Geomorphic development of the Giants of the Mimbres, Grant County, New Mexico

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Abstract

The Giants of the Mimbres, named by Bartlett (1851), constitute an assemblage of landforms developed on the Kneeling Nun Tuff (34.9 Ma). These forms include: tall and slender rock columns, shorter and more bulbous pinnacles, convex-upward bedrock slopes, balanced or perched rocks, boulders, and colluvial fills. It can be demonstrated that most of the major forms have developed along fracture-defined blocks and sheets in the bedrock. Conspicuous among the bedrock forms are basal concavities or flared slopes that originally developed in subsurface zones of especially intense attack by chemical and biological weathering. Therefore, the major forms were likely initiated beneath a soil mantle that has subsequently been stripped by surface erosion, producing a suite of bedrock landforms of etch origin. A comparison of modern photographs and those taken by Bell (1867) indicate that there has been little geomorphic change at the Giants in the past 133 yrs.

FIGURE 1—View looking northeast across the dissected plateau from a point just below the bluffs, and showing the proximity of most of the rock columns to the valley floor. Cookes Peak is visible at the far right on the skyline. The tree-lined watercourse in the middle background is the Mimbres River, flowing from left to right.

Introduction

One hundred and fifty-one years ago, John Russell Bartlett, United States Boundary Commissioner, described and sketched a group of tall rock columns standing in a small valley that drains into the Mimbres River of southwestern New Mexico. In his field journal entry for May 1, 1851, Bartlett refers to the group of rocks as the "giants of the Mimbres" (Bartlett papers). Three years later, however, Bartlett published a two-volume book in which he described an especially striking single rock column from among the giants and named it "the Giant of the Mimbres" (Bartlett, 1854: v. 1, p. 224). Unfortunately, this singular noun has since been applied to the entire assemblage of residual forms found in the valley, which is confusing. In this paper, the "Giant" indicates Bartlett's specific column, whereas the term "Giants" refers to the assemblage of rocks.

Topographic setting

The Giants of the Mimbres (Fig. 1) are located in a 300-ft (90-m) deep valley in southeastern Grant County, 3.0 mi (5 km) due east of City of Rocks State Park and 0.5 mi (0.8 km) northwest of NM–61, near the west bank of the Mimbres River (Fig. 2). At this point, where the Mimbres River exits its canyon and enters the broad plains of the northern Chihuahua Desert, rainfall averages approximately 13 inches (33 cm) annually. The landscape in and around the Giants is dominated by plateaus that are bordered by simple faceted slopes comprising bluffs, succeeded below by steeply inclined and convex-upward debris slopes that grade at angles of 4°–8° to the narrow valley floors. Blocks of various sizes are

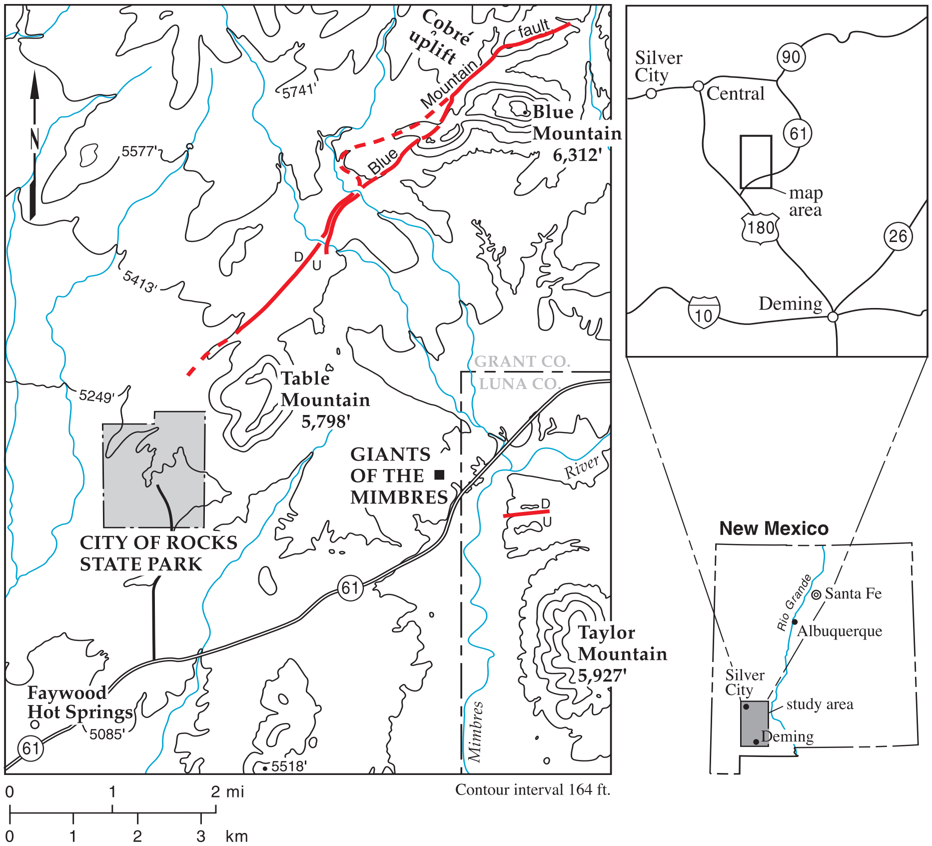

FIGURE 2—Location map of study area.

FIGURE 3—View to the east looking across a long narrow bedrock divide that is traversed by traces of north-south trending vertical fractures colonized by tufts of grass. Note the displaced triangular slabs on the lower slope.

exposed in the bluffs, which are irregular in plan view with alternating bold cliffs and reentrants, the latter most conspicuously developed where fracture density is greatest. Debris slopes take their name from the generally thin and discontinuous regolith that mantles the inclines, but in reality bedrock is everywhere close to or at the surface. The debris slopes appear relatively smooth from afar, but they are irregular in detail. For example, steplike outcrops several feet high break the slope, and blocks and boulders rest on the lower slope below the cliffs. Some of the boulders are in situ, but others have fallen from the bluff, and yet others are derived from the collapse of columns from among the Giants.

Geology

The Giants of the Mimbres, together with City of Rocks and Table Mountain to the west, are developed on a tectonic block that has been uplifted along the normal, northeast-trending Blue Mountain fault. The block is separated from, and upthrown relative to, the much larger Cobré uplift to the north. The southern block, including the study area, is dominated by a series of ignimbrite sheets and associated tuffaceous sediments known as the Sugarlump Rhyolite (Elston, 1957; Seager et al., 1982). McIntosh et al. (1991) later included that portion of the Sugarlump Rhyolite on which the Giants of the Mimbres and City of Rocks are developed as part of the Kneeling Nun Tuff, a formation characterized by phenocrysts of quartz and many horizontally to subhorizontally disposed tabular pumice fragments.

The volcanic rocks exposed in the valley of the Giants are of Oligocene age, with reported radiometric ages of 36.9 Ma from a site near but slightly lower than the Giants; 34.9 Ma from the unit in which the Giants are developed; and 33.5 Ma from a unit some 500 ft (152 m) higher in the relief at Table Mountain (Clemons, 1982; Clemons et al., 1980; McIntosh et al., 1991). These ages are not only internally consistent but are also comparable to many others obtained from ash-flow tuffs associated with east-west crustal extension during the early stages of the development of the southern Rio Grande rift.

Discrete horizontal to subhorizontal fractures subdivide the Kneeling Nun Tuff along the western escarpment, and these fractures also are visible at various levels in many of the isolated rock columns preserved in the valley below. Many steeply inclined fractures further subdivide the ignimbrite into quadrangular, rhomboidal, and triangular blocks. The dominant fractures are all north trending and are readily traced across the local landscape (Fig. 3). Though some fractures have been weathered to form narrow corridors filled with rubble, most are tight and have not been substantially exploited by weathering and erosion. Additionally, convex-upward fractures are exposed in and underlie the lower and middle valley sideslopes. Where combined with the vertical fractures, these sheet fractures produce a patchwork of plates and slabs of various thicknesses.

The origin of these fracture sets varies and is, in some instances, controversial. The steeply inclined partings may be cooling joints associated with the thermal contraction of the ignimbrite. Presumably, certain of the major vertical fractures have a tectonic origin and developed in the same predominantly tensional setting that produced the Blue Mountain fault. Others, including the horizontal and arcuate fractures, are likely the result of the reduction in lithostatic load following erosional offloading (Chapman, 1958), as some 2,000–3,000 ft (610–914 m) of volcanic rocks have been eroded from the valleys. That some fractures have been widened by weathering and erosion to produce

FIGURE 4—Block resting on zone of imbrication and brecciation.

kluftkarren (clefts or corridors), whereas others remain in their pristine state, may be a function of age, but this difference may also reflect local stress fields—whether the fractures are in tension (open) or compression (tight)—possibly related to local shearing (Weissenberg, 1947; Twidale, 1980).

Scarps as high as 15 inches (38 cm) are present on some of the bedrock slopes at the Giants of the Mimbres and are evidence of differential weathering as well as possible tectonic activity. Some scarps, which describe a zigzag pattern in map plan, are typical of brittle tensional fracture, but lack of exposure along the fractures makes it difficult to ascertain the character of most. A few rock columns display gently inclined fractures along which dislocation has produced a zone of brecciation and imbrication (Fig. 4). Displaced slabs associated with the sheeting structures (Fig. 3) and the occasional collapsed columns may attest to the occurrence of recent earth tremors (Twidale and Sved, 1978; Twidale et al., 1991).

Evolution of the valley

Stream dissection and the concomitant lowering of the water table have caused the uppermost volcanic beds to become, and remain, relatively well drained. These beds are therefore less susceptible to weathering and erosion. In this way, although the uppermost layers are not necessarily either compositionally or texturally different from those beneath, the upper units nevertheless form a caprock. Thus at the Giants of the Mimbres, as in other areas of flat-lying structure, it is probable that stream incision has over time produced a succession of valleys of similar morphology but of ever increasing cross section area: depth of the valley increases as streams downcut in response to local base level adjustments, and width increases as the scarp developed on the caprock retreats, albeit at ever decreasing rates as the plateau catchment area is reduced over time (Twidale, 1978a). The similarity of slope form and inclination throughout the area, and regardless of the degree of plateau dissection, corroborates the suggestion that scarp recession has occurred (e.g. King, 1942, p. 42; Fair, 1947).

The convex-upward bedrock sectors of the debris slopes are coincident with arcuate sheet structures in the ash-flow tuff. That they are also former weathering fronts (Mabbutt, 1961) is suggested by evidence from the main channel at a point about 100 yds (91 m) upstream of a stockpond, where the bedrock floor grades laterally beneath a gravelly alluvium. At the contact between bedrock and alluvium, the tuff, which is typically gray and massive, is instead bleached and laminated, a condition typical of a weathering front. The abrupt transition between altered and intrinsically fresh bedrock is a characteristic of weathering fronts, as are the iron staining and flaking evident on many of the exposed bedrock surfaces at the Giants (e.g. Larsen, 1948, p. 115; Hutton et al., 1977; Twidale, 1986).

FIGURE 5—(Upper) Bell's 1867 picture of the Giant of the Mimbres, and (lower) the same view in 2000.

Rock columns or pillars

The most spectacular forms at the Giants of the Mimbres are the rock columns or pillars that rise as much as 50 ft (15 m) above their bases. They are in situ and stand generally low in the valley, adjacent to the stream channel (Fig. 1). The columns are subdivided by essentially horizontal fractures. Technically, the columnar landforms developed in the valley of the Giants are tall pedestal or mushroom rocks, mostly with relatively broad caps and narrow stems (Twidale and Campbell, 1992). Some of the columns are so striking and evocative that they have readily attracted specific names alluding to their perceived resemblance to other objects.

The largest of the rock columns are typically in pairs or groups, although some of the most spectacular forms stand in isolation. Examples of pairs standing but a few feet apart and separated by a well-defined vertical fracture are common in the Giants complex. Such paired columns include the rock Bartlett designated as the "Giant of the Mimbres" and its neighbor to the right, as seen on the far right of Figure 5, behind a balanced rock. The two columns seen in

FIGURE 6—Double Rudder Rock, with a debris-filled arcuate fracture cleft between the two columns.

FIGURE 7—Fortress Rock, comprising several closely spaced, squat, and bulbous columns.

the middle foreground of the same scenes, a short distance upslope of the main channel, make another such pair, one of which is the tallest column in the valley. Double Rudder Rock (Fig. 6), which stands in isolation on a local divide, comprises two elongated residual masses, with a rubble-filled fracture-controlled cleft separating the two columns.

Other columns stand in groups, some several feet apart and others so closely juxtaposed that steeply inclined fractures are tight and essentially impenetrable to water. Fortress Rock, a massive assemblage of columns spread across a well-drained divide (Fig. 7) exemplifies this latter type. However, although the fractures within Fortress Rock remain essentially untouched by weathering and erosion, flared slopes (basal concavities) have developed on the exposed bases of the columns.

Examples of isolated columns at the Giants of the Mimbres include Tortoise Rock and The Toadstool (Fig. 8). Both are symmetrical and low in the landscape, adjacent to the major channel. What we have euphemistically named The Toadstool consists of a column or stem topped by a hemispherical crest that is developed on a separate joint block.

Boulders and perched rocks

Boulders of various sizes and shapes are scattered across the debris slopes. Some are more or less rounded, but others have been weathered into suggestive shapes, some for example resembling a barbell or drumstick. One of the largest boulders at the Giants stands downslope from Double Rudder Rock. It measures 18 ft (5.5 m) long, 8 ft (2.4 m) wide, and 10 ft (3.0 m) high, and its long axis is oriented downslope. Other than its rough, scaly exterior, the rock appears quite fresh. The pumice fragments in the boulder are vertically oriented, indicating that the boulder must have been transported from a site upslope, perhaps as a block dislodged from the escarpment. Another boulder, on the opposite side of Double Rudder Rock, is considerably smaller but more intricately weathered. Not only is it rough and scaly, but several steep-sided, circular rock basins are developed in the crest.

Perched boulders also are well represented in the Giants valley. Some are in situ, but in others the orientation of the contained phenocrysts and pumice plates indicates that the upper perched or balanced rock has fallen downslope to its present position. For example, the balanced rock just downslope from the Giant (Fig. 9) is 31 ft (9.4 m) long, 13 ft (4.0 m) thick, and rests on a pedestal 9 ft (2.7 m) high. The upper rock is an allochthonous boulder, which, according to the near-vertical orientation of its pumice fragments, has been rotated almost 90° from its original position within the ignimbrite sheet.

Among the in situ types of balanced rocks, recesses developed along nearly horizontal fractures separate the upper rock from its pedestal. One of these forms at the Giants bears a remarkable likeness to the cartoon character Snoopy. Other balanced rocks have very limited zones of support and appear to be precariously balanced; east and upslope from the Giant, as Bartlett noted, some have indeed collapsed onto the platform below. In addition to simple perched blocks, many columns and pillars are split by gently inclined fractures, some of which are exploited by weathering, leading to crude cottage-loaf forms with two or more blocks resting one upon the other in orderly arrangement.

Origin

The residual columns and blocks that constitute the Giants of the Mimbres developed from differential weathering and erosion of the country rock. Large volumes of rock have been rotted and removed, leaving the residual forms in positive relief.

Fracture density has played a critical role in the development of the Giants of the Mimbres. At the head of the valley, a bird's-eye view shows the form of the bluff to be directly related to fracture density. Along the lower reach of the valley, the smooth bedrock channel floor has in places been swept clean of debris, revealing a pattern of mostly triangular blocks defined by vertical fractures that range from 1 to 6 ft (0.3 to 1.8 m) apart. This contrasts with the residual columns, in the vicinity of which the vertical fractures exposed on bare rock slopes are 15–25 ft (4.6–7.6 m) apart. It can be argued that the contrasts in fracture density between the columns and adjacent slopes, though real, are irrelevant, for it is the spacing of partings in the compartments of rock that have been eroded that is important, not their spacing in the bedrock that remains. Admittedly, the critical evidence no longer exists, but statistical analysis of fracture spacing at various levels in rock masses has shown that surface geometries are indicative of spacings at depth (Blès, 1986). If extrapolation from the surface down into existing rock masses is valid, then it is surely acceptable to project surface patterns a few feet into now eroded rock masses and take that pattern as indicative of the original fracture spacing (Twidale, 1987).

Another notable obsevation is that the Giant itself, together with many other large and massive columns, stands low in the landscape. This is because, and as argued previously, the higher reaches of the local relief are relatively dry and stable, whereas the lower sections to which water gravitates are areas of marked weathering and erosion. Not only would the weathered mantle tend to be thicker here than upslope, but colluvial and alluvial accu-

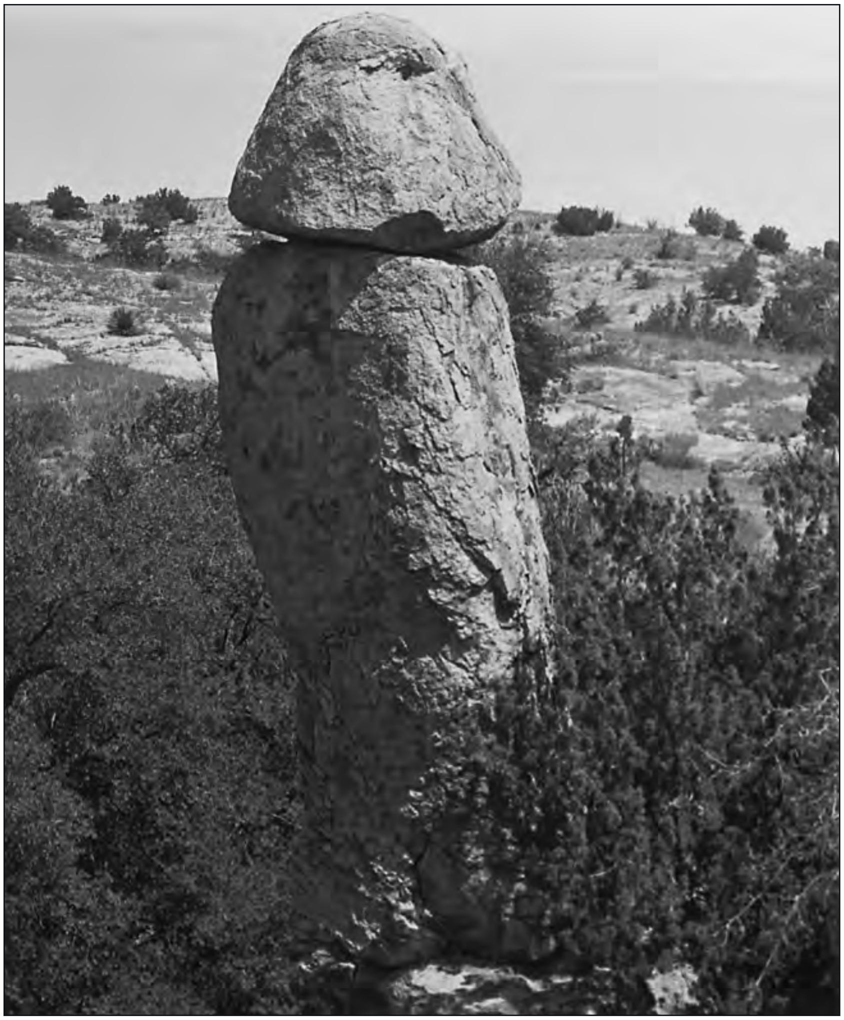

FIGURE 8—Toadstool Rock; note location next to the stream channel, in the lowest part of the valley floor.

FIGURE 9—Large balanced rock near the Giant. Note the scaly surface of the plinth and the contrasted diameters of the two components. The lower block has been reduced by subsurface moisture attack, which is also responsible for the scales or laminations, whereas the exposed upper boulder has been essentially stable.

FIGURE 10—Colluvial fill on the midslope surrounded by bare rock surfaces due to stripping of the regolith.

mulations would also be greater. Seager et al. (1982) mapped patches of "older alluvium" in the vicinity of the valley of the Giants. They attributed these sediments to backfilling following entrenchment of the Mimbres River, and these patches may in broader context represent a response to baselevel adjustments related to downstream autocyclic events (Mack et al., 1997). Because the alluvial-colluvial cover was thickest in and near the valley floor, it follows that greater relief would develop on the partly weathered and buried bedrock remnants near the valley floor.

Thus, it is suggested that the rock columns are of two-stage or etch origin; they were initiated beneath a substantial thickness of colluvial-alluvial fill, the bulk of which has subsequently been removed from the landscape. The comparatively massive rocks that are now the Giants resisted water penetration and hence weathering, and as the surrounding regolithic veneer was removed, these persistent bedrock projections emerged as relief forms. Once standing in positive relief, the bedrock columns shed water, enhancing the likelihood of their survival.

In support of this interpretation, remnants of a regolithic fill presently are preserved not only on the valley floor adjacent to the modern channel, but also in middle-slope depressions well above the modern drainage lines. At one point northwest of the main assemblage of the Giants, a shallow bedrock amphitheatre has been partly exposed as a result of the stripping of a patch of regolith 6–10 ft (1.8–3.0 m) thick. Such remnants suggest that a regolith once blanketed most of the lower and middle slopes of the valley (Fig. 10). During the periodic stripping of the regolith, chemical weathering by soil moisture continued to attack the still-buried parts of the rock columns. Such weathering by moisture held in the regolith accounts for the concavities (flares) and hollows (tafoni) developed on many of the isolated blocks and columns that constitute the Giants of the Mimbres.

Flared slopes (see e.g. Fig. 5) are due to subsurface moisture attack in the scarp foot or piedmont zone of inselbergs, blocks, or boulders. They are two-stage or etch forms that are initiated at the weathering front, at the base of the regolith (Twidale, 1962). Incipient flared forms have now been recognized in the natural subsurface in several quarry and other artificial excavations, and others have been exposed as a result of human-induced accelerated erosion, as, for example, at the City of Rocks, New Mexico (Mueller and Twidale, 1988a, b). Isolated flared forms on boulders merely indicate a former, possibly local regolithic accumulation, but widespread multiple flares in zones high in the landscape indicate former hill-plain junctions and imply pauses in the lowering of the regolith, sufficient to allow time for subsurface moisture attack to etch the concavities in the bedrock. As such, flares are useful in the interpretation of regional landform evolution (e.g. Twidale and Bourne, 1975a; Twidale 1982a). In the valley of the Giants, the distribution of columns with such concavities imprinted on them at various levels confirms that a substantial regolith formerly covered the lower slopes. The tafoni at the Giants of the Mimbres may have also developed in former scarp-foot locations within the regolith (Twidale, 1978b; 1982b, p. 257).

Critique of model

All the columns and pillars and their associated concavities and alcoves in the valley of the Giants can be construed as having evolved within a regolith in association with a fluctuating water table, followed by the virtually complete stripping of the regolith. Multiple minor phases of subsurface weathering are evidenced by the multiple concavities and hollows etched at various levels into the walls of the columns. Subsurface weathering also explains the comparatively narrow waists of many of the pillars and columns.

The suggested mode of development implies a period of relative stability of local baselevel during which fill derived from the valley sides accumulated on the valley floor. Differential fracture-controlled weathering took place beneath and within this regolith. Then followed a period during which there was a net loss of detritus from the valley floor: it was removed faster than colluvium was transported down the valley sideslopes. Phased or episodic lowering of the valley floor, or the water table, or both, allowed the exposure of the columns and corestones (boulders) surviving within the regolith. Once exposed to the air, these bedrock residuals were comparatively dry and hence largely immune to the moisture attack that had shaped them in the subsurface.

Such a mechanism also accounts for the etch character of the hillslopes; for the decoration of the surviving columns and pillars; and for the taller remnants standing low in the landscape where they were associated with a thicker regolith. The crests of the pillars and columns can be construed as approximating an old valley floor beneath which differential fracture-controlled moisture altered most of the bedrock but left a few elongate fracture-defined blocks projecting into the regolith. This suggestion finds support in the rock basins preserved on the crests of some pillars, and the pipes or vertical shafts hollowed out of the flanks of the rocks by meteoric waters, possibly along steeply dipping fractures. It has been demonstrated elsewhere that many rock basins have been initiated in the shallow subsurface at the weathering front (Twidale and Bourne, 1975b), and that pipes or *orgues géologiques* (see e.g. Cuvier and Brogniart, 1822; Twidale and Milnes, 1983, p. 350) are also weathering-front forms and usually indicate proximity to a former land surface.

The model also explains the perched boulders on plinths found in the valley of the Giants (Fig. 11), for although biochemical weathering is especially intense in a narrow zone immediately below the soil surface, where water is commonly available and where biota are abundant (Twidale, 1990), weathering is also particularly effective at greater depths (several feet below the surface), where the water table fluctuates and where, in addition to water-related chemical attack and biotic influences, wetting and drying also occur. Though the provenance of the balanced blocks varies (some in situ, others allochthonous) differential weathering and protection against water contact have played a significant part in their development. The uppermost boulder is protective, for it serves as an umbrella that in some measure shades or protects the underlying block or blocks from meteoric water, even if the underlying blocks are still in the subsurface. At the same time, water is diverted to the surrounding areas, thus accelerating and intensifying the alteration of the bedrock with which it comes in contact (Twidale and Bourne, 1976, 2000). In this way, the perched block and its pedestal come into prominence and persist.

The forms described here have their congeners in other parts of the world (e.g. Twidale and Campbell, 1984, 1992; Twidale and Centeno, 1993), but few, if any, rock columns are as intricately sculptured and stand so prominently in the landscape as the Giants of the Mimbres. However, the earth pillars reported from several parts of the world (see e.g. Holmes, 1965, p. 495 et seq.) combine elements of both the columns and the perched blocks of the Giants valley, for they are tall and slender, and they owe their existence entirely to the protection provided by blocks and boulders randomly distributed on top of unconsolidated sediment.

Comparison to nearby City of Rocks State Park and Little City of Rocks

Two other similar landform assemblages are developed in the Cenozoic tuffs of southwestern New Mexico. Both comprise ordered rows of rather squat columns, and both have been likened to cities (Weber, 1980; Mueller and Twidale, 1988 a,b; McLemore, 1997). One of these groups of rocks is developed on top of the plateau near the eroded edge of the escarpment that overlooks the valley of the Giants of the Mimbres. It is known locally as "Little City of Rocks" and consists of a group of bulbous pillars less than 25 ft (7.6 m) high having flared lower sidewalls 4–5 ft (1.2–1.5 m) high (Fig. 12). These forms are created by the weathering and erosion of systems of steeply dipping fractures that are orthogonal in plan view. The City of Rocks State Park is similar in form and origin but is more extensive.

The landform assemblages at both cities and at the Giants of the Mimbres are of etch origin. Fracture density and fracture pattern have played a significant role in the development of the landforms at all three sites. Although they are fashioned from the same volcanic unit, the forms at both cities differ considerably from those of the Giants in the valley, though mainly in degree of development.

Both cities of rocks are dominated by rows of pillars separated by long corridors. At the Giants of the Mimbres, bedrock slopes associated with sheet structures are areally dominant, many with a thin and discontinuous regolith. The few columns at the Giants that have survived weathering and erosion are tall and slender, and their visual impact is enhanced by their isolation.

One reason for the different landform assemblages is location. The Giants of the Mimbres stand in a valley, whereas the City of Rocks is situated on a low divide in an open plain, and the Little City of Rocks is at the level of the escarpment. At the Giants, water has flowed toward, and been concentrated in, the valley axis, which has become the locus for maximum weather-

FIGURE 11—A spectacular in situ balanced rock with a very narrow stem that is located just below the bluff. Cookes Peak dominates the skyline.

FIGURE 12—Corridor at Little City of Rocks lined with bulbous and flared columns or pillars.

FIGURE 13—(Upper) Bell's 1867 photo of the Giants, and (lower) the same view in 2000.

ing: landscape development here can be regarded as being more advanced than at either of the city sites, where drainage is external or radial, and the stripping of the regolith is virtually complete. At both cities, less water has been concentrated along fractures; weathering, therefore, has been correspondingly slower than in the valley.

Another difference between the cities and the Giants valley is that in the latter tectonism has played a discernible role in the development of the landforms. Displaced slabs and small steplike scarps might attest to recent tectonic activity. In addition, earth movements may have opened some fractures, facilitating weathering and hence erosion. This in turn would promote the development and ultimate preservation of the columns that now stand in such spectacular isolation. Earth tremors may also have contributed to the detachment of blocks from the bluffs, causing them to tumble downslope, where some have since become perched or balanced boulders. Primarily, however, it is the more rapid and intense weathering associated with a valley setting that has rendered much bedrock susceptible to erosion and produced fewer, but taller and isolated and hence eye-catching, residuals in the valley of the Giants of the Mimbres.

Evidence for environmental change

In 1867, 16 yrs after Bartlett's exploration of the valley of the Giants, an English physician and photographer, William A. Bell, who was employed by the Kansas–Pacific Railroad survey after the Civil War, crossed Cookes Range from the east and descended into the Mimbres Valley. According to Bell:

> 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 not compare 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).

Bell had probably read Bartlett's recently published narrative of his travels, for like Bartlett before him, Bell incorrectly described the rocks as sandstone. It is not known what Bell meant by "valley of rocks" and "city of rocks," as both appear in lower case. The term "city of rocks" certainly better applies to the state park of the same name, where orderly rows of bulbous rock columns (rows of houses) stand in orderly fashion along fracture-controlled corridors (streets).

After his brief visit at the Giants of the Mimbres, Bell went on to the site now known as Faywood Hot Springs, where he may have discussed his activities of earlier that day with the proprietors. The owners of the springs may have mistakenly gathered that Bell had photographed the area adjacent to the springs now known as City of Rocks. Such a misunderstanding might account for Bell's published caption to a woodcut version of one of his photographs, for he did not use the term "valley of rocks," but instead indicated that it represented "The City of Rocks, Rio Mimbres." Thus was introduced a confusion concerning the names of the two localities that has persisted to the present time.

Apart from their inherent interest as examples of early landscape photography, Bell's work is additionally important because he provides unadorned and accurate pictures of the 1867 Giants valley as it was. As such, the photos are germane to explanations of any soil erosion and changes in vegetation that have occurred since his visit.

It has been mentioned that at the Giants of the Mimbres some debris slopes carry a regolith, whereas others are devoid of soil cover, and it has been suggested that the latter have been stripped of a previous cover. In general terms such degradation has been attributed to climatic fluctuations and/or human interference within the ecosystem (e.g. Duce, 1918; Schumm and Hadley, 1957; Balling and Wells, 1990; Jacobson, 1995). Bell's photographs have been enlarged (11 inches x 17 inches) and enhanced in order to better assess geomorphic change at the Giants of the Mimbres.

The vantage points of Bell's photographs have been located in the field to within a few feet. His photographs of October 1867 (Figs. 5, upper, and 13, upper) are shown with their modern-day counterparts (Figs. 5, lower, and 13, lower) taken on February 27, 2000. The earlier pictures provide clear evidence first, that the gross and detailed morphology of the bedrock columns has not changed in any significant way and second, that the bedrock slopes Bell captured on plates were already partly stripped of their regolith to the same extent as at present. This implies that human impacts, notably cattle grazing, have had little direct influence on soil erosion during the past 133 yrs. The pre-1867 erosion of the regolith could be the result either of natural processes (climatic fluctuation) or of environmental change brought about by the activities of Native Americans and/or the Spanish, both of whom frequented this area before 1867. Very recent erosion at the Giants, however, is evidenced by gullies developed in the thicker regolithic covers and in the alluvial fills found on the valley floor adjacent to the main channel. Recent stripping of soil is also suggested by the exposures of pale, clean rock surfaces around the bases of blocks and boulders: there has been insufficient time since the last phase of erosion for the exposed rock surfaces to accumulate oxides or to be colonized by algae and the other biota that discolor most of the remnants at the Giants. This recent erosion could be a response to trampling, depletion of vegetation, and compaction of soil by humans and cattle, combined with the natural concentration of water and localized runoff from the bare surfaces of blocks, boulders, and bedrock slopes of areas already stripped of regolith.

By contrast, but not surprisingly, a comparison of Bell's and modern photographs of the same sites shows that major vegetation changes have occurred at the Giants. Grasses and yucca are less abundant today, but prickly pear and the woody plants are more common. Some of the juvenile plants in Bell's photos can be identified as mature plants still present in the valley, and overall, of course, the woody plants, including juniper and Emory oak, are larger now than in 1867. At one site south of the main channel and along the lower end of the valley, an assemblage of medium-sized columns photographed by Bell are totally obscured from view today by an immense Emory oak. Whether all these vegetation changes are natural, or human-induced related to land use practices, remains conjectural.

Conclusions

The Giants of the Mimbres are an assemblage of landforms basically created by the water-related chemical exploitation of the volcanic bedrock along steeply inclined fractures in the shallow subsurface. Many of the forms, including the rock columns and perched blocks and boulders, are of etch or two-stage origin. Positive and protective feedback mechanisms have had a conservative effect, for once standing higher than the regolith, an outcrop, however low, sheds water, and its chances of survival are enhanced. Continued subsurface moisture attack rotted the still-covered bedrock, but if a mass of rock were of a diameter sufficient to persist through such weathering, the outcrop became a column of intrinsically fresh rock as the regolith was lowered. To the contrary, however, the stripping of some sectors of the regolith caused an increased runoff from the resultant bare rock surfaces to any patches of soil persisting downslope, thereby increasing the probability and rate of their removal. The unusual morphology of the columns that constitute the core of the assemblage known as the Giants attracted the attention of early travelers whose records allow significant deductions to be made concerning the date and origin of recent erosion in the area.

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