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Spencer G. Lucas and Steven N. Hayden

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Type section of the Permian Bernal Formation and the Permian–Triassic boundary in north-central New Mexico

by *Spencer G. Lucas*, New Mexico Museum of Natural History, P.O. Box 7010, Albuquerque, New Mexico 87194
and *Steven N. Hayden*, Department of Geology, University of New Mexico, Albuquerque, New Mexico 87131

Introduction

Since Bachman (1953) introduced the term Bernal Formation, it has been used widely throughout northern and southeastern New Mexico. The name has been applied to the supposed youngest Permian red beds (sandstones and siltstones) above the San Andres or Glorieta Formations and below the Upper Triassic Chinle and Santa Rosa Formations. However, recent studies of the Middle Triassic Moenkopi Formation across northern New Mexico (Hayden and Lucas, 1988a, b; Lucas and Hunt, 1987, 1989; Lucas and Hayden, 1989a, b) identified many outcrops previously assigned to the Bernal Formation as Triassic Moenkopi Formation. The question thus arose, what is the Bernal Formation? Identification and characterization of a type section for the Bernal Formation is essential to answering this question and is the first purpose of this article. This allows us to distinguish the Bernal unambiguously from the overlying Triassic rocks and thus locate correctly the Permian–Triassic boundary in northern New Mexico. Furthermore, it leads us to support Tait et al. (1962) in abandoning the term Bernal Formation in north-central New Mexico and replacing it with Artesia Formation.

Previous studies

Tait et al. (1962, p. 511) noted that Charles B. Read first informally used the term Bernal Formation in 1939. Read intended to use the name in a U.S. Geological Survey map of part of north-central New Mexico (Read and Andrews, 1944; Read et al., 1944), but at that time the Survey did not want to adopt new stratigraphic names. Indeed, Read et al. (1944) used the acronym "Pb" to identify the "upper member" of the San Andres Formation. In the map legend, they described the unit as "a fine-grained clastic member." Measured sections with the map indicate this unit is mostly orange siltstone and massive sandstone with a bed of white gypsum. The maximum thickness of the upper member of the San Andres Formation reported by Read et al. (1944) was about 66 m (218 ft) at "Bernal Butte and Chapelle Butte, near Bernal, New Mexico" (their section 35). Here, the upper member rests on limestone of the San Andres Formation and is overlain by sandstone that Read et al. (1944) termed "Dockum Formation."

Two years later, Wood and Northrop (1946) mapped the upper clastic member of the San Andres Formation, identified as "Pb" in their legend, in the Nacimiento Mountains of Sandoval County. Kelley (1949, fig. 2) first published the term Bernal in a table, apparently believing that Read had already defined it formally. However, it was Bachman (1953) who first formally introduced the term Bernal Formation. In so doing, Bachman (1953) described the Bernal as brownish-red siltstone and fine-grained sandstone and mapped its distribution in the Ocate area of northwestern Mora County (Fig. 1). However, he failed to describe a type section, although Bachman (1953) noted "the type sequence is near the villages of Bernal and Chapelle, San Miguel County, and the formation has been recognized over much of central and northwestern New Mexico."

The term Bernal Formation was used frequently in the guidebook to the seventh field conference of the New Mexico Geological Society held in 1956. Baltz et al. (1956, especially p. 42) identified "Bernal Butte" in a photograph labelled to show the extent of the Bernal and adjacent units. Baltz and Bachman (1956, pp. 101–102) summarized the lithology and distribution of the Bernal Formation in the southeastern Sangre de Cristo Mountains and noted its correlation with the Guadalupian Whitehorse group of southeastern New Mexico. In 1958, Read and Hayes discussed the nomenclatural problems in eastern New Mexico and correlation of the Bernal, Whitehorse, and Chalk Bluff.

By 1962, Bernal Formation was a well-accepted name for the youngest Permian strata in northern New Mexico (Baars, 1962). It also was being applied to the youngest Permian strata in south-central New Mexico (Wilpolt and Wanek, 1961; Anonymous, 1955; Smith and Budding, 1959). Tait et al. (1962) presented a unified stratigraphic terminology for Guadalupian clastic/evaporitic units in southeastern New Mexico. They proposed the term Artesia Group to encompass five formations (Grayburg, Queen, Seven Rivers, Yates, and Tansill, in ascending order). Because the Bernal Formation is equivalent to the lower part of the Artesia Group (Grayburg and Queen Formations), Tait et al. (1962) recommended abandonment of the term Bernal. Few subsequent authors followed this recommendation (Dixon, 1967 is an exception), and Bernal Formation continues to be used for youngest Permian strata in north- and south-central New Mexico. We have discovered, however, that many Bernal outcrops in north-central New Mexico are Triassic Moenkopi Formation, thus greatly abridging the former extent of the Bernal Formation (Fig. 1). For this reason, we describe the type section of the Bernal Formation and thus clarify the difference between Permian Bernal strata and Triassic Moenkopi strata. ☞

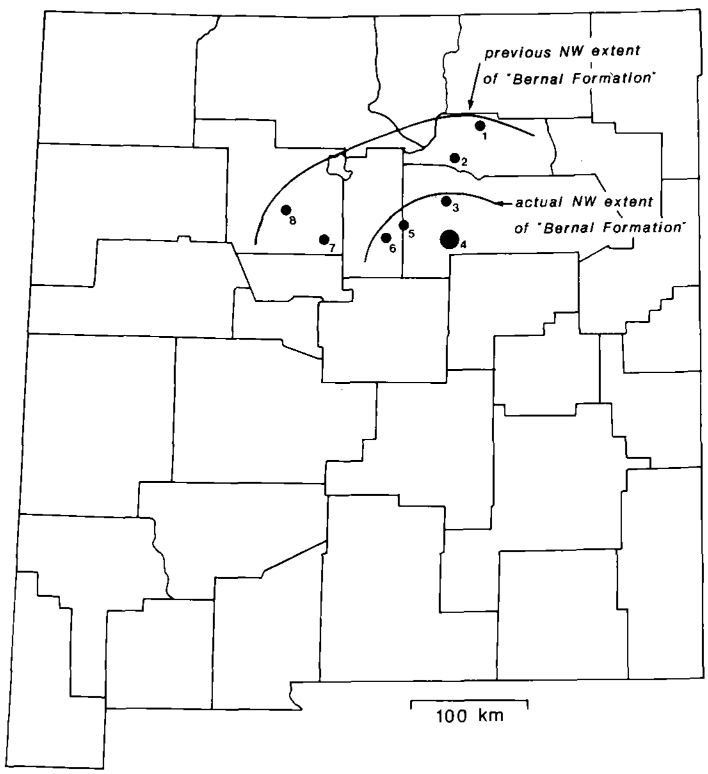

FIGURE 1—Map of New Mexico showing principal locations referred to in the text and the previously identified and revised extent of the Bernal Formation. Numbered locations (also see Fig. 5) are: **1,** Ocate, Mora County; **2,** La Cueva, Mora County; **3,** Montezuma Gap, San Miguel County; **4,** Villanueva area (includes location of type section of the Bernal Formation), San Miguel County; **5,** Rowe–Glorieta Mesa, San Miguel and Santa Fe Counties; **6,** Lamy, Santa Fe County; **7,** Hagan–Placitas, Sandoval County; **8,** San Ysidro–Red Mesa, Sandoval County.

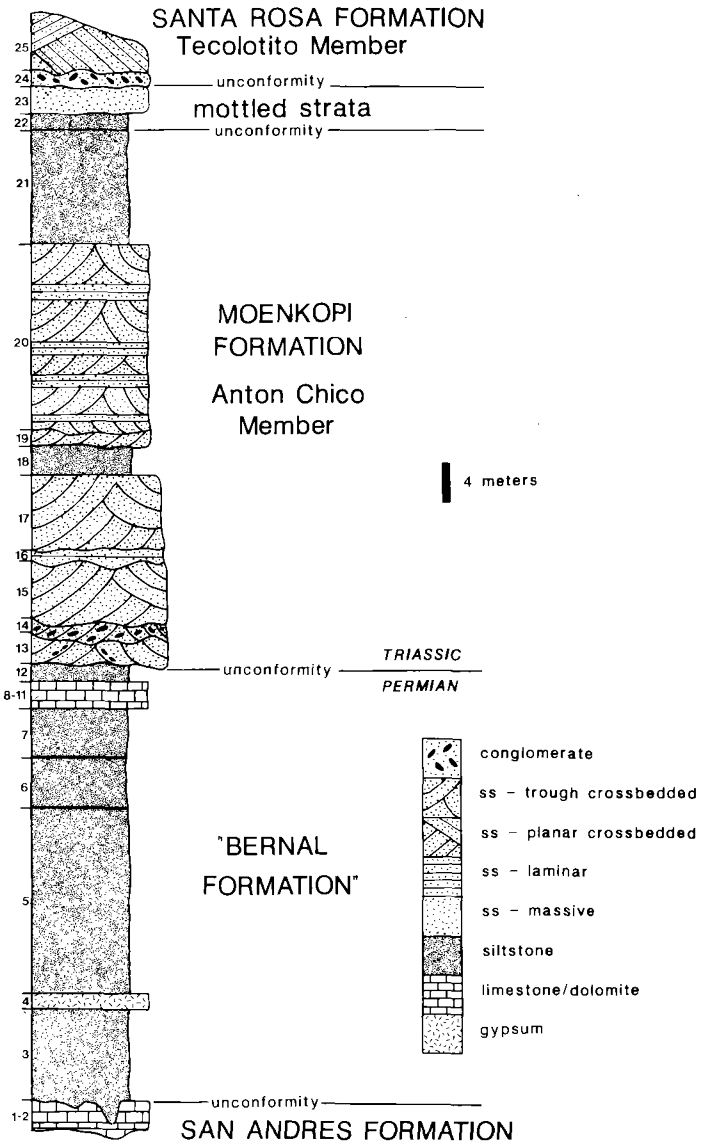

FIGURE 2—Type section of the Bernal Formation. See Table 1 for descriptions of the lithologic units.

Type section

The type section of the Bernal Formation intended by Read is on Bernal Butte near Bernal, San Miguel County (Figs. 1, 2, 3A). The Bernal Formation at the type section (Fig. 2; Table 1) consists mainly of moderately reddish brown and moderately reddish orange siltstone (87%) with minor gypsum near the base (3%) and dolomitic limestone near the top (5%) (rock colors after Goddard et al., 1984). The siltstone is mostly quartzose (>95%) with minor feldspar, mica, and anhydrite, which may be authigenic, and with abundant calcite cement (Fig. 4A). About 10 m (30 ft) above the base is a 1.5-m-thick (4.5 ft) layer of massive gypsum (Fig. 3B). This is overlain by gypsiferous siltstone, and then by a thick layer of orange siltstone with interbeds of reddish-brown sandy siltstone. The unit just below the top of the Bernal is a 2.3-m-thick (7.6 ft) carbonate layer with abundant limpid dolomite (Folk, 1980) (Fig. 4B). These crystals are dedolomitized to calcite near the top of the bed. The upper layer of this carbonate unit has abundant large crystals of sparry calcite. Overlying the carbonate layer, the uppermost unit in the Bernal Formation is a 1.4-m-thick (4.3 ft) layer of light-brown siltstone.

The Middle Triassic Anton Chico Member of the Moenkopi Formation (Lucas and Hunt, 1987, 1989), which overlies the Bernal Formation at its type section (Fig. 2), consists mostly of grayish-red, pale-yellowish-brown and pale-brown sandstone (80%) and conglomerate (3%) with some grayish-red and moderately reddish-brown siltstone (17%) interbeds (Figs. 4C, 4D). The conglomerates consist of matrix-supported clasts, mostly limestone and siltstone pebbles up to 4 mm on the long axis, that are 25% of the rock volume. These are contained in a matrix of sandstone, which includes as much as 40% calcareous fine silt. This is similar to the composition of the sandstone that makes up 80% of the units in the formation at this locality and is a lithic wackestone (rock classifications after Williams et al., 1982). Monocrystalline quartz makes up 50% of the sand-sized fraction. The remainder consists of: 1–4% tartan-twinned microcline; 20% calcite, much of which has been recrystallized to intrasparite cement; 10% mica, most of which is muscovite with minor biotite and chlorite; and as much as 15% other lithic rock fragments including metamorphic clasts, polycrystalline to cryptocrystalline quartz, and a trace of opaque minerals. The Moenkopi sands are very fine to medium-grained, very angular to subrounded, and very poorly sorted. Cementation is by intramicrite and intrasparite calcite, clays, hematite, and quartz overgrowths, in decreasing order of abundance.

Overlying the Moenkopi Formation are the mottled strata (Stewart et al., 1972; Lucas et al., 1990) at the base of the Upper Triassic part of the section (Figs. 3C, 4E). These consist of 3.3 m (10 ft) of sandstone (73%) and siltstone (27%), which are mottled very dusky red, grayish red, very light gray, and dark yellowish orange. The sandstone consists of 30–35% matrix of silt, 40% quartz, 16% chert, and 10% siltstone clasts. Cementation is by hematite and opaque iron oxides, chalcedony, and chert.

At the top of the section is the Upper Triassic Tecolotito Member of the Santa Rosa Formation (Lucas and Hunt, 1987) that has a 1.2-m-thick (4 ft) basal conglomerate (Fig. 3D) with very light gray and white limestone-cobble clasts in a matrix of quartz arenite sandstone that is very pale orange and weathers to dusky yellow brown. This sandstone (Fig. 4F) is medium- to very coarse grained, subrounded, and mature, in contrast to the quartz wackestones of the underlying Moenkopi Formation. Overlying this is a sandstone unit, which was not measured, of essentially the same lithology that forms the top of the hill. This sandstone consists of >95% quartz with interlocking silica overgrowths.

Sedimentology

Regional deposition of the Bernal Formation is related to transgressions and regressions of the sea that deposited marine facies in the Permian Basin of southeastern New Mexico during the Late Permian (Guadalupian) (Silver and Todd, 1969, figs. 3, 12; Sarg and Lehman, 1986). This clastic shelf origin of the Bernal Formation is evidenced by the presence of limestones and evaporites (deposited in sabkha environments with periodic inundations of sea water) interbedded with siltstone (deposited during shoreline retreat). Carbonates near the top of the Bernal type section were deposited in a brackish- to fresh-water environment evidenced by limpid dolomite crystals (Folk, 1980), indicative of a much lower Mg/Ca ratio than is present in sea water or evaporitic brines. This interpretation is also supported by 1) increasing dedolomitization upward, which suggests a possible freshening of the ground water present during diagenesis (Folk, 1980), and 2) Silver and Todd's (1969, fig. 12) interpretation of the Artesia Group as progradational over the San Andres Formation in the Delaware Basin, southeast of the study area. The abundant sparry calcite at the top of the Bernal Formation at its type section suggests the influence of meteoric waters, which have an excess of calcium, during lithification (Folk, 1980).

The Middle Triassic Moenkopi Formation is much coarser grained than the Bernal, consisting mostly of trough-crossbedded sandstone and conglomerate. Deposition took place in a low- to medium-energy fluvial environment in braided to slightly meandering

TABLE 1—Type section of the Bernal Formation. Measured on the western end of Bernal Butte in the SE¼NW¼SE¼ sec. 36 (unsurveyed), T14N, R15E, San Miguel County.

Unit	Lithology	Thickness (m)
	Upper Triassic Santa Rosa Formation Tecolotito Member:	
25.	Sandstone, quartz arenite, very pale orange (10 YR 8/2), weathers grayish orange (10 YR 7/4), quartzose, slightly micaceous and calcareous, submature, medium- to coarse-grained, subangular, moderately sorted; planar crossbeds.	Not measured
24.	Conglomerate: matrix is quartzose sandstone that is very pale orange (10 YR 8/2), weathers dusky yellowish brown (10 YR 2/2), slightly calcareous, medium-grained, subrounded, well-sorted, and slightly micaceous; clasts are limestone that is very light gray (N 8) and white (N 9), micritic, matrix-supported, unstratified. Clasts are as much as 15 cm in diameter.	1.2
	Disconformity	
	Mottled strata:	
23.	Silty sandstone, very dusky red (10 R 2/2) and grayish-red (5 R 4/2), quartzose, noncalcareous, fine- to medium-grained, poorly sorted, subangular to subrounded; massive.	2.4
22.	Sandy siltstone, mottled very dusky red (10 R 2/2), grayish red (5 R 4/2), very light gray (N 8) and dark yellowish orange (10 YR 6/6), noncalcareous; sand is medium grained, subrounded, quartzose; bioturbated to massive.	0.9
	Disconformity	
	Middle Triassic Moenkopi Formation Anton Chico Member:	
21.	Sandy siltstone, grayish-red (5 R 4/2) to dark reddish-brown (10 R 3/4), micaceous, noncalcareous; massive.	8.8
20.	Sandstone and silty sandstone interbeds; sandstone same colors and lithology as unit 15; silty sandstone same colors and lithology as unit 16.	19.5
19.	Sandstone, grayish-red (10 R 4/2); same lithology as unit 15; trough-crossbedded.	0.9
18.	Siltstone, grayish-red (10 R 4/2), weathers moderately reddish brown (10 R 4/6), micaceous, and calcareous; laminar.	2.9
17.	Silty sandstone, grayish-red (10 R 4/2), weathers moderately reddish brown (10 R 4/6), fine- to medium-grained, subangular to subrounded, poorly sorted, micaceous; lithic quartz wackestone; trough-crossbedded.	7.6
16.	Silty sandstone, grayish-red (10 R 4/2) with some yellowish-gray (5 Y 8/1) mottles, fine- to medium-grained, subangular, poorly sorted, calcareous, and micaceous; lithic quartz wackestone; has some 5-mm siltstone pebble clasts; laminar.	0.8
15.	Sandstone, grayish-red (10 R 4/2), fine- to medium-grained, subangular to subrounded, calcareous, and micaceous; lithic quartz wackestone; trough-crossbedded.	6.2
14.	Conglomerate, pale-brown (5 YR 5/2) and grayish-red (10 R 4/2): matrix is calcareous siltstone, clast-supported; clasts are as much as 1 cm in diameter; trough-crossbedded.	1.5
13.	Sandstone, contains minor lenses of conglomerate and sandy siltstone. Sandstone is lithic quartz wackestone, which is yellowish gray (5 Y 7/2), weathers light olive gray (5 Y 5/2), very fine grained, subangular, well-sorted, micaceous and quartzose; conglomerate is grayish red (10 R 4/2) and pale yellowish brown (10 YR 6/2), composed of siltstone clasts as much as 1 cm in diameter; sandy siltstone is grayish red (10 R 4/2), calcareous; trough-crossbedded. Azimuths of 070°, 270°, and 340° were obtained from axes of troughs.	2.3
	Disconformity	
	Permian Bernal Formation (type section):	
12.	Sandy siltstone, light-brown (5 YR 6/6) and moderately reddish brown (10 YR 4/6); sand is very fine grained, subrounded, poorly sorted, quartzose, calcareous; bioturbated to massive.	1.4
11.	Limestone, very pale orange (10 YR 8/2) and white (N 9) with olive gray (5 Y 3/2) horizontal streaks.	0.1
8-10.	Interbedded silty limestone and silty dolomitic limestone; dark reddish-brown (19 R 3/4) with greenish-gray (5 GY 6/1) reduction spots; dolomitic areas are grayish red (10 R 4/2) to dark reddish brown (10 R 3/4); dolomite crystals are zoned euhedral rhombs (limpid texture); beds are approximately 0.1 m thick.	2.2
7.	Sandy siltstone, moderately reddish brown (10 R 4/6) and moderately reddish orange (10 R 6/6) with yellowish-gray (5 Y 8/1) mottles, noncalcareous; sand grains are very fined grained, subangular, quartzose; bioturbated.	5.3
6.	Siltstone, moderately reddish brown (10 R 4/6) and moderately reddish orange (10 R 6/6) with yellowish-gray (5 Y 8/1) reduction spots.	3.9
5.	Sandy siltstone, moderately reddish brown (10 R 4/6) and moderately reddish orange (10 R 6/6) with yellowish-gray (5 Y 8/1) reduction spots, slightly calcareous; sand is subangular to subrounded, very fine grained, moderately sorted, quartzose, and gypsiferous; massive to bioturbated.	18.4
4.	Massive anhydrite, white (N 9) with brownish-gray (5 YR 4/1) "chicken wire" texture; has an aphanitic groundmass of anhydrite with euhedral porphyroblasts of gypsum growing within.	1.5
3.	Siltstone and sandy siltstone, moderately reddish brown (10 R 4/6) with yellowish-gray (5 Y 8/1) reduction spots; sand is very fine grained, subrounded, well-sorted quartz, gypsiferous; bioturbated with some laminar beds.	9.7
	Disconformity	
	San Andres Formation:	
2.	Limestone; same colors and lithology as unit 1, but with larger clasts (as much as 20 cm in diameter) of Bernal Formation breccia in fissures.	0.8
1.	Limestone, yellowish-gray (5 Y 7/2 and 5 Y 8/1); bedding is convoluted and fissures are filled with breccia like unit 2 above with angular fragments as much as 3 cm in diameter.	2.0+

streams (Lucas and Hayden, 1989b). Moenkopi sandstones are immature lithic quartz wackestones and lithic arenites (classification after Williams et al., 1982). Many of the larger clasts in the Moenkopi are limestone and siltstone that appear to have been eroded from the underlying Permian rocks and are probably intrabasinal in origin. This is evidenced by the large clast size of these soft and easily abraided fragments.

The overlying Santa Rosa Formation consists of much coarser grained sand and shows much larger scale and higher energy bedforms. Santa Rosa quartz arenites made up of medium- to very coarse grained quartz sand were probably derived from extrabasinal sources to the south (Lupe, 1988).

Permian–Triassic boundary in north-central New Mexico

The oldest Triassic strata in north-central New Mexico are the Anton Chico Member of the Moenkopi Formation and are of Middle Triassic (Anisian) age (Lucas and Morales, 1985; Lucas ☞

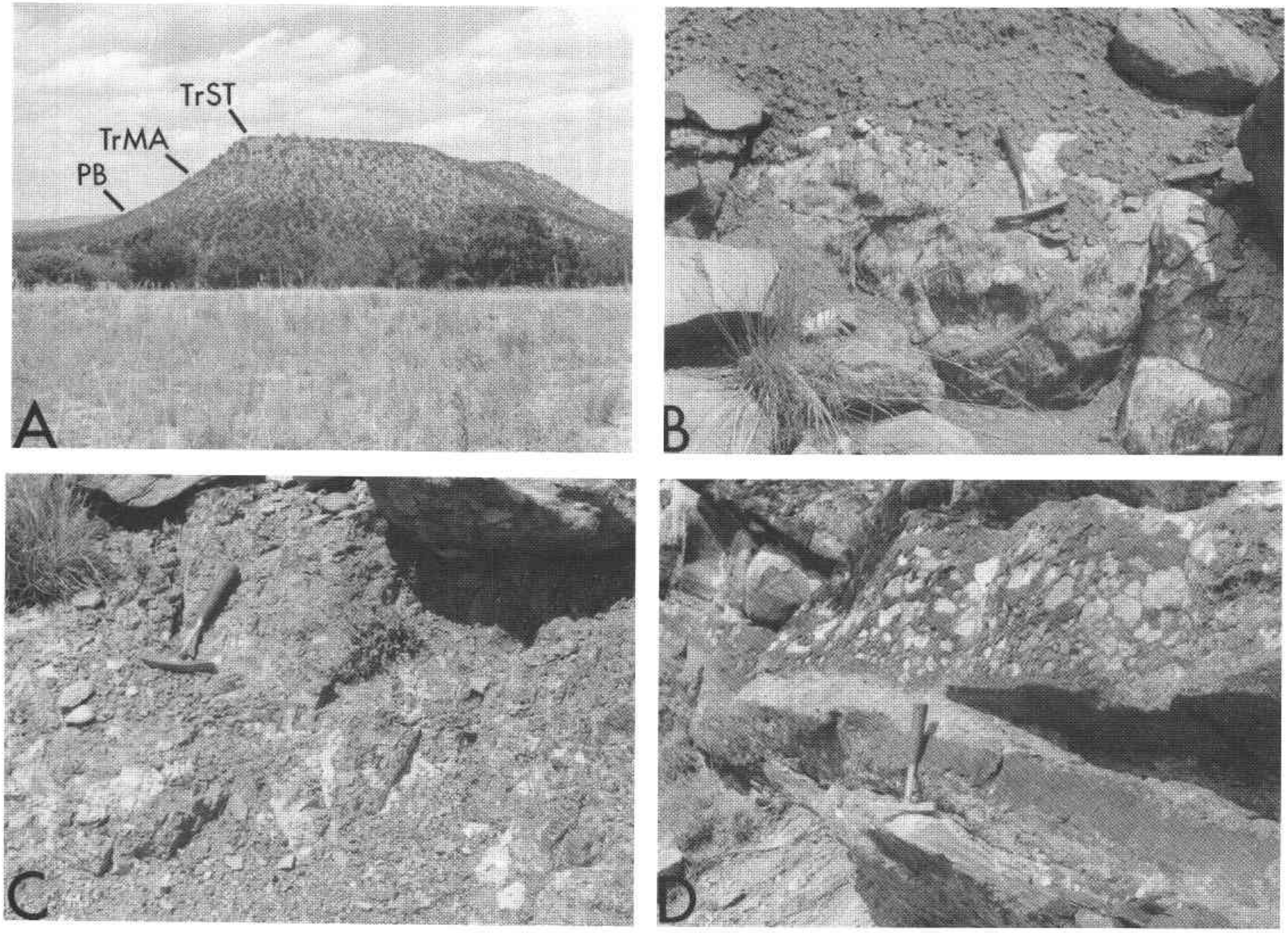

FIGURE 3—Outcrops of Permian and Triassic strata at Bernal Butte. See Fig. 2 for units of the measured section and Table 1 for descriptions. **A**, View of Bernal Butte from the southwest shows Permian Bernal Formation (Pb), Middle Triassic Anton Chico Member of the Moenkopi Formation (TRma), and Upper Triassic Tecolotito Member of the Santa Rosa Formation (TRst). **B**, Gypsum bed in Bernal Formation at Bernal Butte (unit 4). **C**, Mottled strata beneath Santa Rosa Formation at Bernal Butte (units 22 and 23). **D**, Basal limestone-cobble conglomerate of Santa Rosa Formation at Bernal Butte (unit 24).

and Hunt, 1987, 1989; Lucas and Hayden, 1989b; Kietzke, 1989a, b). The youngest Permian strata beneath the Moenkopi Formation in this area have been termed Bernal Formation and are of Late Permian (late Guadalupian) age (see Sarg and Lehman, 1986 for the age of Bernal correlative strata). At some outcrops in north-central New Mexico, older Permian (Leonardian–Guadalupian) strata (San Andres and Glorieta Formations) underlie the Moenkopi or younger, Upper Triassic (Carnian) strata of the Santa Rosa or Chinle Formations. Miscorrelation of the Permian–Triassic boundary in north-central New Mexico has resulted where Moenkopi red beds have been misidentified as Bernal Formation and assigned a Permian age.

The type section of the Bernal Formation and overlying Moenkopi strata described here indicates that in outcrop, hand sample, and thin section, rocks of the Moenkopi Formation are readily distinguished from those of the Bernal Formation on the basis of mineralogy, textural and mineralogical maturity, sedimentary structures, and color. Based on these distinctions, most strata previously termed Bernal in north-central New Mexico, especially on maps published by the U.S. Geological Survey, are Moenkopi strata. Critical locales (Figs. 1, 5) are:

1. Ocate–Naranjos, Mora County, especially NW1/4 sec. 3, T22N, R18E (unsurveyed) along NM 120. Here, Bachman (1953) identified 38.4 m (126.7 ft) of "brownish red siltstone and fine-grained sandstone" that he mapped as Bernal Formation. We have examined these strata and they consist of two lithologies typical of the Moenkopi Formation: grayish-red-purple (5 RP 4/2), very fine grained, subangular, well-sorted, noncalcareous, micaceous, trough-crossbedded litharenite and grayish-red-purple (5 RP 4/2), medium- to coarse-grained, subrounded, poorly sorted, noncalcareous, trough-crossbedded litharenite. The Moenkopi Formation, not the Bernal Formation, rests on the Glorieta Sandstone near Ocate (Lucas et al., 1990).

2. La Cueva, Mora County, especially NE1/4 sec. 21, T20N, R16E along NM–94. Here, Baltz and O'Neill (1984) identified 47.9 m (158.1 ft) of mostly grayish-red, trough-crossbedded litharenites and lithic wackestones as Bernal Formation. However, these strata are Moenkopi Formation resting disconformably on the Glorieta Sandstone and are disconformably overlain by the Santa Rosa Formation (Lucas et al., 1990).

3. Montezuma Gap, San Miguel County, especially NW1/4 sec. 4, T16N, R16E (unsurveyed) along NM–65. This is the northeasternmost outcrop of the Bernal Formation known to us. Here, the Bernal rests on the San Andres Formation and is overlain by 28 m (92.4 ft) of Moenkopi strata (Lucas et al., 1990). However, Northrop et al. (1946), Baltz and Read (1956, especially the photograph on p. 63), and Baltz and O'Neill (1986) mapped the Moenkopi and Bernal together as Bernal at Mon-

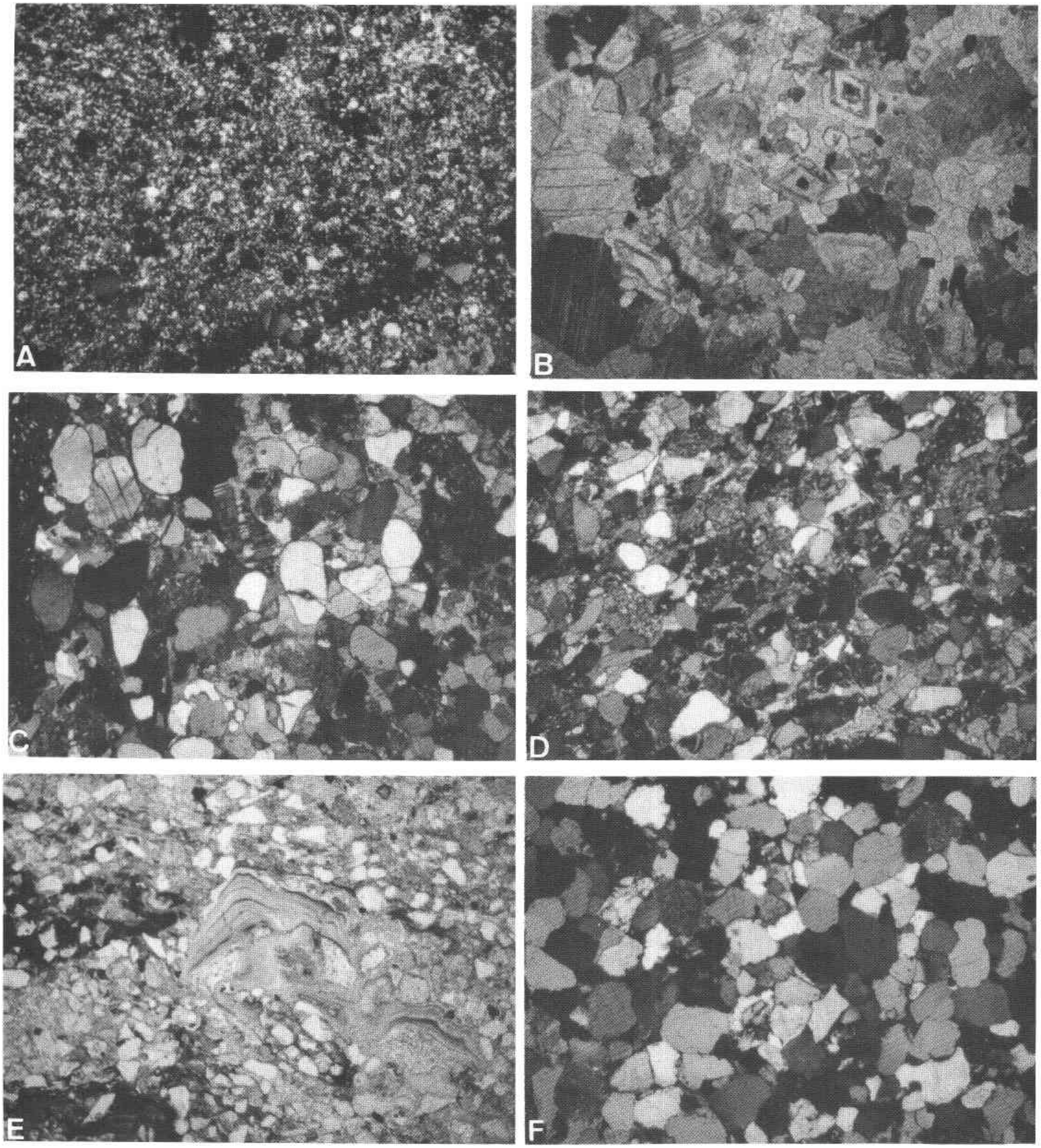

FIGURE 4—Photomicrographs of selected thin sections from Permian and Triassic strata at Bernal Butte (field of view: 3 mm). See Fig. 2 for units of the measured section and Table 1 for descriptions. **A**, Bernal Formation, typically calcite cemented, quartzose siltstone (unit 7). **B**, Bernal Formation, limestone with abundant sparry calcite and zoned euhedral crystals of dolomite (units 8–10). **C–D**, Moenkopi Formation, Anton Chico Member, lithic quartz wacke sandstones (unit 16). **E**, Mottled strata, sandy siltstone (unit 22). **F**, Santa Rosa Formation, Tecolotito Member, quartz arenite (unit 25).

tezuma Gap. North of Montezuma Gap they mapped Moenkopi strata as Bernal as far north as Cebolla Creek in southernmost Mora County.

4. Villanueva–Apache Springs, San Miguel County, from the Bernal type section to Tecolotito on the Pecos River, T12 and 13N, R15, 16 and 17E. We initially recognized problems with the placement of the Permian–Triassic boundary in north-central New Mexico when comparing the mapping of Gorman and Robeck (1946) with that of Johnson (1974). Strata Gorman and Robeck (1946) mapped as "lower sandstone member of the Santa Rosa Sandstone" (= Anton Chico Member of the Moenkopi ☞

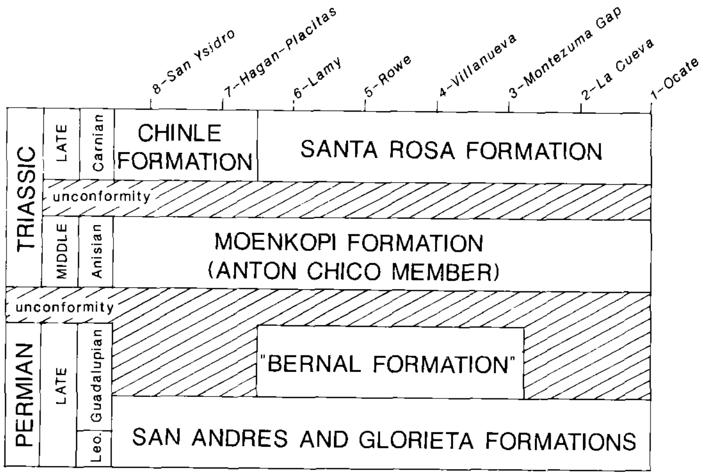

FIGURE 5—Correlation of the Permian–Triassic disconformity across north-central New Mexico. See Fig. 1 for locations of numbered control points.

Formation of our usage) near Tecolotito are the same as those mapped as Bernal Formation by Johnson (1974) near Apache Springs. Indeed, Johnson's (1970, 1974) "Bernal Formation" in this area includes Bernal and Moenkopi strata. The base of the Triassic on Johnson's maps is at the base of the Santa Rosa Formation, i.e., at the color change from red beds (Bernal, Moenkopi) to brown/gray sandstones (Santa Rosa Formation). The position of the Permian–Triassic boundary needs to be located correctly throughout this area by remapping the unit Johnson (1970, 1974) mapped as Bernal into separate Bernal and Moenkopi Formations.

5. Rowe–Glorieta Mesa escarpment, San Miguel and Santa Fe Counties, T15N, R11 and 12E. A similar interpretation has included the Bernal and Moenkopi Formations here in one map unit named Bernal (Read et al., 1944; Budding, 1972). Just south of Rowe Peak (SE1/4 sec. 30, T15N, R12E), a typical Permian–Triassic boundary section in this area encompasses at least 25 m (82.5 ft) of Bernal Formation disconformably overlain by 33 m (109 ft) of Moenkopi Formation.

6. Lamy–San Cristobal Ranch, Santa Fe County, especially T12, 13 and 14N, R10 and 11E. Here, also, strata mapped as Bernal by Read et al. (1944) and Johnson (1973) include both Bernal and Moenkopi rocks. A characteristic section is in SE 1/4 sec. 7, T12N, R11E where 21 m (69.3 ft) of Bernal strata rest on the San Andres Formation and are overlain by 30 m (100 ft) of Moenkopi Formation (Allen and Lucas, 1988). These are the northwesternmost outcrops of the Bernal Formation.

7. Hagan–Placitas, Sandoval County, T12 and 13N, R4 and 5E. Strata previously identified here as Bernal Formation (Kelley and Northrop, 1975; Ingersoll and Kelley, 1979) are Moenkopi Formation (Menne, 1989). A characteristic section is just south of the ghost town of Tejon in NE1/4 sec. 24, T13N, R4E (unsurveyed). About 20 m (66 ft) of trough-crossbedded litharenite, conglomerate, and siltstone of the Moenkopi Formation overlie limestone of the San Andres Formation, and the Moenkopi is overlain by quartz arenites of the Santa Rosa Formation. Reports of "small brachiopods" from the "Bernal Formation" in this area (Kelley and Northrop, 1975, p. 52; Ingersoll and Kelley, 1979, p. 198) have not been substantiated. We suspect the brachiopods are from San Andres limestone and were located as float on Moenkopi strata in this rugged, structurally complex area.

8. San Ysidro–Red Mesa, Sandoval County, T16N, R1E. Here, in the southern Jemez Mountains and along the Nacimiento uplift as far north as La Ventana (T18N, R1E), strata previously mapped as Bernal Formation (e.g., Wood and Northrop, 1946; Woodward, 1987) are Moenkopi Formation (Lucas and Hayden, 1989a). No Bernal strata are present on the Colorado Plateau (Lucas and Hayden, 1989a, b).

Bernal Formation should be abandoned

Tait et al. (1962, p. 505) aptly described the Bernal Formation as "a truncated remnant of the Upper Guadalupian sequence of eastern New Mexico." They recommended abandoning the term Bernal Formation in favor of "Artesia Group (undifferentiated)." Dixon (1967) followed this recommendation, but Kelley (1972a, p. 15) suggested that Bernal Formation "should be retained and used for the uncertain Artesia facies north of about latitude 35°N and west of the longitude of Vaughn." Kelley further followed prior usage (Anonymous, 1955; Smith and Budding, 1959; Kottlowski, 1963; Smith, 1964; Weber, 1964; Kelley, 1971) in suggesting use of Bernal Formation from the Tularosa Valley north through the Estancia Valley in Otero, Lincoln, Torrance and Santa Fe Counties (Kelley, 1972b; Meyers et al., 1986). Kelley justified this by arguing that "the Bernal is too thin and too uniform to fit a group terminology" and "the name is well entrenched in the literature."

However, as Tait et al. (1962) demonstrated, the Bernal Formation in its type area, however thin, is the equivalent of the Artesia Group of southeastern New Mexico, mostly of the Grayburg and Queen Formations, but strata equivalent to part of the Seven Rivers Formation may be present as well. And, if the name Bernal is well entrenched in the literature (but see Cys et al., 1976), it is entrenched largely as a misnomer for Triassic Moenkopi strata.

We thus follow Tait et al. (1962) in recommending the term Bernal be abandoned in favor of Artesia Formation. Use of the name Artesia Formation for the youngest Permian strata in north-central New Mexico simplifies nomenclature, clarifies regional correlation, and should be an inducement to trace the separate formations of the Artesia Group in southeastern New Mexico to their supposed pinchouts near Lamy and Montezuma Gap. The Permian–Triassic boundary in north-central New Mexico is a profound disconformity between Upper Permian (Guadalupian) strata of the Artesia Group and the overlying Middle Triassic (Anisian) Moenkopi Formation.

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