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LANDFORM DEVELOPMENT OF CITY OF ROCKS STATE PARK AND GIANT OF THE MIMBRES

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Abstract—Bedrock landforms at City of Rocks State Park and Giant of the Mimbres are developed in the lowermost ash-flow tuff unit of the Sugarlump Rhyolite. Convex-upward sheeting fractures and an orthogonal fracture set in the ignimbrite sheet have been exploited by weathering and erosion to produce a landscape of pinnacles, boulders, balanced rocks, clefts or corridors and rock platforms. Flared sidewalls on the pinnacles and the presence of rock basins and stains on the platforms indicate that the bedrock landforms are of etch origin. Etch forms develop beneath a soil mantle at the weathering front, but are subsequently exposed as the overlying regolithic cover is stripped. The occurrence of multiple flares on some pinnacles suggests that several episodes of alternate weathering and erosion were required to produce the modern landscape.

INTRODUCTION

City of Rocks State Park and the nearby Giant of the Mimbres area are developed in outcrops of Oligocene volcanics mapped by Elston (1957) as the Sugarlump Rhyolite. City of Rocks is 41 km north–northwest of Deming, 4.3 km north–northeast of Faywood Hot Springs and 2.6 km north of State Highway 61. The Giant of the Mimbres area is 4.8 km east of City of Rocks and 0.5 km northwest of Highway 61, near the west bank of the Mimbres River. Between the two areas and overlooking both is Table Mountain, a mesa underlain by three distinctive ash-flow tuff units of the Sugarlump. City of Rocks and Giant of the Mimbres are sculpted in the lowermost ash-flow tuff unit that has been dated at 35.12 my (W. C. McIntosh, oral commun. 1987). The tuff consists of 20–25% phenocrysts of quartz, sanidine, plagioclase and hornblende in a devitrified matrix. Chemically, the tuff consists of approximately 74% silica, 14% alumina and minor amounts of iron oxide, potash and soda.

The major attraction at City of Rocks is a cluster of several hundred pinnacles and boulders that occupy approximately 20 hectares of the 259-hectare State Park (Fig. 1). These rocks, all less than 15 m high, stand in orderly fashion on the crest and sides of a low rise. The main rock assemblage trends 800 m north–northeast and is about 240 m wide. Long a popular stop for picnickers, hikers and campers, City of Rocks is readily accessed from a dirt road which follows the perimeter of the main rock cluster.

The Giant of the Mimbres area is less well known and its limits are less well defined, but some of its forms are more spectacular. Rock columns developed on the slopes of a broad divide are both taller and more widely separated than their City of Rocks counterparts (Fig. 2). Of special interest is a massive balanced rock that rests on a small and narrow pedestal. Shorter rock columns and smaller balanced rocks are common on the steep valley side slopes along the modern, incised drainage system.

Almost without exception, the pinnacles and columns in the two areas have lower sidewalls that are flared or concave outward (Fig. 3).



FIGURE 1. Main assemblage of pinnacles at City of Rocks State Park. Numerous rock basins are developed on tops of pinnacles and in rock platform in foreground. Oak tree provides scale.



FIGURE 2. Massive rock columns at Giant of the Mimbres. Height of tallest column is estimated at 16 m. Person provides scale.



FIGURE 3. Flared lower sidewalls of pinnacles at City of Rocks. The clefts or corridors are aligned along a common fracture. Person stands on inclined rock platform.

Flared slopes have been described from many parts of the world and in various lithologic and climatic environments, but they are best developed in Precambrian granites of South Australia and Western Australia. Twidale (1962, 1982) has demonstrated that flared slopes are a type of etch form, having developed in the subsurface at the weathering front of Mabbutt (1961). Etch forms are exposed at the surface as the overlying regolith is stripped. Here it is argued that the flared slopes and related forms now displayed at City of Rocks and Giant of the Mimbres are also of subsurface origin.

EARLY VISITORS

Evidence of Indian occupation of the two study areas is abundant. Though artifacts have been removed for well over 100 years, pictographs, potsherds and the occasional stone implement remain for the discerning eye. Artifacts from Faywood Hot Springs, a site venerated by the Indians, indicate considerable travel by early man between the springs and the Rio Mimbres.

It is not known who was the first white man to visit City of Rocks or Giant of the Mimbres. Spanish expeditions along the Mimbres began about 1780, and copper mining by the Spanish at Santa Rita del Cobre flourished in the early 1800s, bringing many settlers to the region. Faywood Hot Springs, then known as Ojo Caliente by the Indians and Spanish, attracted many visitors, some of whom undoubtedly also visited City of Rocks.

John R. Bartlett, United States Boundary Commissioner, camped along the Mimbres in 1851 at a point approximately 8.0 km south of Giant of the Mimbres. On May 1 of that year, after hearing stories from his men of intricately sculptured rocks farther upstream, Bartlett rode to the area he described as ". . . singular masses of sandstone. . . ." According to Bartlett's account,

> Around us stood these singular isolated rocks, some appearing like castles, others like single pedestals and columns. The one resembling a human figure I christened the "Giant of the Mimbres." My timid mule was much alarmed at the gigantic object which stood before it, trembling from head to foot (Bartlett, 1854, vol. 1, p. 224).

Bartlett also states that the Giant of the Mimbres rock column measured about one meter in diameter at its narrowest point near ground level. Though his detailed sketch of the landscape, published in 1854, unequivocally identifies the area Bartlett visited, one puzzle remains. The only rock column with a narrow base has a top that resembles the head of a reptile (Fig. 4). Yet a few meters away is an equally tall but much more massive and imposing column whose top resembles the head of a person, including a weathered eye. Did Bartlett confuse the two rock columns between the time of his field visit and the time of his publication three years later?

On May 2, 1851, Bartlett broke camp along the Mimbres and traveled west–northwest toward the main road to Santa Rita, but detoured a few miles to the north to visit the famed Ojo Caliente. While departing the spring, Bartlett fell from his mount and broke his arm near the shoulder. He walked out about 3.2 km to the west, intercepted the main road to the north, and continued by carriage another 29 km to Santa Rita. Though Bartlett visited both Giant of the Mimbres and Ojo Caliente briefly, he did not travel the direct route between the two sites, therefore missing City of Rocks.



FIGURE 4. Two tall rock columns at Giant of the Mimbres. Sleeping Giant Rock, with person for scale, is in foreground. Behind the Giant is a much narrower column with a reptile-like head at the top. Bartlett sketched these columns in 1851 and Bell photographed them in 1867.

Another early visitor to the area was William A. Bell in 1867. Bell was part of a railroad survey expedition that came upon the Rio Miembres (Mimbres) after having crossed the Cooke's Range from the east. In describing the Mimbres Valley, Bell states:

> Many curious natural ruins are to be found near the western bank. There are the valley of rocks, the city of rocks, &c., in which huge masses of sandstone form pillars, chimneys, altars, giant mushrooms, and temples which would compare not unfavorably with Stonehenge, had they not been geological curiosities only. I enjoyed a few hours' photographing amongst these grotesque forms, for they made splendid subjects for the camera (Bell, 1869, p. 26).

Intutition suggests that Bell's reference to a city of rocks is in fact City of Rocks, and his valley of rocks is the Giant of the Mimbres area visited by Bartlett sixteen years earlier. However, a lithograph of the Giant of the Mimbres area appears in Bell's 1869 book, *New Tracks in North America,* but carries the caption "The City of Rocks, Rio Miembres." Did Bell mislabel the lithograph that was published two years after his field visit? If not, where is the valley of rocks he refers to, and did Bell ever visit the area now named, or misnamed, City of Rocks?

STRUCTURAL FEATURES OF THE IGNIMBRITE SHEET

City of Rocks is developed in a more or less horizontal ignimbrite sheet. The same sheet can be traced to the base of Table Mountain and to a hillside in the southeast corner of the park. There, similarly weathered forms occur at essentially the same elevation as those found in the main rock complex. The ignimbrite sheet is truncated by two types of rock platforms. Rock pediments with slopes of $<3°$ extend outward from the base of the main complex to nearby arroyos. Upslope of these erosional forms are steeper rock platforms with slopes of 5°–10° (Fig. 1). They are of probable structural rather than erosional origin, for in places their trace continues as a fracture through the bases of large pinnacles. This suggests that the rock platforms have developed along convex-upward sheeting fractures.

The structural setting of Giant of the Mimbres is quite similar to that of City of Rocks, but the general aspect of the landscape differs in several respects. The Giant of the Mimbres area is a series of interconnected valleys and broad interfluves cut below the rim or escarpment of the ash-flow tuff. Steep valley side slopes of 10°–14° truncate the tuff unit, which dips southerly a few degrees. Sheeting fractures are clearly evident across the surface of the steep rock platforms. In places, entire hillsides appear to be made up of a series of steeply-inclined plates.

The bedrock in both areas is further subdivided into columns and blocks by an orthogonal fracture set. Horizontal to subhorizontal fractures are conspicuous in most but not all pinnacles. Vertical to near-vertical fractures subdivide the ignimbrite sheet into blocks that are rhomboidal, quadrangular or triangular in plan. These major vertical fractures at City of Rocks trend north–northeast, east–northeast and northwest. The fractures at Giant of the Mimbres have not yet been mapped in detail, but they are conspicuous on aerial photos.

It is not known whether the fractures are cooling cracks associated with the thermal contraction of the ignimbrite, or whether they are related to the release of the gravitational load as the overlying units of the Sugarlump and younger volcanics were eroded. Perhaps both mechanisms apply and fractures of different generations are present. This might explain why two adjacent vertical fractures, in some cases no more than a meter or so apart, appear to have vastly different weathering and erosional histories (Fig. 5). One appears fresh and closed, the other deeply and widely exploited. Whatever their origin, the fractures play a dominant role in the development of pinnacles and platforms.

LANDFORMS

The vertical fractures, subject to downward and lateral weathering, have been exploited to produce linear clefts or slots in the rock (Fig. 6). At City of Rocks, where the rock corridors are especially well developed, one finds the "streets" of Weber (1980). Some corridors are five or more meters wide and are due to the complete evacuation of regolith between as well as along two parallel fractures. In places, all that remains of the original rock mass between the fractures is a low rock mound or "traffic island" (Fig. 7). Although most corridors intersect with others, some terminate against rock walls.



FIGURE 5. Two nearly vertical fractures in the tuff at City of Rocks, one exploited by weathering and erosion to produce a narrow cleft, the other tightly closed. Flared slopes are visible in pinnacle on right. Hammer hangs on right wall of slot.

A great array of shapes is found among the pinnacles and columns. Most of the fracture-defined blocks have become more or less rounded as a result of weathering and widening of the fracture zones. Rounding has produced pinnacles with convex-upward tops, but the bases of these rocks are characteristically concave-outward or flared, so that many of the forms are bulbous in overall appearance. Where two or more higher and presumably older flared zones can be distinguished on the middle and upper sidewalls, the pinnacles look like mushrooms, hourglasses or dumbbells. The fanciful imagination of popular writers has also identified broccoli spears, nutcrackers, etc. The forms range between short, nearly round pinnacles and boulders to the chimneys and altars described by Bell (1869) at Giant of the Mimbres.

Some horizontal fractures in the pinnacles and columns have been exploited by weathering to produce in situ balanced rocks and/or boulders resting on pedestals. Anvil Rock, an outlier of the main assemblage at City of Rocks, is especially impressive (Fig. 8). At Giant of the



FIGURE 6. Typical cleft or corridor developed along fracture line at City of Rocks. A thin rubbly regolith remains where once a much thicker soil cover extended through the cleft to the drainage divide in background. Three separate flares are evident. The "s" marks the stain line or upper limit of the most recent soil cover.



FIGURE 7. A boss or shield is all that remains between two parallel clefts on left that intersect perpendicularly a corridor on the right. A zone of intense chemical attack and etching is visible along upper limit of flare. Hammer provides scale. Several of these forms are preserved at City of Rocks.

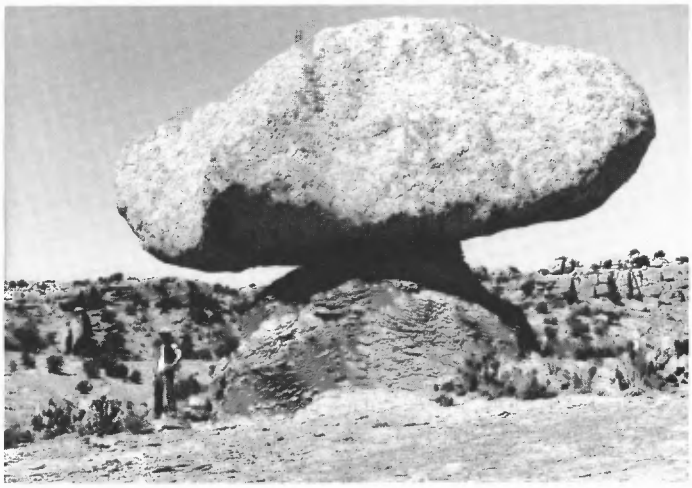


FIGURE 9. The largest of the balanced rocks at Giant of the Mimbres. The flaggy, weathered pedestal is in situ, but the massive balanced rock is rotated nearly 90° from its original position. The balanced rock came to rest on a former land surface, nearly all of which has been removed by subsequent erosion.

Mimbres, a smaller balanced rock and pedestal look much like the cartoon character Snoopy.

Unique among these forms is a massive balanced rock at Giant of the Mimbres (Fig. 9). Supported by a pedestal three meters high, this rock is 9.5 m long and four meters thick. The balanced rock is rotated nearly 90°, along its main axis, from its original attitude, but its highly weathered pedestal is in situ. This finding is based on the fact that the pumice fragments are foliated nearly vertically in the balanced rock, but are essentially horizontal in the pedestal and surrounding ignimbrite sheet. The underside of the balanced rock, which surely came to rest on a higher and older land surface, closely parallels the modern land surface below. Weathering and erosion have removed all evidence of the sheet structure between the two surfaces, save for small segments preserved in the bases of a few nearby rock columns and in the pedestal itself.

The pinnacles and pedestals merge basally with the sloping rock platforms. At City of Rocks, the platforms are narrow within the clefts but are 10 or more meters across where all remnants of the upper sheet have been removed. At Giant of the Mimbres, platforms developed on the upper slopes of interfluves are especially broad. In all platforms, however, traces of vertical fractures are clearly evident. Some fractures have been deeply exploited to produce narrow gorge-like slots or chutes (Fig. 10). Others contain enough soil, debris and water to support oak trees rising above the otherwise barren platforms. Organic soils occur in patches, especially on the platforms, but nearly all of the former soil cover has been stripped from both areas.



FIGURE 8. Anvil Rock at City of Rocks. Weathering has exploited a subhorizontal fracture to produce a massive balanced rock on a narrow pedestal.

Depressions or rock basins are found in both areas, but are more common at City of Rocks. These basins are developed in the platforms, on pedestals and at or near the crest of many pinnacles (Fig. 11). Many basins are shallow, flat-floored pans (Wentworth, 1944); others are large, deep armchair-type depressions and some are pits of conical or hemispherical shape. Among the latter are more than a dozen Indian grinding pits, all less than 32 cm diameter. These pits are located within 45 m of a rock shelter on the west side of City of Rocks. Three of the pits retain smoothly-ground upper sidewalls, but in others the deeply-etched and roughened sidewalls indicate weathering by standing water (Fig. 12). According to S. Upham (oral commun. 1987), the grinding pits date back at least to the Mogollon Culture (pre-1400 A.D.) and may date back as far as 6000 B.C.

INTERPRETATION

Flared slopes strongly suggest that the lower sidewalls of pinnacles have been etched by moisture attack below the land surface, at the contact between soil and rock. Much evidence has been presented by Twidale (1962, 1982) to argue the case for subsurface initiation of most, if not all, flared slopes. Particularly convincing are those flared slopes that have been uncovered in areas of artificial excavation. The evidence at City of Rocks for subsurface initiation of flares is compelling. The upper limit of the basal flares on the pinnacles is demarcated by a stain or line of discoloration. Above this line the tuff is gray; below the line and extending across the platforms is a surface that is both reddish-brown and pitted. The stain line is the approximate upper limit of the old land surface, the top of the former regolith. Each flare, then, has a two-stage development, and the stages are temporally distinct. The first stage involves weathering and the development of a regolith, below which the details of the weathering front are etched. The second stage requires evacuation of the regolith and exposure of the weathering front. At City of Rocks, the occurrence of multiple flares on a single pinnacle suggests several alternations of weathering and erosion (Fig. 13).

Rock platforms, like flares, are etch forms developed at the weathering front. This can be demonstrated at both City of Rocks and Giant of the Mimbres where patches or remnants of the former regolith cover are in the process of being stripped. The freshly-exposed platforms are rough and scaly and display numerous rock basins. These basins are developed where points of weakness are exploited along the weathering



FIGURE 10. The longest and most deeply exploited fracture line at City of Rocks. At this locality, only a few pinnacles associated with the upper sheet structure remain. Instead, broad rock platforms extend both left and right of the fracture. Person in background for scale.

front, perhaps in association with a higher than average concentration of soil water. Rock basins are best developed in massive rock between, rather than along, the vertical fractures. Once exposed, the basins continue to evolve under the influence of surface processes.

It is more difficult to explain the great number of rock basins, some of considerable size, that are developed at or near the tops of pinnacles at City of Rocks, for one would expect water to run off rocks with convex crests. One possible explanation is that the whole of City of Rocks developed as a topographic dome beneath a thick soil mantle. If this interpretation is correct, then the initial phase in the development of City of Rocks included rounding of the upper corners of the fracture-defined blocks and the development of rock basins between fractures at the weathering front. The second phase included the development of clefts and flared slopes during three or more alternations of soil formation and regolith stripping. Basins on the tops of rock domes are known from other parts of the world and have been interpreted as etch forms. Ayers Rock in central Australia and Pildappa Rock in South Australia are two examples (Twidale, 1978). Both also display superbly developed flares on their flanks.

The current phase of soil erosion and exposure of the weathering fronts at City of Rocks and Giant of the Mimbres is nearly complete. Given that the grinding pits at City of Rocks have a minimum age of 600 years, the rock platforms in which they are developed must be of considerable age, and consequently, a long interval of soil erosion is implied. The picture at Giant of the Mimbres is less clear, although the coincidence of forms and the close proximity of the two areas suggests Giant of the Mimbres may have developed concurrently with City of Rocks.



FIGURE 11. One of many rock basins developed on the tops of convex-upward pinnacles. Their origin is uncertain, but some may be etch forms developed below a former soil cover. This pan is 1.25 m long, 0.75 m wide and 15–25 cm deep.

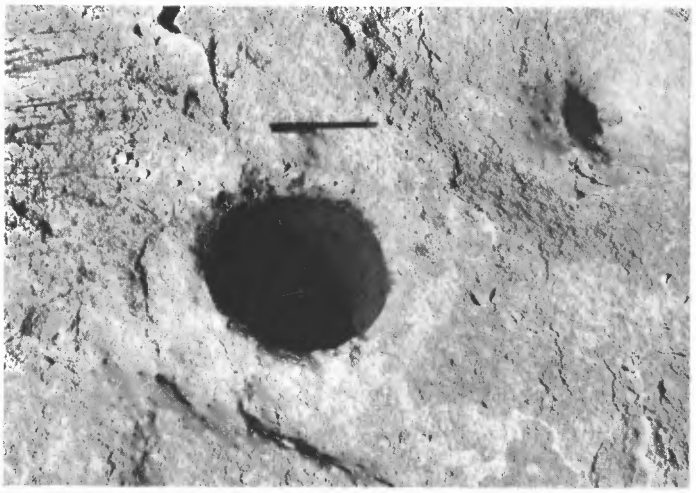


FIGURE 12. An Indian grinding pit on the west side of City of Rocks. This pit holds water for long periods of time and has developed etched and roughened sidewalls. A 15-cm pen provides scale.

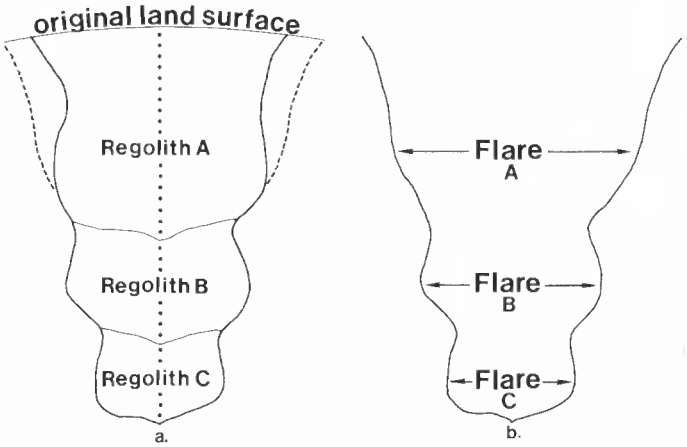


FIGURE 13. The development of multiple flared slopes through episodic weathering and erosion. The cleft or corridor develops along a vertical fracture represented by the dotted line.

CONCLUSION

Many of the landforms at City of Rocks and Giant of the Mimbres developed not at the surface, but in the subsurface, beneath a soil cover, by moisture attack at the weathering front. The clefts and corridors, the platforms and the basins and the pitting and the staining are all of etch-form development. Like their counterparts elsewhere, these forms have developed on rock that is both massive and impermeable. The exposure and preservation of these forms in the arid region of southwestern New Mexico is fortuitous.

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