone takes place within a few tens of feet. Schlee and Moench (1963b) mapped such an intertonguing just west and south of the stratotype in the same quarter section (Fig. 1).

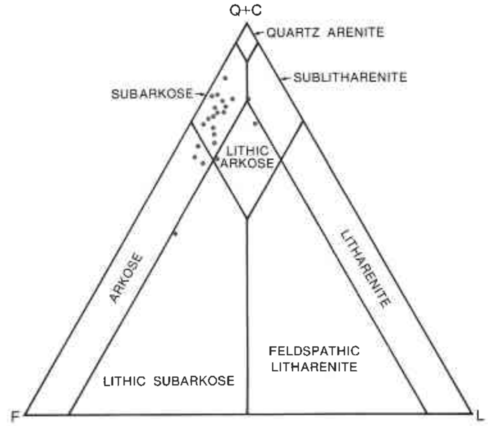

FIGURE 5—Plot of classification of Jackpile Sandstone samples from the stratotype. The sandstone classification is from McBride (1963). The Jackpile sandstones are predominantly subarkosic (15 of 22 samples).

The upper contact of the Jackpile Sandstone with the Dakota Sandstone is an easily recognized unconformity with a typical lithologic and color change from the light-colored, near-white Jackpile sandstone to the darker colored, commonly iron-oxide-stained Dakota sandstone (Fig. 7). A very thin conglomerate or pebbly sandstone bed is fairly common on the unconformity. The basal Da-

TABLE 2—Modal compositions of the Jackpile Sandstone at the stratotype.

	Constituents (%)													
Sample (unit)	Quartz	Chert	Plagioclase	K-Feldspar	Rock fragments	Clay[1]	Porosity	Heavy minerals	Biotite	Calcite	Iron oxide/ iron carbonate	Pyrite/ OCM[2]	Total	Points counted
1(1)	42.4	1.0	5.6	3.4	1.0	41.2	tr	1.0	tr	0.0	4.6	1.0	101.2	323
2(2)	47.0	2.9	10.8	3.5	1.3	30.2	1.0	tr	0.0	0.0	0.0	2.9	99.6	315
3(2)	39.7	4.0	9.0	9.3	5.7	10.7	18.0	0.0	0.0	2.0	1.3	tr	99.7	300
4(2)	31.2	1.3	17.2	12.7	7.1	15.3	12.3	1.0	0.0	tr	1.9	tr	100.0	308
5(3)	57.7	1.0	12.5	5.1	2.5	2.9	15.1	tr	0.0	0.0	tr	2.6	99.4	312
6(4)	52.1	1.0	16.5	3.6	3.6	4.6	14.2	1.0	tr	0.0	1.6	1.6	99.8	303
7(5)	50.2	1.6	10.5	1.6	3.3	13.8	8.8	tr	1.0	0.0	5.9	3.6	100.3	305
8(6)	21.0	4.8	4.8	0.0	0.0	66.3	1.6	0.0	1.0	0.0	tr	tr	99.5	309
9(7)	41.5	2.6	11.3	5.0	7.4	15.3	9.3	0.0	tr	tr	1.0	6.3	99.7	301
10(8)	48.9	tr	10.5	1.6	3.3	15.4	14.1	0.0	tr	0.0	1.0	4.9	99.7	305
11(9)	41.3	1.2	14.9	3.5	3.9	4.8	1.6	1.0	0.0	0.0	16.2	11.7	100.1	315
12(10)	51.8	1.3	10.2	2.0	3.3	10.2	12.5	tr	0.0	0.0	0.0	8.5	99.8	305
13(11)	45.8	1.0	10.4	2.6	3.9	13.6	7.8	0.0	tr	0.0	0.0	14.9	100.0	308
14(11)	56.4	1.6	9.0	3.2	4.5	8.0	16.3	0.0	tr	0.0	0.0	1.0	100.0	312
15(11)	48.0	3.9	7.2	2.9	2.0	8.5	17.0	0.0	tr	0.0	9.1	1.0	99.6	306
16(11)	49.8	2.2	13.8	1.3	6.1	11.2	12.9	0.0	tr	0.0	1.3	1.3	99.9	311
17(12)	51.3	1.2	6.7	3.8	4.2	12.8	18.3	0.0	0.0	0.0	0.0	1.6	99.9	312
18(13)	61.4	2.6	7.5	1.3	2.3	9.1	10.4	0.0	1.0	0.0	0.0	4.9	100.5	308
19(14)	44.7	2.0	11.3	3.6	5.8	18.8	9.1	0.0	0.0	0.0	0.0	4.8	100.1	301
20(15)	52.4	1.6	8.4	1.9	3.2	20.4	3.6	0.0	0.0	0.0	2.6	5.8	99.9	309
21(15)	46.6	2.0	6.2	1.6	4.6	28.5	7.5	0.0	0.0	0.0	0.0	2.9	99.9	305
22[3](16)	48.6	4.5	3.7	3.7	11.1	28.4	—	0.0	0.0	0.0	0.0	0.0	100.0	109
Mean	46.8	2.0	9.9	3.5	4.0	17.7	10.0	tr	tr	tr	4.2	3.7	99.9	
Dakota Sandstone														
23(17)	65.3	1.6	1.6	0.0	tr	0.0	tr	0.0	0.0	0.0	0.0	31.5	100.0	311
24(18)	82.4	0.0	1.0	0.0	0.0	7.1	7.8	0.0	0.0	0.0	1.0	1.0	100.3	307

Notes: 1. Includes clay pore fillings, clay rims, and matrix
2. OCM = Organic carbonaceous material
3. Grain mount, porosity was not determined

FIGURE 6—Brushy Basin–Jackpile contact at the stratotype. Note the ledge of Jackpile Sandstone resting on fractured Brushy Basin mudstone.

FIGURE 7—Jackpile–Dakota contact at the stratotype. The contact, an unconformity, is at the color change from light-colored Jackpile to dark-colored Dakota midway on hammer handle. The Dakota is characteristically more resistant than the Jackpile and forms an overhanging ledge.

kota is a fluvial-channel sandstone at some localities and a transgressive-marine sandstone with sand-filled burrows of *Planolites* extending down a few inches into the Jackpile at other localities, including the stratotype (Fig. 8). The uppermost Jackpile may be green or red mudstone instead of sandstone at some localities. Rarely, a basal Dakota sandstone bed is not present, which leaves a black, carbonaceous shale of the Dakota resting directly on the unconformity.

Recognition of the Jackpile Sandstone Member contacts on subsurface well logs is difficult. The basal Jackpile contact is fairly easy to recognize due to the deflection to the left of spontaneous potential (S.P.) and gamma-ray curves and an increase in resistivity due to the lithologic change from Brushy Basin mudstone to Jackpile sandstone (Fig. 3). However, because the lower Jackpile locally intertongues with the upper Brushy Basin, because mudstone lenses occur in the Jackpile, and because channel-sandstone lenses occur in the Brushy Basin, the exact location of the contact on some well logs is debatable.

The Jackpile–Dakota contact, an unconformity, does not register distinctly on well logs because it is generally a sandstone–sandstone contact. It can be correlated with some uncertainty. However, in the subsurface reference drill hole (Fig. 3) the uppermost Jackpile is mudstone and the lowermost Dakota is sandstone, so that the contact may be placed at the S.P. and resistivity deflections.

Distribution

The extent of the Jackpile Sandstone to the south, southwest, and southeast of the stratotype is closely limited by truncation along the basal Dakota unconformity. Accordingly, the Jackpile is not present south of the Rio San Jose valley (Fig. 9) southwest of the stratotype (Moench, 1963; Moench and Schlee, 1967, pl. 3). The Jackpile also is truncated southeast of the stratotype on the northern part of Mesa Gigante (Moench and Puffett, 1963a, b; Moench and Schlee, 1967, pl. 3) and is not present south of there. Moench and Schlee (1967, pl. 3) showed that the Jackpile extends northwest into the subsurface only 2–3 mi (3–5 km), and Adams and Saucier (1981) showed that it extends only 6 mi (10 km) northwest from the vicinity of the stratotype.

The extent of the Jackpile north of the stratotype is a subject of some disagreement, although most recent authors agree that it extends north 50–70 mi (80–110 km) to approximately latitude 36° N. near Cuba, New Mexico (Fig. 9). Woodward and Schumacher (1973) traced it north to latitude 36°2′. Flesch (1974) mapped the Jackpile north to 35°7′30″ and was confident that it extended at least north of 35°45′ (Flesch, personal communication 1975). Saucier (1974) extended the Jackpile north to approximately 35°45′. Lupe (1983) correlated the Jackpile in the subsurface near the outcrop north to approximately 35°50′. Santos (1975) mapped the Jackpile north to approximately 36°; Owen and Siemers (1977) gave evidence that the Jackpile extends to approximately 36°.

The problem in defining the northern extent of the Jackpile lies in distinguishing between the Jackpile Sandstone and the Burro Canyon Formation. These two units are of similar lithology and identical stratigraphic position between the Brushy Basin Member of the Morrison Formation and the Dakota Sandstone along the Nacimiento front near Cuba. Owen and Siemers (1977, p. 180) ☞

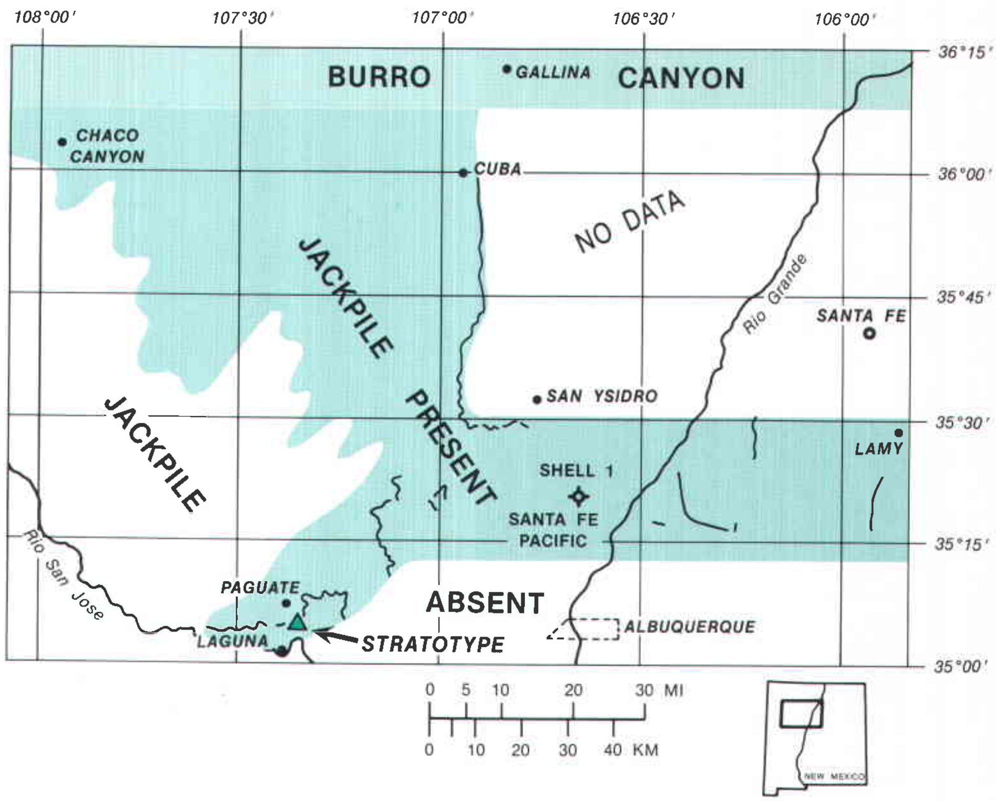

FIGURE 9—Map of approximate distribution of Jackpile Sandstone in west-central New Mexico. The Jackpile probably was deposited in the "no data" area in the eastern part of the study area, but has been removed by erosion on uplifts or covered by thick Rio Grande graben fill. The boundary on the south is due mostly to tilting and erosion along the basal Dakota unconformity. The subsurface distribution west of the outcrops is from Adams and Saucier (1981, pl. 3). The approximate southern limit of the Burro Canyon Formation is shown diagrammatically along the northern edge of the map.

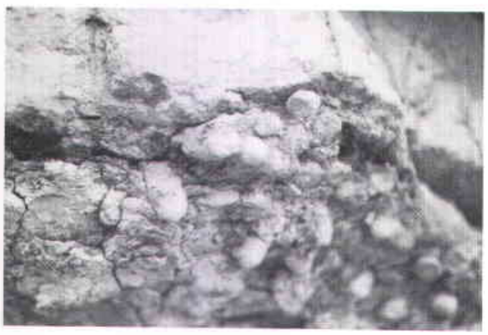

FIGURE 8—Close-up view of sand-filled *Planolites* burrows on Dakota–Jackpile unconformity. The burrow fillings are approximately 1 inch (2.5 cm) in diameter.

pointed out that the only noticeable differences between the Burro Canyon and the Jackpile along the eastern flank of the San Juan Basin are: 1) the Burro Canyon has an unconformable basal contact, whereas the Jackpile has a conformable, but locally scoured, basal contact; 2) the Burro Canyon is generally a conglomeratic sandstone, whereas the Jackpile is generally free of conglomeratic sandstone except for a few pebbles near the base. Based on these criteria, we conclude that the Jackpile extends north to the excellent exposure at lat. 35°59′20″ N. in the roadcut between the Nacimiento open-pit copper mine and tailings pond in SW1/4 NE1/4 SE1/4 sec. 2, T. 20 N., R. 1 W., 3.8 mi (6.1 km) southeast of Cuba. Exposures north of this locality are rare for about 17 mi (27 km) and so poor that a clear Burro Canyon–Jackpile distinction could not be made. However, the next series of well-exposed outcrops near Gallina (Fig. 9) from about 36°15′ north clearly shows Burro Canyon characteristics.

The Jackpile Sandstone can be recognized in some wells near the outcrop west of the Nacimiento front, but we have not studied to any great extent its distribution in the subsurface of the San Juan Basin. However, Adams and Saucier (1981, pl. 3) have mapped the subsurface Jackpile along a northwest trending zone from the outcrop to near Chaco Canyon (Fig. 9). Saucier (personal communication 1984) reported good control for the Jackpile mapped north to about lat. 35°40′ N., but less control for the area northwest to Chaco Canyon. The sandstone cored in the Department of Energy holes near Chaco Canyon may be from the Burro Canyon Formation. Lupe (1983) was rather conservative when he correlated the Jackpile from the outcrop into the subsurface. It appears that the Jackpile can be correlated several miles farther west and north on many of his well logs.

The Jackpile can be mapped easily to the points where it enters the subsurface in the Rio Grande graben 20–25 mi (32–40 km) northeast of the stratotype. It is present in some wells in the graben area. For example, the Jackpile can be recognized on the electric log of the Shell No. 1 Santa Fe Pacific well 43 mi (69 km) northeast of the stratotype (Fig. 9) at depths from 6812 to 6907 ft (2076–2105 m). A core across the Jackpile–Dakota unconformity allows identification of this contact. Lupe (1983) picked this contact 22 ft (7 m) high in this well by including the Oak Canyon basal sandstone in the Jackpile. East of the Rio Grande, the Jackpile is present at nearly all the isolated outcrops as far northeast as Lamy, New Mexico (Fig. 9), 14 mi (23 km) south of Santa Fe and 87 mi (140 km) northeast of the stratotype. This distribution east of the Rio Grande has not been well known, but was recently pointed out by Owen (1982, p. 268).

Thickness

At the stratotype, the Jackpile Sandstone is 100 ft (30 m) thick; in the subsurface reference section 0.8 mi (1.3 km) to the northeast, it is 125 ft (38 m) thick. The Jackpile varies considerably in thickness in the vicinity of the stratotype. The stratotype is located on the west flank of a syncline mapped by Moench and Schlee (1967, pl. 3) in which the Jackpile varies in thickness from 90 to 120 ft (27–37 m) due to slight discordance in structure between the Jackpile and Dakota. At another section, measured on the south face of South Oak Canyon Mesa, 0.7 mi (1.1 km) south of the stratotype (**LE** on Fig. 1), the Jackpile is only 52 ft (16 m) thick.

Regionally, the Jackpile also varies considerably in thickness. The Jackpile attains its maximum thickness and greatest average thickness northeast of the stratotype in an east–northeast-trending, thick belt that is 13 by 33 mi (21 by 53 km; Moench and Schlee, 1967, pl. 3). It reaches 200 ft (61 m) in thickness at several places in this belt, but thickens locally to the extreme of 300 ft (91 m; Kozusko and Saucier, 1980). Santos (1975, pl. 2) showed that most of the Jackpile is between 60 and 120 ft (18 and 37 m) thick and that it wedges out locally. Farther north, the Jackpile averages about 60 ft (18 m) in thickness, but it varies locally in the outcrops between about lat. 35°30′ and 35°40′ N. (Fig. 9). The Jackpile is thicker, generally about 130 ft (40 m), but locally variable from 35°40′ to its northern extent near 36° (Fig. 9). Santos (1975, pl. 1) mapped one outcrop approximately 0.7 mi (1.1 km) long where the Jackpile wedged out in this area. At the isolated outcrops east of the Rio Grande, the Jackpile varies considerably in thickness, even in short distances. Measured thicknesses there range from about 50 to 110 ft (15–33.5 m).

Sedimentary structures

Crossbedding is the dominant sedimentary structure in Jackpile sandstones (Fig. 10).

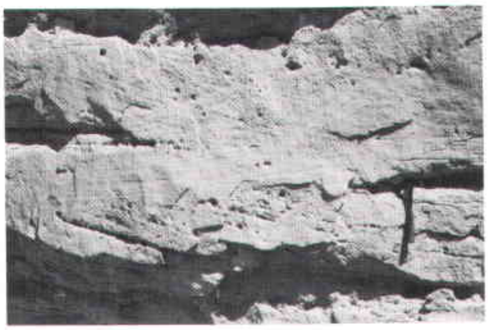

FIGURE 10—Easterly dipping crossbedding in lower part of Jackpile Sandstone at stratotype. Note the thinner, plane-bed zone in the middle part. Large holes in sandstone are molds formed by weathering out of mudstone clasts.

About 90% of Jackpile sandstones are crossbedded; most of the remainder are flat-bedded and a few are massive. The typical crossbed is a medium-scale wedge set with internal, planar cross-laminations. Tabular-sets, trough-sets, and concave-up cross-laminations are less common. Thickness of sets averages about one foot (0.3 m), but ranges from one inch to several feet. Regionally, the average dip direction of the crossbedding is easterly, but local and bed-to-bed variations do occur. At the stratotype, 32 measurements of crossbedding (Fig. 9) distributed throughout the Jackpile yielded a northeasterly mean dip direction of 53° (Fig. 11) with a vector magnitude of 52.5% and an F statistic of 2.23 (statistically significant at greater than 1%). The crossbedding would be oriented even more strongly if it were not for a scattering of five westerly dip directions in the upper part of the Jackpile. Other sedimentary structures seen in the Jackpile include rare parting lineations, ripple marks, load casts, and very rare insect burrows.

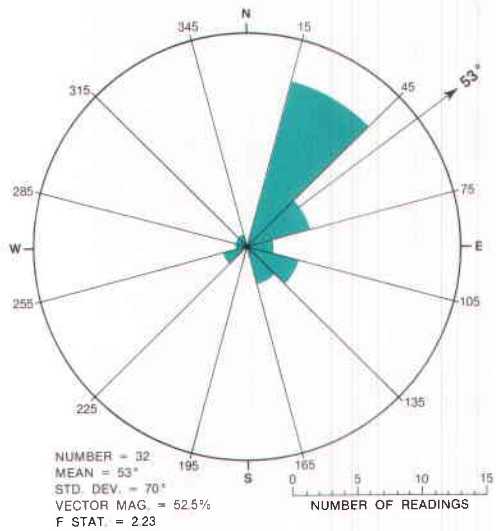

FIGURE 11—Compass rose diagram of Jackpile crossbedding directions at stratotype. The northeasterly mode and mean (53°) indicate paleocurrent-flow direction. The mean direction is statistically significant at greater than 1%. The small, southeasterly mode is not statistically significant. All five westerly readings are from the upper part of the Jackpile.

Interpretation

Age

No index fossils have been reported from the Jackpile Sandstone; therefore, no well-defined, paleontologically based age is known. The only fossils that have been discovered in the Jackpile are a few specimens of carbonaceous and petrified wood fragments and logs, insect burrows, and unidentified dinosaur bones. The stratigraphic position of the Jackpile between the rest of the Morrison Formation (reportedly Upper Jurassic) and the Dakota Sandstone (Cenomanian or lowest Upper Cretaceous) would allow it to be placed in the Upper Jurassic or Lower Cretaceous or both. Rubidium–strontium isotopic ages of very early, diagenetic barren-rock montmorillonite from nine samples of the Jackpile Sandstone at the Jackpile–Paguate mine have a mean isotopic age of 142 ± 14 Ma according to Brookins (1980, p. 54). This isotopic age was recalculated from the 146 ± 5 Ma age reported by Lee and

Brookins (1978). Such an isotopic age would give a minimum age for deposition of the Jackpile, but probably it is close to the actual age of deposition. Unfortunately, the numerical boundaries for ages of the Late Jurassic and Early Cretaceous are in considerable disagreement in the four most recently published radiometric time scales (Odin, 1982a, b; Harland et al., 1982; Palmer, 1983; van Hinte, 1976a, b). The Jurassic–Cretaceous boundary occurred 130 Ma according to Odin (1982a, b), 135 Ma according to van Hinte (1976a, b), and 144 Ma according to Harland et al. (1982) and Palmer (1983). An age of 142 Ma would have occurred sometime during the Late Jurassic Epoch according to almost all recently published time scales except the ones of Harland et al. (1982) and Palmer (1983), where it just barely falls within the Early Cretaceous (by only 2 m.y.). On Odin's scale (1982a, b) 142 Ma occurred during the Oxfordian Age of the Late Jurassic.

Until much closer agreement is reached on numerical calibration of Late Jurassic and Early Cretaceous age boundaries, we can only conclude that the Jackpile Sandstone probably was deposited during the Late Jurassic because Brookins' dates (1980) are minimum dates of deposition. Yet there still remains a slight possibility that it could have been deposited during the Early Cretaceous.

Brookins (1980) also reported that the rubidium–strontium isotopic age for Jackpile clays contemporaneous with uranium mineralization was 113 ± 7 Ma and that the age for very early diagenetic clays from the Dakota was 93 ± 8 Ma. These data indicate that the hiatus associated with the Jackpile–Dakota unconformity might be on the order of 40 m.y. (approximately all of Early Cretaceous time) and that uranium mineralization occurred during the middle of this hiatus. The 93 Ma minimum isotopic age for the Dakota agrees closely with its paleontologically determined Cenomanian age and with all of the time scales cited above.

Correlation

Significant uncertainties exist in lithostratigraphic correlation of the Jackpile Sandstone in the subsurface of the San Juan Basin and the possible confusion of the Jackpile with the Burro Canyon Formation, a Lower Cretaceous unit. For example, Swift (1956, p. 45) included all of what is now known as Jackpile and Burro Canyon from the Colorado state line to Mesa Gigante in his informal Deadmans Peak formation.

The exact age of the Jackpile is so poorly known that little can be said regarding chronostratigraphic correlation except that beds of the same age as the Jackpile may occur in the much more extensive Brushy Basin Member where the Jackpile was not developed.

Genesis

There is broad agreement among many authors who have discussed the provenance and depositional setting of the Jackpile Sandstone that it is dominantly a braided-stream deposit derived from a source area to the southwest and deposited in a fairly arid climate. Recently, Bell (1981) found evidence of tuffs that were altered in an arid climate and closed-basin evaporite minerals in the associated Brushy Basin Member including the area where the Jackpile Sandstone is present. In order to account for the logs deposited in the Jackpile, the source area of Jackpile sediments may have been somewhat less arid than at the depositional site. However, after Jackpile deposition and before Dakota deposition, there was a period of intense weathering in a humid climate that produced the weathered feldspars and white kaolinite in the Jackpile (Adams and Saucier, 1981, pp. 33–34).

In our view, the Jackpile was deposited by low to moderate sinuosity, easterly flowing, sandy braided-stream systems and on the distal portion of low-gradient alluvial-fan complexes. Migrating sand bars of various shapes in shallow water under low to moderate flow velocities in the lower flow regime formed the abundant crossbedding in the sandstones. The considerably less abundant, flat-bedded sandstones may have been formed during periods of higher flow velocity which produced upper flow regime plane-bed conditions. Paleocurrent data derived from the abundant crossbeds indicate a mean easterly paleoflow direction, although local variations occurred. The thin lenses of mudstone were deposited mostly in temporarily abandoned braid channels; many of the deposits were later ripped up to form mudstone clasts when the channel was reoccupied. The less common, thick lenses and beds of mudstone may represent local overbank deposits.

The thickest part of the Jackpile was deposited in a contemporaneously subsiding, structural depression according to Schlee and Moench (1961). Other fan complexes were developed near Cuba and Lamy (Fig. 9), but they are generally thinner. Local areas where the Jackpile is absent within its area of distribution may represent small interfluvial areas between braided-stream systems.

The proximal part of the alluvial-fan complex south and west of the stratotype has been removed by truncation along the basal Dakota unconformity. Therefore, the distance to the source area is conjectural. Moench and Schlee (1967, p. 21) suggested that the source of the Jackpile was a rejuvenated area south of Gallup, New Mexico, that was also the source area of other Morrison sandstone members. In this case the Jackpile would be a more easterly alluvial-fan complex similar to, but smaller than, the alluvial-fan complexes in the Salt Wash, Recapture, and Westwater Canyon Members as mapped by Craig et al. (1955) and discussed by Saucier (1976) and Galloway (1979). The Mogollon Highlands of southwest New Mexico and southeast and central Arizona also may have contributed detritus derived from basement rocks that mixed with the closer sedimentary source areas to form the Jackpile and other Morrison alluvial-fan complexes.

Conclusions

The Jackpile Sandstone Member is named here formally as the uppermost member of the Morrison Formation (Upper Jurassic) from a stratotype exposed near the Jackpile–Paguate uranium mine in Cibola County, west-central New Mexico. The stratigraphic name, Jackpile, has been used informally for this unit by numerous authors for many years.

The Jackpile is typically a whitish, medium- to coarse-grained, crossbedded, subarkosic sandstone with clay matrix and interbedded, variegated, pale-green to red, bentonitic mudstone lenses. At the stratotype the sandstone averages 58% quartz and chert, 16% feldspars, 5% rock fragments, and 21% clay matrix.

The lower contact of the Jackpile with the Brushy Basin Member of the Morrison Formation is gradational through a few inches, locally scoured, and interbedded at a few localities. The upper contact with the Dakota Sandstone is an unconformity.

The Jackpile extends only about 10 mi (16 km) southwest and 8 mi (13 km) southeast of the stratotype due to truncation along the basal Dakota unconformity, but it also extends northeast across the Rio Grande to Lamy, New Mexico, 87 mi (140 km) from the stratotype. It appears to extend north about 65 mi (105 km) to just south of Cuba, New Mexico. The Jackpile has been mapped northwest into the subsurface of the San Juan Basin to near Chaco Canyon by Adams and Saucier (1981, pl. 3).

The thickness of the Jackpile increases to the northeast from 100 ft (30 m) at the stratotype to 200 ft (61 m) or more in a contemporaneously subsiding depression. Farther north, it thins to approximately 60 ft (18 m) in the outcrops near San Ysidro, New Mexico, but thickens to approximately 130 ft (40 m) along the Nacimiento front south of Cuba, New Mexico. The Jackpile wedges out in several places and varies in thickness east of the Rio Grande.

Regionally, the crossbedding of the Jackpile indicates an easterly paleocurrent direction, but at the stratotype the direction is more northeasterly (56°). The Jackpile was deposited by braided-stream systems and on the distal portions of alluvial-fan complexes in a fairly arid climate. Source areas were a rejuvenated upland south of Gallup, New Mexico, and the distant Mogollon Highlands.

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Wyoming Geological Association

Fall field conference and symposium

The Wyoming Geological Association will hold its annual field conference and symposium entitled *The Permian and Pennsylvanian geology of Wyoming* September 23-26, 1984, at the Hilton Inn, Casper, Wyoming. The tentative schedule is: Bighorns field trip and evening icebreaker on Sunday, September 23; symposium on Monday, September 24; and Hartville Uplift and Black Hills field trip (overnight in Newcastle, Wyoming) on Tuesday and Wednesday, September 25-26. Some of the subjects to be discussed at the symposium are the Goose Egg salts and the Tensleep, Casper, Leo, and Minnelusa Formations. For further information contact Paul Trump, ℅ Mitchell Energy Corp., 1670 Broadway, Suite 3200, Denver, CO 80202 (303-861-2226) or Alec Steele, ℅ Marathon Oil Co., P.O. Box 2659, Casper, WY 82602 (307-577-1555).

MINING REGISTRATIONS
(OCTOBER 25, 1983 THROUGH APRIL 16, 1984)
State Mine Inspector — 2340 Menaul N.E. — Albuquerque, NM 87107

Date and operation	Operators and owners	Location
10-25-83 clay	Operator—Garrett Mine, D'Appolonia Consulting Engineers, 2340 Alamo SE, Suite 306, Albuquerque, NM 87106; Gen. Mgr.—Dr. A. K. Kuhn, same address, phone: 842-0835; Person in charge—Bruce W. Hassinger, same address and phone; Gen. Supt.—Jerry Farris, P.O. Box 687, Grants, NM 87020; Property owner—Frank J. Burke, P.O. Box 278, Gallup, NM 87301	McKinley Co.; sec. 22, T. 15 N., R. 18 W.; Gallup mining district; private land; drift-abandoned; no material to be mined; existing adits to be opened in order to investigate subsidence problems; directions to mine: immediately east of NM-32, 0.5 mi south of the intersection of NM-32 and NM-40 in Gallup, NM
10-25-83 mill	Operator—Ambrosia Lake Mill, Quivera Mining Co., P.O. Box 218, Grants, NM 87020; Supt.—Charley Stanley, same address; Gen. Mgr.—Arthur Gebeau, same address; Other officials—Rob Luke, Rod Tregembo, Billy Stevens, Kerr-McGee Center, Oklahoma City, OK 73125	McKinley Co.; sec. 31, T. 14 N., R. 9 W.; Grants mining district; private land; ores milled—uranium; custom milling; capacity of mill—7,000 tons per day; directions to mill: approximately 21 mi north of Grants, NM on NM-509 spur
12-20-83 gold, silver	Operator—U.S. Treasury, St. Cloud Mining Co., P.O. Box 1670, Truth or Consequences, NM 87901, phone: 744-5215; Gen. Mgr.—P. S. Freeman, 1006 Kopra St., Truth or Consequences, NM, 87901, phone: 894-7739; Gen. Supt.—James Ray Nations, General Delivery, Winston, NM, phone: 894-7495; Other official—Walter Palass, Admin. Mgr., Box 1670, Truth or Consequences, NM 87901; Property owner—The Goldfield Corp., P. O. Box 1899, Melbourne, FL 32901	Sierra Co.; sec. 25, T. 11 S., R. 9 W.; private land; directions to mine: 12 mi SW of Winston, NM, past St. Cloud mill, follow signs
12-20-83 mill	Operator—St. Cloud Mill, The St. Cloud Mining Co., P.O. Box 1670, Truth or Consequences, NM 87901, phone: (505) 744-5215; Supt.—John Gilson, same address and phone; Gen. Mgr.—Patrick Freeman, same address and phone; Other official—Walter Palass, Admin. Mgr., same address and phone; Property owner—The Goldfield Corp., P.O. Box 1899, Melbourne, FL 32901	Sierra Co.; sec. 4, T. 12 S., R. 8 W.; Chloride mining district; private land; ore milled—copper, silver, and gold; capacity of mill—400 tons per day; directions to mill: 10 mi SW of Winston
1-18-84 silver	Operator—Black Silver Venture, Gold-Silver Exploration, Inc., 631 Broadway, Truth or Consequences, NM 87901; Gen. Mgr.—Dan Medley, 631 Broadway, phone: 894-2121; Person in charge—Arthur Misquez, 1315 Caballo Rd., Truth or Consequences, NM 87901, phone: 894-3943; Gen. Supt.—A. D. Richins, P.O. Box 155, Hillsboro, NM 88042, phone: 895-5694; Property owner—Black Silver Venture, 631 Broadway, Truth or Consequences, NM 87901	Sierra Co.; sec. 13, T. 15 S., R. 9 W.; Kingston mining district; federal land; directions to mine: turn north on forest road 157 halfway between Hillsboro and Kingston, go 9.5 mi to mine

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