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Magnetostratigraphy of a core from Raton Basin, New Mexico—implications for synchroneity of Cretaceous/Tertiary boundary events

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The magnetic polarity stratigraphy of a 30.5-m (100.1-ft)-long core from the Raton Basin in New Mexico has been obtained. The core includes the palynologically determined Cretaceous–Tertiary boundary and an iridium abundance anomaly. The boundary is shown to lie in a normal polarity zone, as verified by hand samples collected from the basin, thus placing in grave doubt the validity of a synchronous worldwide extinction event.

Introduction

The Raton Basin is a large sedimentary and structural basin in northeast New Mexico and southeast Colorado 10,000 km² (3,861 mi²) in area (Fig. 1). More than 3,700 m (12,138 ft) of sedimentary rocks of Late Cretaceous–Eocene age are present in the Raton Basin (Johnson and Wood, 1956; Baltz, 1965). The Upper Cretaceous and Paleocene rock units, in ascending order, are the Trinidad Sandstone, the Vermejo Formation, the Raton Formation, and the Poison Canyon Formation; these rock units record the final regression of the Cretaceous epeiric seaway from the Western Interior of North America.

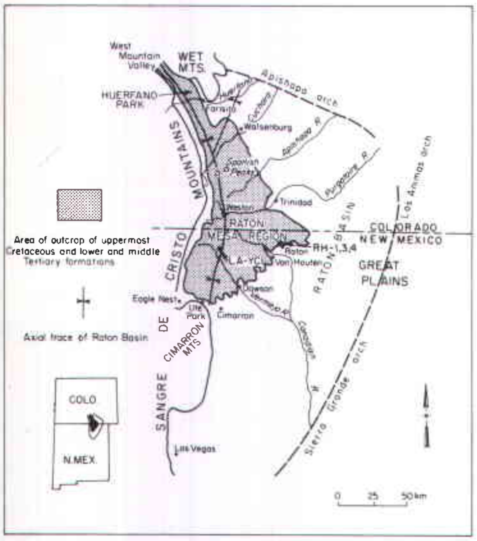

FIGURE 1—Location map of study area showing structural boundaries, distribution of Cretaceous and Tertiary rocks, and sampling localities for Raton core (LA–YCI) and exposures (RH–1, 3, 4; after Johnson and others, 1966).

The Raton Formation may be up to 610 m (2,001 ft) thick (Ash and Tidwell, 1976) and contains the Cretaceous–Tertiary (K–T) boundary. Fossils are poorly represented with the exception of paleobotanic materials. Leaf floras are known from the Trinidad Sandstone, the Vermejo Formation, and the Raton Formation (Brown, 1943). Brown (1943, 1962) considered the lower 15 m (49 ft) of the Raton Formation, containing the problematic plant fossil *Paleoaster inquirenda* Knowlton, to be Cretaceous in age and the upper part Paleocene. Tschudy (1973) located the palynological Cretaceous–Tertiary boundary at 81 m (266 ft) and 88 m (289 ft) above the base of the Raton Formation on the basis of core samples. Tschudy (*in* Orth and others, 1981) reestablished the palynological Cretaceous–Tertiary boundary in a newly drilled core "within a 1 m interval between a coal bed centered at a depth of 255.7 m and a carbonaceous shale at 256.7 m." This palynological boundary occurs at the same stratigraphic position as an iridium abundance anomaly with concentrations of up to 5,000 ppt, and it is the first record of an iridium anomaly in continental sediments.

We found it apparent that 1) anomalously high concentrations of Ir at the Cretaceous–Tertiary boundary, when combined with magnetic polarities, might have a far-reaching value for stratigraphic correlation of geographically widely separated rock units and that 2) the concentrations might provide useful data for resolving stratigraphic arguments regarding the stratigraphy of the San Juan Basin at or adjacent to the Cretaceous–Tertiary boundary. Paleontologic/magnetostratigraphic data were interpreted to indicate that the Cretaceous–Tertiary boundary, based on the highest occurrence of dinosaurs, occurs within the normal polarity zone correlative with anomaly 29 (Butler and others, 1977; Lindsay and others, 1978; Lindsay and others, 1981). Thus, dinosaur extinction in the San Juan Basin occurred later than marine foraminiferal extinctions at Gubbio, Italy, where extinctions occurred high in the reversed magnetozone between anomalies 29 and 30 (Alvarez and others, 1977).

To date, our efforts to locate an iridium anomaly in the San Juan Basin at or near various proposed Cretaceous–Tertiary boundaries have proven inconclusive. This situation is unfortunate given the extant paleomagnetic/paleontologic documentation available. However, Orth provided access to the 30.5-m (100.1-ft) Raton core, drilled by Los Alamos Laboratory, with a demonstrated iridium anomaly at the palynologic Cretaceous–Tertiary boundary. Additionally, samples were taken from surface exposures near the town of Raton at the Cretaceous–Tertiary boundary. Fig. 3 is a generalized representation of the 30.5-m (100.1-ft) core showing dominant lithologies and paleomagnetic sampling intervals.

Experimental procedure

Cylindrical plug samples were obtained at approximately 30-cm intervals from the Los Alamos core (Fig. 3). The well-consolidated siltstones were cored and sliced wet to 2.5 cm (1 inch) cylinders. The friable shales were sliced dry to fit inside 1.7 × 2 × 2 mm plastic containers. Three additional oriented samples were collected in Raton Park on the west side of Raton, New Mexico. These samples were between 15 cm below and 57 cm above the palynological Cretaceous–Tertiary boundary and iridium abundance zone. Three specimens were taken from each sample. Extreme care was taken to maintain vertical up for all specimens.

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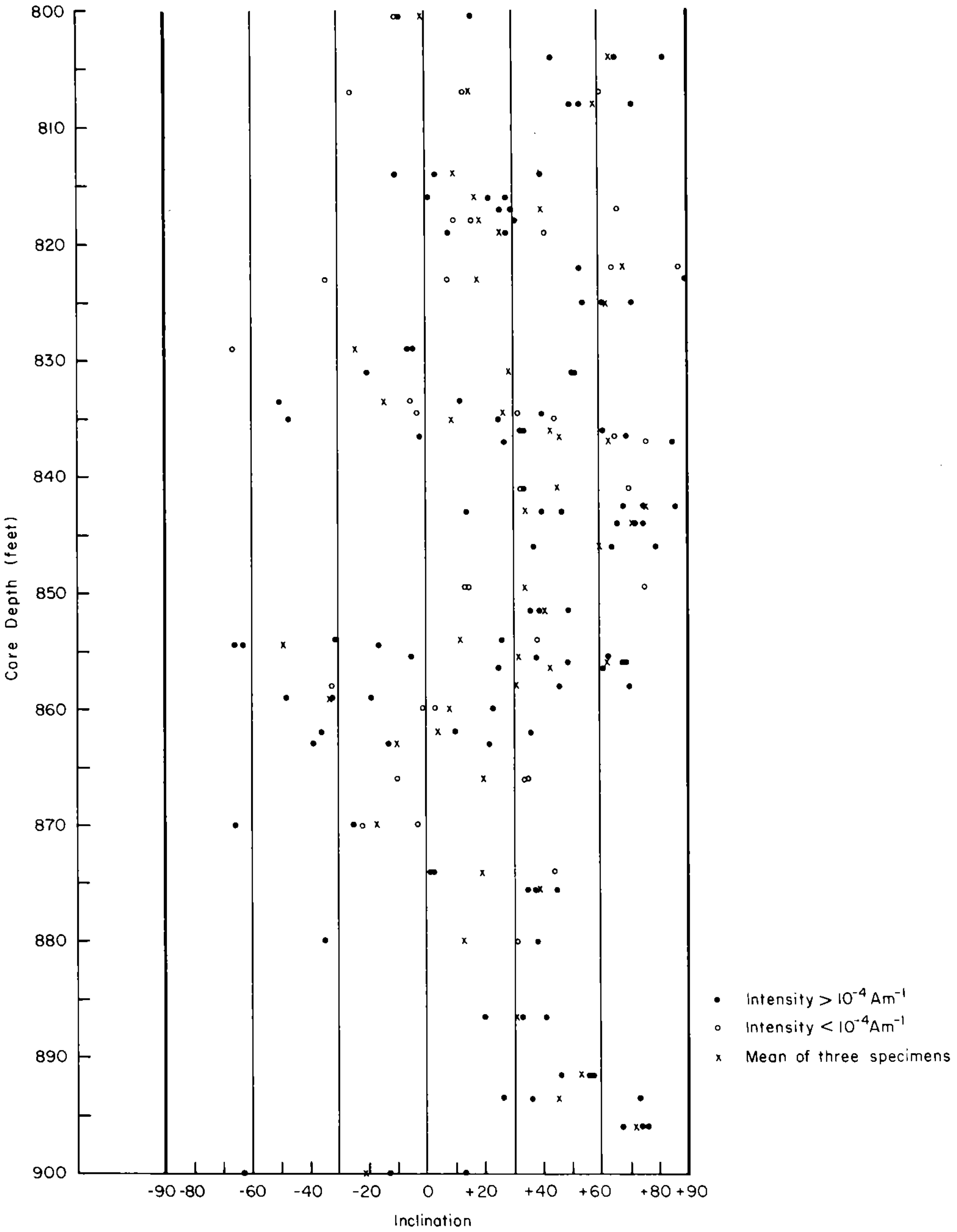

FIGURE 2—Inclination of magnetization for specimens from Raton Basin core as a function of core depth. The palynological Cretaceous–Tertiary boundary and iridium abundance zone occurs at 839 (Orth and others, 1981). Solid dots represent samples with intensities greater than 10^{-4} A m^{-1}; open dots represent samples with intensities less than 10^{-4} Am^{-1}. The mean of three specimens yielding sample inclination is represented by an **x**.

A few of the cylindrical samples were initially measured on a Schonstedt SSM–1 spinner magnetometer interfaced with a North Star microcomputer. The specimens were demagnetized in 5-mT (milliteslas—measurement of magnetic intensity) steps using a home-built alternating-field demagnetizer. The weakness of the magnetization precluded demagnetizing beyond 15 mT or, in some cases, 20 mT. Most of the measurements and further demagnetizations of the specimens initially measured at New Mexico Institute of Mining and Technology were made at the Paleomagnetics Laboratory at the University of Arizona. An ScT two-axis cryogenic magnetometer interfaced with a microprocessor was used to make the magnetization measurements. Demagnetizations were performed using a Schonstedt GSD–5 tumbling specimen AF demagnetizer. At least one specimen from each sample was fully stepwise demagnetized in 10 mT steps to at least 40 mT. The natural remanent magnetization (NRM) and the magnetization remaining after at least one demagnetization (usually 20 mT) were measured for each of the remaining specimens. Fisher statistics were then applied to the three specimens from each sample to obtain sample mean directions. Because declinations were arbitrary, the declination for each specimen was first converted to zero.

Results

The samples from the Raton Basin core were generally very weakly magnetized. NRMs were typically on the order of a few times 10^{-9} A m^2 (10^{-4} A m^{-1}). Demagnetization to 20 mT usually decreased this by a factor of 2 to 5. In addition, the median destructive field (MDF) for these samples was relatively low. MDFs were typically less than 20 mT with many of them being less than 10 mT. This lowness usually indicates that the primary magnetic carrier is magnetite, assumed to be detrital. Fig. 2 is a plot of the inclination of the magnetically cleaned specimens as a function of core depth; the mean inclination for each sample is also plotted. A certain degree of scatter in the paleomagnetic data is apparent. Therefore, a set of criteria was developed after the one mentioned by Lerbekmo and others (1979). Because the inclination to be expected for a Cretaceous–Paleocene sample collected from the Raton Basin is about 60°, and the inclinations measured for normal-polarity San Juan Basin samples were on the order of 30°–50° (Lindsay, Butler, and others, 1981), the range of possible inclinations was divided into three segments: −90° to −30° (reversed), −30° to +30° (indeterminate), and +30° to +90° (normal). A sample was deemed to be of reversed (R) polarity if one or more of its specimens were reversed and none were normal; or if two were reversed and one were normal; or if there were one specimen in each of the three segments. A sample was deemed to be indeterminate (I) if all three specimens were indeterminate; or if two were indeterminate and one were normal; or if two were

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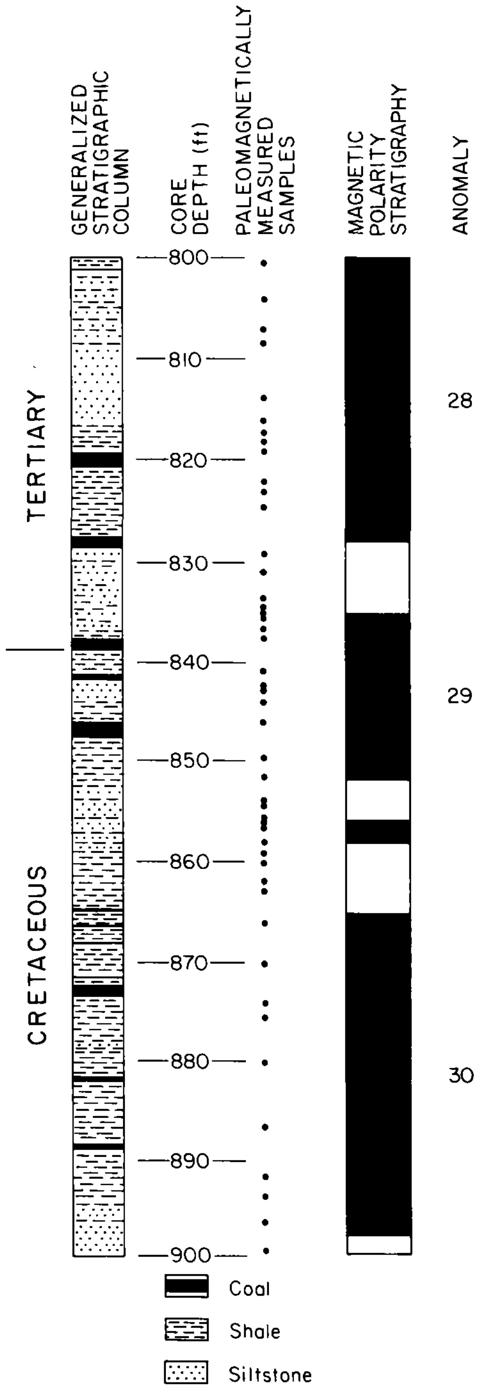

FIGURE 3—Generalized lithologic column of Raton Basin core with location of paleomagnetic samples and favored interpretation for polarity zonation. Black is normal, white is reversed.

normal and one were reversed. A sample was deemed to be normal (N) if all three specimens were normal or if two were normal and one were indeterminate. This scheme is biased in favor of reversed polarities because it assumes that overprinting is predominantly of a viscous nature acquired in the present Brunhes normal-polarity zone.

Fig. 3 gives our interpretation of the magnetic polarity zonation of the Raton core using the above set of criteria. The interval between 835 and 852 is without doubt normal. This includes the palynological boundary and iridium abundance anomaly found by Orth and others (1981) at 839. Not only did the core data give good, reliable, and normal inclinations in this interval, but the three hand samples from Raton Park, New Mexico yielded well-defined positive inclinations. Measured inclinations after cleaning were +73.6°, +49.0°, and +61.2° (mean of +61.3°); +32.9°, +39.5°, and +67.0° (mean of +46.4°); and +87.3°, −2.0°, and +26.5° (mean of +36.0°) for the samples 25 cm below, 10 cm below, and 75 cm above the palynological boundary, respectively. Although these samples were oriented in the field on a horizontal plane, declinations were lost in the slicing process as a result of the attempt to maximize specimen volumes.

We offer the following tentative zonation assignments based upon palynological data and lengths of polarity zones. Our favored interpretation is that the upper normal is anomaly 28, the one between 835 and 852 is anomaly 29, and the one between 865 and 898 is anomaly 30. The small normal in the interval 856 and 858 can be correlated to the short normals found by Lerbekmo and others (1979). From this interpretation, the average sedimentation rate between the base of anomaly 28 and the base of anomaly 30 (a total of about 2,130 cm) is 6 mm/1,000 yrs when correlated to the Ness and others (1980) time scale. The uniformity of the average sedimentation rate for each polarity zone is remarkable. The rate is 0.5 cm (.20 in), 0.66 cm (.26 in), 0.56 cm (.22 in), and 0.55 cm (.22 in) per 1,000 yrs for the reversed zone between anomalies 28 and 29, anomaly 29, the reversed zone between anomalies 29 and 30, and anomaly 30, respectively. An alternative explanation, though less favored, is that the core is entirely within anomaly 29 and would therefore have a minimum average sedimentation rate of 3.8 cm/1,000 yrs. In any case, the average sedimentation rate is indicated to be very low.

Conclusions

Our results demonstrate that the Cretaceous–Tertiary palynological boundary and an iridium anomaly in the Raton Basin occur within a normal polarity zone. Based upon the palynology, this normal polarity zone can best be correlated with magnetic anomaly 29 (Ness and others, 1980; Lowrie and others, 1981). The result of this placement is a diachronous Cretaceous–Tertiary boundary with respect to terrestrial and marine extinctions. Anomalously high concentrations of iridium undoubtedly occur within this normal polarity. A number of possibilities exist to explain this result: 1) more than one iridium anomaly zone exists or 2) the Raton iridium occurrence is the product of other concentrating mechanisms (not an extraterrestrial impact).

These results tend to confirm the data from the San Juan Basin. The Raton Cretaceous–Tertiary boundary and the San Juan Basin magneto/paleontologic Cretaceous–Tertiary boundary both clearly seem to occur within normal polarity zones. Additional palynological work on the San Juan Cretaceous–Tertiary boundary magnetozone may yield pollen data to support or refute this line of reasoning.

Lerbekmo and others (1979) established that Cretaceous dinosaurs in the Red Deer Valley of Alberta became extinct within a reversed polarity zone correlated with the reversed zone between anomalies 29 and 30. This dinosaur extinction was followed within a few meters by a major palynofloral change. Possibly terminal Cretaceous extinctions began earlier in the north than in the south where, as in the Raton and San Juan Basins, a major palynofloral change does not occur prior to magnetic anomaly 29. Thus, if the base of anomaly 29 is accepted as the worldwide Cretaceous–Tertiary boundary as suggested by Lerbekmo and others (1979), or if the Cretaceous–Tertiary boundary is placed somewhat lower, within the 29–30 reversed polarity zone, the palynofloral change seen in the Raton Basin and the extinction of the dinosaurs in the San Juan Basin are Paleocene events. Extinction was not a synchronous worldwide event and catastrophic events at or near the Cretaceous–Tertiary boundary as indicated by iridium abundance anomalies (Alvarez and others, 1980) did not result in the extinction of dinosaurs and Cretaceous floras everywhere.

ACKNOWLEDGMENTS—We wish to thank Carl Orth for providing us access to the Los Alamos core and showing us the location of the palynological boundary and iridium abundance anomaly in Raton Park. We wish to thank Robert Butler and Everett Lindsay, University of Arizona, for providing access to facilities under their charge and for thoughtful discussions. The views expressed in this paper are our own.

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* * *

Geographic names

U.S. Board on Geographic Names

Chaves Canyon—canyon, 5.6 km (3.5 mi) long, heads in the Sierra Blanca at 33°29′20″ N., 105°50′55″ W., trends northwest to join Sanders Canyon at the head of Chaves Draw, 1.1 km (0.7 mi) northeast of Chaves Mountain and 14.5 km (9 mi) south-southwest of Carrizozo; Lincoln County, New Mexico; sec. 22, T. 9 S., R. 10 E., New Mexico principal meridian; 33°30′55″ N., 105°53′35″ W.

Chaves Draw—ravine, 12.9 km (8 mi) long, heads in the Sierra Blanca at the junction of Chaves Canyon and Sanders Canyon at 33°30′55″ N., 105°53′35″ W., trends northwest to Willow Draw 11.3 km (7 mi) southwest of Carrizozo; Lincoln County, New Mexico; sec. 26, T. 8 S., R. 9 E., New Mexico principal meridian; 33°35′22″ N., 105°58′47″ W.; *not:* Sanders Canyon.

Diamond Peak—peak, elevation 2,577 m (8,453 ft), in the Sierra Blanca 3.5 km (2.2 mi) west of Church Mountain and 12 km (7.5 mi) southeast of Carrizozo; Lincoln County, New Mexico; sec. 10, T. 9 S., R. 11 E., New Mexico principal meridian; 33°32′50″ N., 105°47′48″ W.

Goat Canyon—canyon, 3.2 km (2 mi) long, heads on the northwest slope of Church Mountain in the Sierra Blanca at 33°33′23″ N., 105°46′11″ W., trends north to open out 11.3 km (7 mi) southeast of Carrizozo; Lincoln County, New Mexico; sec. 26, T. 8 S., R. 11 E., New Mexico principal meridian; 33°35′02″ N., 105°46′12″ W., *not:* Pine Canyon.

Jakes Spring—spring, 0.81 km (0.5 mi) north of Cottonwood Creek and 16 km (10 mi) southwest of Carrizozo; Lincoln County, New Mexico; sec. 10, T. 9 S., R. 9 E., New Mexico principal meridian; 33°32′05″ N., 105°59′50″ W.; *not:* Nickeles Spring

—Dave Love
NMBMMR Correspondent

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Gallery of Geology

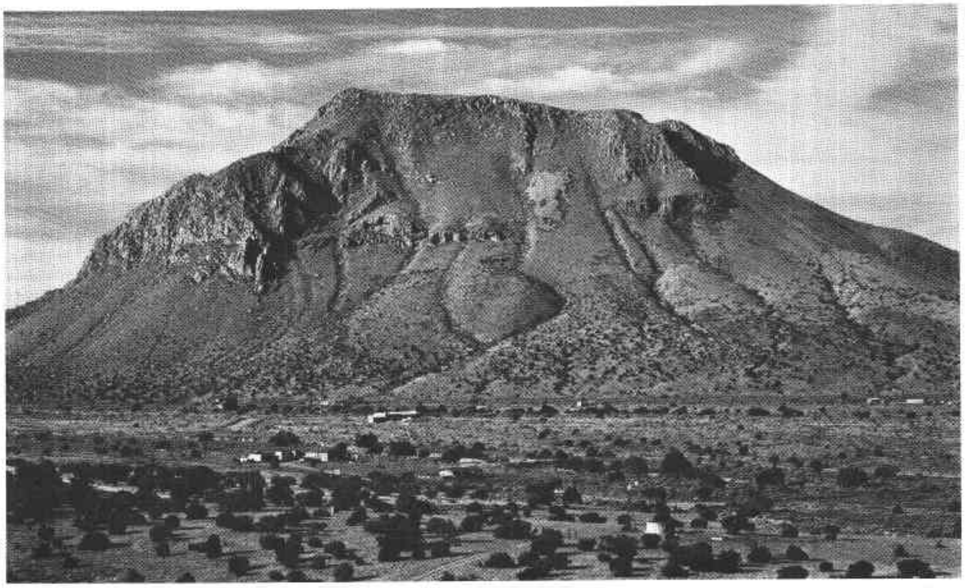

Photo by Glenn R. Osburn

The face of Mary Magdalene on Magdalena Peak is a startling sight to today's traveler on the road between Magdalena and Kelly, New Mexico, but certainly not as startling as it must have been to the superstitious Indians who doubtless first observed this geological/botanical phenomenon sometime in the distant past.

Just who that first observer may have been we'll probably never know—few legends or writings regarding the event from either the Indians or Spanish seem to have survived. Nor do we know for sure who named the feature "Our Lady Magdalena." According to research conducted by the W.P.A. (Works Progress Administration) during the 1930's, the feature was discovered and named over three centuries ago (circa 1630) by a group of Spanish explorers who had separated themselves from the main expedition body. They were so impressed by the image that they named the mountain "La Sierra de Maria Magdalena" in memory of Mary Magdalene who "spent her last days in penance and prayer on a mountain" in Spain (W.P.A. Collection, 1938).

Several legends about the effect of the figure do exist, however. The earliest legend dates at least to the late Spanish or early Mexican occupation period during which a party of travelers was surrounded by a band of Apaches. Death was imminent when suddenly, it is said, the image appeared on the side of the mountain. This appearance was more than enough to rout the superstitious Apache (Pearce, 1965, p. 95).

The image was apparently well known thereafter. According to Allen (1916, p. 26), Indians actually avoided the mountain during their wars and depredations spanning a century in time. Both Geronimo and Victorio were said to have particularly avoided it. The east side of Magdalena Peak became known as "a place of refuge and the savage Indian would forego his bloody deeds under the shadow of the holy mount" (Jones, 1904, p. 119).

Geologically "Our Lady Magdalena" is a talus slope composed of loose angular blocks of rhyolitic lava partially held in place and enhanced in outline by various shrubs. Despite one's intuitive feeling that such a rock slope should be unstable, this particular feature has been amazingly stable, perhaps a result of our presently dry climate. Comparison with photographs nearly 100 yrs old (NMBMMR photo collection) shows virtually no changes, and if the above legends are to be believed, the image must have existed at least 200 yrs before that.

Magdalena Peak itself is a magnificently dissected and exposed Miocene-age (14-m.y.-old) volcanic dome. Erosion has removed roughly three-fourths of this old rhyolite volcano, exposing the vent area on the left (south) shoulder of the mountain. During the last stages of the eruption, the vent was plugged by intrusive rhyolite which now forms the rugged nonlayered area there. The prominent ledge to the right (north) of the vent just below "our lady" is well-indurated, pyroclastic material from an early violent stage of the eruption. The upper third of the mountain above this ledge consists of Magdalena Peak rhyolitic lavas. These lavas piled up above the vent and flowed several miles to the south where they form many of the intermediate-height hills just west of the main Magdalena ridge. Danny Bobrow (New Mexico Institute of Mining & Technology M.S. candidate) has recently mapped Magdalena Peak in detail and is currently doing a detailed chemical study of this and similar rhyolitic lavas in the Socorro–Magdalena area. This study should be completed in 1983.

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—Robert Eveleth and Glenn R. Osburn, New Mexico Bureau of Mines and Mineral Resources