Cadernos Lab. Xeolóxico de Laxe
Coruña. 2010. Vol. 35, pp. 163 - 188 ISSN: 0213-4497

Geologic encounters of John Russell Bartlett in the American Southwest

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Abstract
John Russell Bartlett made hundreds of drawings of the American Southwest during the period 1850-1852. Many of these drawings, some quite detailed, are of a geological and geomorphological nature, and they are among the earliest images of the sites they represent. In many cases, Bartlett's drawings and descriptions can be used to assess environmental change in the past 160 years or so. Given his limited knowledge of geology and the period in which he operated, his interpretations and insights have proved to be reasonably accurate.

Key words: J.R. Bartlett; drawings; Texas; New Mexico; Arizona; California.

In June 1850, John Russell Bartlett (1805-1886) was appointed United States Commissioner on the field survey that helped establish the international boundary between Mexico and the United States. Bartlett's background was in mercantile and banking, and for the period 1836-1849, he was a book dealer in New York City, selling volumes he had largely imported from Europe, especially England. Because he offered relatively rare and fine books, his shop was patronised by well established professionals from among the ranks of science, literature, medicine, exploration, and politics. There is anecdotal evidence that one of his bookstore customers was Washington Irving, one-time U.S. Minister to Spain and author of *Tales of the Alhambra* (1832). It was also in this period that Bartlett became very active in the New-York Historical Society, and with the esteemed Albert Gallatin, he co-founded the American Ethnological Society in 1842. He also held literary soirees in the parlor of his house, meetings that were well attended by men of prominence, including the poet, Edgar Allen Poe, and foreign dignitaries such as Guillaume T.L. Poussin, the French Minister to the United States (MUELLER, 2006).

Bartlett's first task as commissioner was to appoint his key civilian personnel. He chose as his commission secretary Dr. Thomas Hopkins Webb, a Boston newspaperman and publisher. Bartlett and Webb had previously been close associates in Bartlett's hometown of Providence, Rhode Island, where the two men belonged to the Providence Franklin Society beginning in the late 1820s, and where Bartlett and Webb, along with Dr. Frederick A. Farley, co-founded the Providence Athenaeum in 1831. Although Bartlett had no formal university training, Webb possessed an undergraduate degree from Brown University and a medical degree from Harvard. In addition to his duties as secretary on Bartlett's commission, Webb also served as mineralogist, as there was no geologist assigned to the survey. Much of what Bartlett would eventually write about the geology of the southwestern United States was likely derived from Webb's as well as his own interpretations.

Bartlett's tenure on the Boundary Commission lasted thirty-three months, until incoming U.S. President, Franklin Pierce, terminated Bartlett's appointment in March of 1853. Shortly thereafter, Bartlett began work on a two-volume book that recorded his travels and observations of the American Southwest—*Personal Narrative of Explorations and Incidents in Texas, New Mexico, California, Sonora, and Chihuahua*—published in two volumes by D. Appleton & Company, 1854. Included in this classic are a great number of illustrations that are based on field sketches made by Bartlett and his associates (MUELLER, 2000). Many of these drawings are the first graphic record of the areas they depict. Thus they serve as a baseline against which environmental change in the landscape during the past 160 years or so can be assessed.

It is likely that Bartlett and Webb were at least familiar with certain aspects of the geology and topography of the American Southwest before they visited the region. In particular, they would have had available the recent book of William H. Emory, who crossed the Southwest in the 1840s as part of a U.S. military expedition to California during the Mexican-American War (EMORY, 1848). What follows is a discussion of some of the landforms that Bartlett encountered and described during his travels between West Texas and northern California (figure 1). The

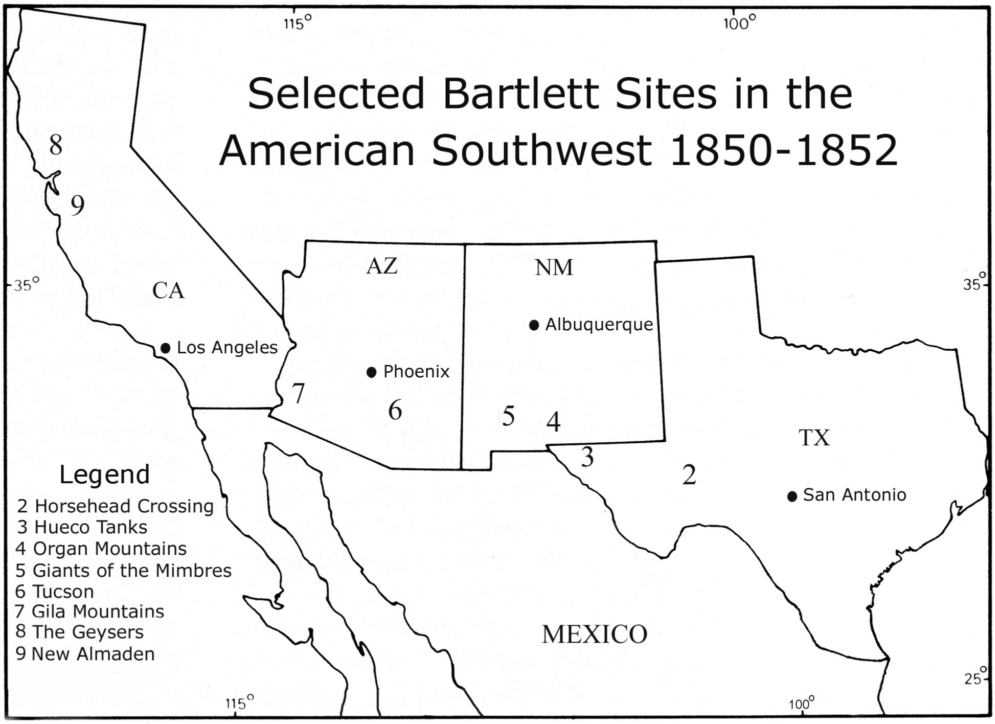

Fig. 1. Location map. The numbers refer to the sites of figures reproduced in the text.

drawings that accompany the discussion were all made by Bartlett; many of the blemishes and other imperfections on the originals have been removed prior to publication.

TEXAS

The Boundary Commission left San Antonio in two large groups, each destined for El Paso in far West Texas. Bartlett's group, the northern contingency, left San Antonio on 10 October 1850, and soon thereafter, his wagon train ascended the slopes of the Texas Hill Country, reaching the broad and fairly level upland that is known today as the Edwards Plateau. This plateau is a true tableland, dissected by few streams, and capped by the Lower Cretaceous Fredericksburg Group, of which the resistant Edwards Limestone is both extensive and thick. In one instance, the wagon train appears to have followed the contours and rock benches of a conical hill in order to ascend from a lower level in the landscape to a higher one. Bartlett clearly recognised that the benches were the result of relative rock resistance and differential erosion: "These terraces [sic] are formed by layers or strata of limestone, which jut out from the sides of the hills, the rains having washed away the soil" (BARTLETT 1854, vol. 1, p. 57).

A few hundred kilometres further brought Bartlett to the vicinity of modern-day San Angelo, Texas, where he crossed the south fork of the Concho River, then followed the west fork of the same river to its source. Thereafter, he traversed semi-arid and arid country in which water supplies were both meager and unreliable, eventually reaching a canyon, the historically important Castle Gap, which separates two large mesas capped by limestone. The mesas, part of the vast oil country of West Texas, are Castle Mountain and King Mountain, prominent landmarks that rise some 125-130 metres above the surrounding landscape. In addition to Bartlett's wagon train, Castle Gap at one time was an important thoroughfare for Native Americans, cattle drives, stagecoach lines, military expeditions, and immigrant wagon trains destined for California during the Gold Rush. It has long been rumored that the jewels of Maximilian and the treasures of Spanish explorers are buried within Castle Gap, but none have ever been found (DEAREN, 1988).

Bartlett exited Castle Gap and rode another 20 kilometres west to Horsehead Crossing on the Pecos River, a major tributary to the Rio Grande (figures 2a & 2b). In its natural state, the Pecos River, whose source is in northeastern New Mexico, had a highly variable discharge, its water supply dependent upon spring snow melt from the southern Rocky Mountains, summer thunderstorm runoff, and numerous springs. At

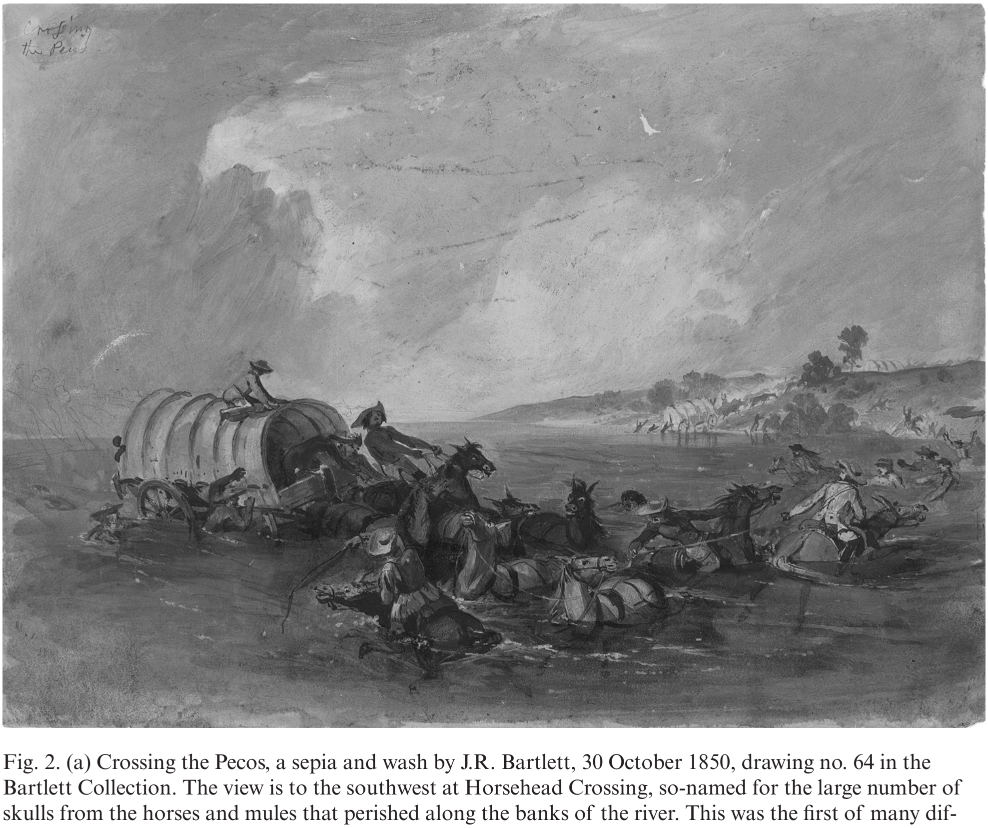

Fig. 2. (a) Crossing the Pecos, a sepia and wash by J.R. Bartlett, 30 October 1850, drawing no. 64 in the Bartlett Collection. The view is to the southwest at Horsehead Crossing, so-named for the large number of skulls from the horses and mules that perished along the banks of the river. This was the first of many difficult river crossings that Bartlett encountered during his travels in the American Southwest.

Fig. 2. (b) Looking south (downstream) at Horsehead Crossing on the Pecos River, 19 km NNW of Girvin, Texas. In the distance, and extending into the channel from the terrace on the right, is a triangular wedge of young sediment that constricts the width of the channel. The light-colored area in the far right background is the notch in the upland where westward-bound wagons ascended the upper valley wall.

the time of his visit on 29-31 October 1850, Bartlett reported that the river had an average width of approximately 20-30 metres and a depth of some 1.22 metres. He also has an entry in his field journal where he estimates the velocity at 0.61–0.91 m/sec, but afterwards, he made a notation that indicates he revised these figures upwardly to 0.91–1.22 m/sec (BARTLETT, 1850-1853). In addition, the channel was incised nearly four metres below the surrounding landscape; the treeless banks of the river, comprised of Quaternary alluvium, were nearly vertical; there was a small terrace 1–2 metres above the level of the river, mostly on the opposite (west) side of the stream; and floodplains were absent, giving the river the overall appearance of a canal.

Bartlett's drawing of Horsehead Crossing (figure 2a) depicts the difficulties his wagon train experienced as it forded the treacherous Pecos: "When we had reached about two thirds the distance across, or some thirty feet [9.14 metres] from the opposite bank, the mules either lost their footing, or were swept by the current into deeper water. . . . The teamster . . . endeavored in vain to bring them to their places with their heads towards the shore. The frightened creatures . . . in struggling to extricate themselves . . .

extended their alarm to the other mules. . . . Just at this moment the last wagon, which had been behind, attempted to pass us, the driver thinking the other mules would follow his team; but in the attempt, the current swept his wagon, which was half buried in the water, against ours . . . and led to greater confusion and alarm" (BARTLETT, 1854, vol. 1, p. 97-98).

Bartlett and his wagons and animals were rescued by others in his party who earlier in the day had already crossed to the west bank of the river. Although no one crosses the Pecos at this site today, the conditions there remain no less dangerous, as the bottom material consists of unconsolidated clays, silt, and organic material. In 2006, a metal rod, 2.29 cm in diameter, was inserted by hand into the bed of the channel; the rod penetrated 60 cm without reaching a firm stratum.

The modern Pecos River at Horsehead Crossing is a mere vestige of its former self, its size and discharge having been greatly altered following the construction of upstream dams and water diversion schemes during the twentieth century. Based on Bartlett's description of the geometry of the river in 1850 and on recent measurements made in the field, it appears that during periods of 'normal' flow the river has lost a minimum of 78% of its discharge. As a result, this reach of the Pecos River is considerably shallower, narrower, and slower than the one Bartlett crossed in 1850. At times, the velocity is diminished to the point where the somewhat brackish water stands in nearly stagnant pools.

In the vicinity of the point where the wagon trains ascended the west bank of the Pecos, considerable erosion has occurred, producing a large plume of sediment that extends into the river and constricts the channel. Some of this disturbance is undoubtedly the result of more recent human activity, including vehicular traffic. Also quite well preserved in the landscape is the notch in the upland that Bartlett's men cut in order to allow the wagons to reach that level from the terrace. Lastly, the saline soils in the vicinity of Horsehead Crossing were probably responsible for the absence of shrubs and trees along the Pecos River. That aspect of the river is largely true today, although a few salt-cedar (tamarisk) shrubs have invaded the area.

From Horsehead Crossing, Bartlett followed the Pecos River northward for 200 kilometres until he intersected Delaware Creek, a small perennial stream that he followed in a westerly direction towards the base of the Guadalupe Mountains. This historically popular route was followed by many wagon trains because of the availability of water, not only from the creek, but also from groups of frequently flowing springs that are located in close proximity to Delaware Creek and its tributaries. The Guadalupe Mountains culminate in their southwestern extent at Guadalupe Peak (2667 m), the highest point in Texas; nearby is the bold face of El Capitan, a Permian limestone reef that overlooks the valley of Salt Flat Graben at the eastern margin of the Rio Grande Rift (PRAY, 1988). Bartlett descended the foothills of the Guadalupes, crossed Salt Flat, traversed Otero Mesa, and passed through the Hueco Tanks area, reaching El Paso on 13 November 1850.

Bartlett and ten others returned to Hueco Tanks on 28 March 1851 to inspect further the peculiar rock assemblages and the great number of Indian drawings he had seen here briefly the previous November (figures 3a & 3b). The rocks at the Tanks, a monzonitesyenite complex of Oligocene age (35 Ma), were intruded into a thick sequence of relatively flat-lying Upper Palaeozoic limestone dominated by units of the Magdalena and Hueco groups. These intrusions, as well as a large number of similar forms in the nearby Hueco Mountains, have been described as "laccolith-like" by WISE (1977). Extensive erosion of the overlying limestone at Hueco Tanks has exposed three large hills of igneous rock that rise 65-125 metres above the surrounding pediment: one hill is dominated by broad, arcuate sheet structures, presenting an overall smooth appearance; another hill is a combination of sheets and boulders; and the third hill is comprised of boulders that are developed by preferential weathering along orthogonal fracture systems. Bartlett was reasonably accurate when he identified the rocks at Hueco Tanks as granite, although he seems to suggest that the igneous rocks were already exposed at the surface by the time the local mountains were uplifted. In all likelihood, he believed that the igneous rocks had been thrust upwardly on to the surface as part of some great cataclysmic event.

The 'huecos' at Hueco Tanks are natural rock basins, some quite large, that are weathered out of the igneous rocks. These basins have relatively high width/depth ratios, and for long periods of time, they hold water, a welcome relief to the many Native Americans and wagon trains that passed through this arid region. Beneath a major rock overhang on the north hill, within the recesses of two adjacent sheets of porphyritic monzonite, is an even more permanent source of water—a narrow but deep rock basin comparable to the gnammas, in particular the pit type, of the Australian literature (TWIDALE and CORBIN, 1963). While camped near this overhang, Bartlett copied a large number of pictographs to his sketchbook, including a sketch of a geometric design that he took while lying on his back between two sheets of monzonite that are spaced less than one metre apart.

Given that some of the rock art at Hueco Tanks was subsequently stolen or vandalised, Bartlett's record of these images is all the more important to archaeologists and historians. He also suggested that some of the rock art must be of great age, as it is covered in part by younger drawings. Some of the oldest and simplest designs at Hueco Tanks have been identified as belonging to the 'Desert Archaic Culture' from the period prior to the Common Era. The great majority of the images, more than 2000 pictographs, are assigned to the Jornada Mogollon Culture that dates from the beginning of the Common Era to approximately 1500 C.E. During the period following 1500 C.E. numerous images were added by the Apaches, with some contributions likely from the Comanches and Kiowas. Recent chemical tests on the carbon in the pigments suggest that some of the Jornada Mogollon drawings are centuries older than previously assumed (HYMAN et al., 1999).

While at Hueco Tanks, Bartlett walked more than three kilometres northeast to another assemblage of sculptured rocks, a site he believed might have been the ruins of an edifice of possible archaeological interest. These rocks, known today as Castle Rocks, are of the same composition and age as those at Hueco Tanks, but instead of forming convex-upward hills, they rise in spectacular fashion as tall, slender columns above the surrounding desert floor. "There were three groups of these singular rocks, a few rods apart, entirely disconnected, yet of the same general character. Their sides

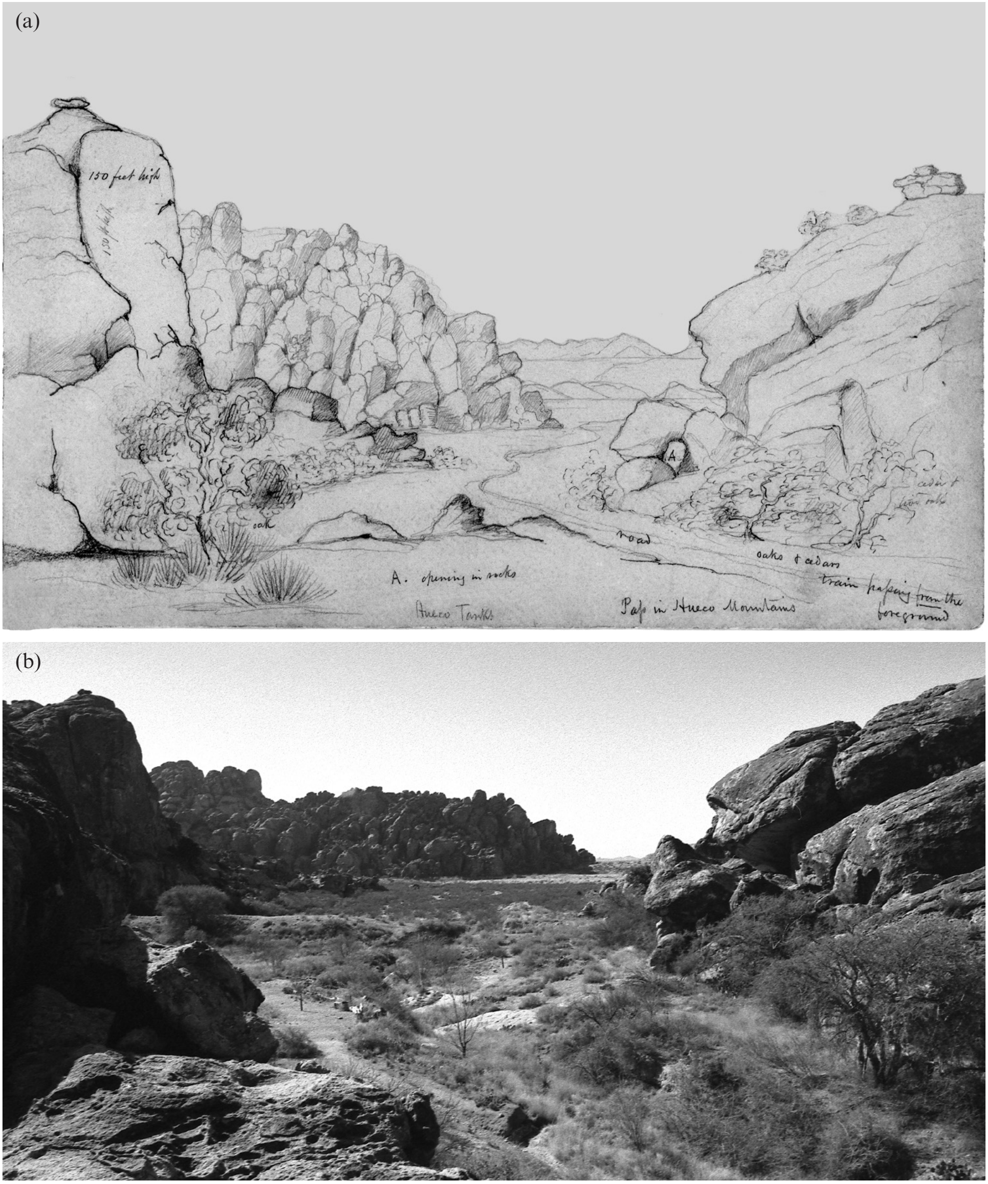

Fig. 3.
(a) Pass in Hueco Mountains, a pencil sketch by J.R. Bartlett, 29 March 1850, drawing no. 145 in the Bartlett Collection. Portions of the three major hills at Hueco Tanks are shown. The hills and the platform between them are comprised of intrusive igneous rocks.
(b) Looking west through the pass at Hueco Tanks, 45 km ENE of El Paso, Texas. The rock overhang on the right provided shelter and water for the passing wagon trains. The former wagon road through the pass is now a moderately deep gully.

were perpendicular, like walls; their height about sixty feet [18.29 metres] . . . But the most singular feature about them was, that many portions of their exterior surface were as smooth and as highly polished as though they had been submitted to some artificial process. It was probably the effect of exposure for ages to the weather" (BARTLETT, 1854, vol. 1, p. 175).

Bartlett was in part deceived by the appearance of these rocks, for he mistakenly believed that the shiny surfaces, coated with desert varnish, would therefore have to be smooth and polished, whereas the exteriors of these coarse-grained igneous rocks are actually quite rough and abrasive. However, his suggestion that the varnished surfaces were somehow related to weathering processes was especially insightful.

NEW MEXICO

In September 1852, Bartlett visited Fort Fillmore, an army installation a few miles south of Las Cruces, New Mexico, on the east bank of the Rio Grande. From there, Bartlett and several others travelled some 25 kilometres east to explore the western face of the Organ Mountains. The Organs, a prominent range within the geologically young Rio Grande Rift, are part of a N-S oriented horst block that has been rotated to the west. Although Bartlett intended to visit a silver mine owned by Hugh Stevenson of El Paso, he stopped eight kilometres south of the mine to examine the great variety of rocks and landforms found in the vicinity of Fillmore Canyon, a major reentrant with an intermittent stream (figures 4a & 4b; MUELLER and MUELLER, 1998):

"I then took my rifle, and walked a couple of miles through it and the deep gorges which indent the ridge. In this ramble I passed a beautiful little stream, which, rising far within the defile, wound its way along through many intricacies, where it had worn for itself a deep bed, until it tumbled over the rocks in a single fall of some fifty feet [15.24 metres]. Although the quantity of water was small, the fall was exceedingly picturesque . . . From the place where we halted and lunched, I took a sketch of these mountains and of the defile through which I had passed. A small stream flowed near us, marked by a line of fine large oaks" (BARTLETT, 1854, vol. 2, p. 393-394).

The remarkable columns and spires depicted in the left background of Bartlett's drawing are part of the Organ Needles, a chain of pinnacles that are developed on the quartz monzonite phase (32.8 Ma) of the Organ Batholith. He describes these mountains as "The 'Sierra de los Organos' . . . so named from their pinnacled summits and sides, which resemble the pipes of an organ. They are of a light gray granite. . . ." (BARTLETT, 1854, vol. 2, p. 394). At the base of the Needles is a series of upturned and steeply inclined Upper Palaeozoic sedimentary rocks; these units include the Abo, Hueco, and Panther Seep formations, and the Lead Camp Limestone. Near the base of the exposure of the Palaeozoic rocks is a low, broad, dark hill developed on the Orejon Andesite of Eocene/Oligocene age (SEAGER, 1981).

The Orejon Andesite, comprised of andesitic flows with interbedded volcanoclastics, also forms the very dark and steep ridges shown in the right middle ground of the drawing (figure 4a). Not visible in the drawing, hidden from view by the andesite, is the southern continuation of the Organ Needles, including the highest point in the

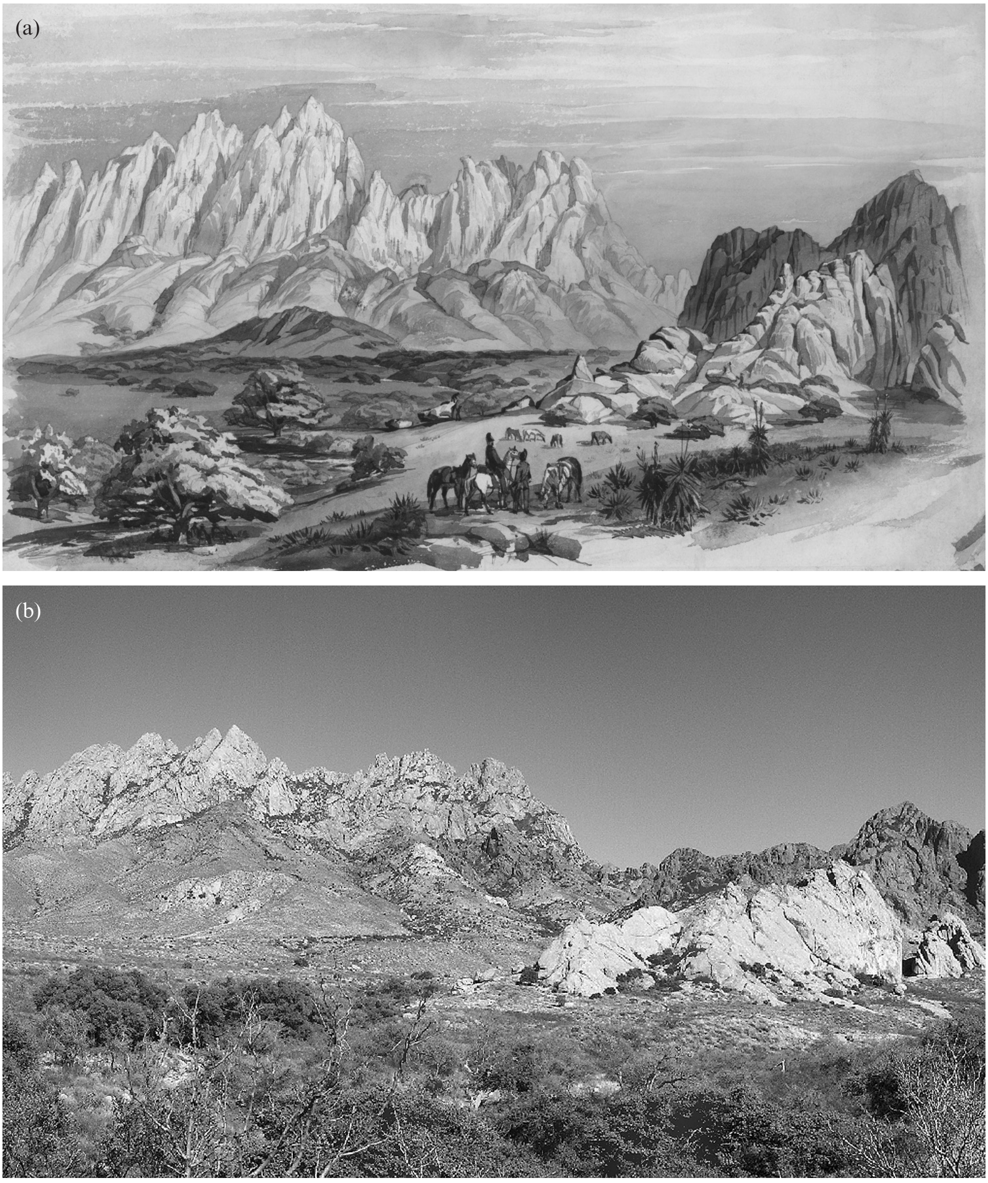

Fig. 4.
(a) Organ Mountains New Mexico, a sepia and wash by J.R. Bartlett, 27 September 1852, drawing no. 82 in the Bartlett Collection. This drawing was made from the shoulder of lower Fillmore Canyon. The original pencil sketch of this scene is a two-page panorama with extensive notations.
(b) Looking NE towards the Organ Mountains and Fillmore Canyon, 15 km east of Las Cruces, New Mexico. The tall columns on the left are developed in quartz monzonite; the bold dark rocks on the right are andesite; and the light-colored ridge (right foreground) is an ash-flow tuff.

range, Organ Needle at 2747 metres. In front of the andesite is a small, light-coloured, and steep-sided ridge developed in an Oligocene ash-flow unit, the Cueva Tuff. This ridge, also called the Cueva (cave), does in fact have a large recess weathered out of its southern base, just above the level of the modern soil line. Although the external colour of the Cueva is pink to orange, and the unit is covered with extensive patches of yellow, green, and orange lichens, BARTLETT (1854, vol. 2, p. 394) describes the Cueva as "a bold mass of white granite," suggesting his view of the ridge might have taken place in extremely bright sunlight.

Bartlett left El Paso in April 1851 to establish his summer camp at Santa Rita del Cobré, a former centre of copper mining for both the Spanish and the Mexicans. He followed the Rio Grande northward, crossing the river at a ford on the north side of San Diego Mountain. From a point several kilometres north of present-day Hatch, New Mexico, Bartlett's wagon train travelled westerly towards Santa Rita, stopping en route to camp along the Mimbres River. A member of Bartlett's party reported the next day that he had seen some spectacular rocks in a tributary canyon approximately 8-10 kilometres upstream of the camp. Intrigued by the man's description of the rocks, Bartlett immediately set off for the site with his mule and his sketchbook (figures 5a & 5b):

"Arriving at the place, I found some singular masses of sandstone standing detached from the adjacent hills, one of them bearing a curious resemblance to a man. My timid mule was much alarmed at the gigantic object which stood before it, trembling from head to foot. We therefore stopped a short distance from it and hitched our animals to an oak which hid from view the source of their terror. Around us stood these singular isolated rocks, some appearing like castles, others like single pedestals and columns. The one resembling a human figure, which is shown in the accompanying sketch, and which I christened the 'Giant of the Mimbres,' measured but three feet [0.91 metres] in its narrowest part near the ground; while its upper portion must have been at least twelve feet [3.66 metres] through, and its height about fifty [15.24 metres]. Others of equal height stood near. All are disintegrated near the earth, and are gradually crumbling away, several having already fallen" (BARTLETT, 1854, vol. 1, p. 224-225).

Although Bartlett refers to the rocks as sandstone, the bedrock is actually part of a broad, thick sequence of Oligocene ash-flow tuff (ELSTON, 1957; McINTOSH, 1991). The moderately-welded tuff has been subdivided by multiple fracture sets, producing arcuate sheeting structures and orthogonal blocks. Bartlett's "Giant" and other similar forms are now collectively referred to as the "Giants of the Mimbres," a group of intricately sculptured rock columns that are erosional remnants of a massive sheet structure. Field evidence indicates that the columns develop and survive best in those areas where the vertical fractures are widely spaced. Elsewhere, moisture and biota in the vertical fractures chemically and biologically attack the host rock, which then decomposes and disintegrates, producing a soil cover. The soil cover is eventually removed through surface erosion, exposing bedrock slopes, a dominant feature at the Giants.

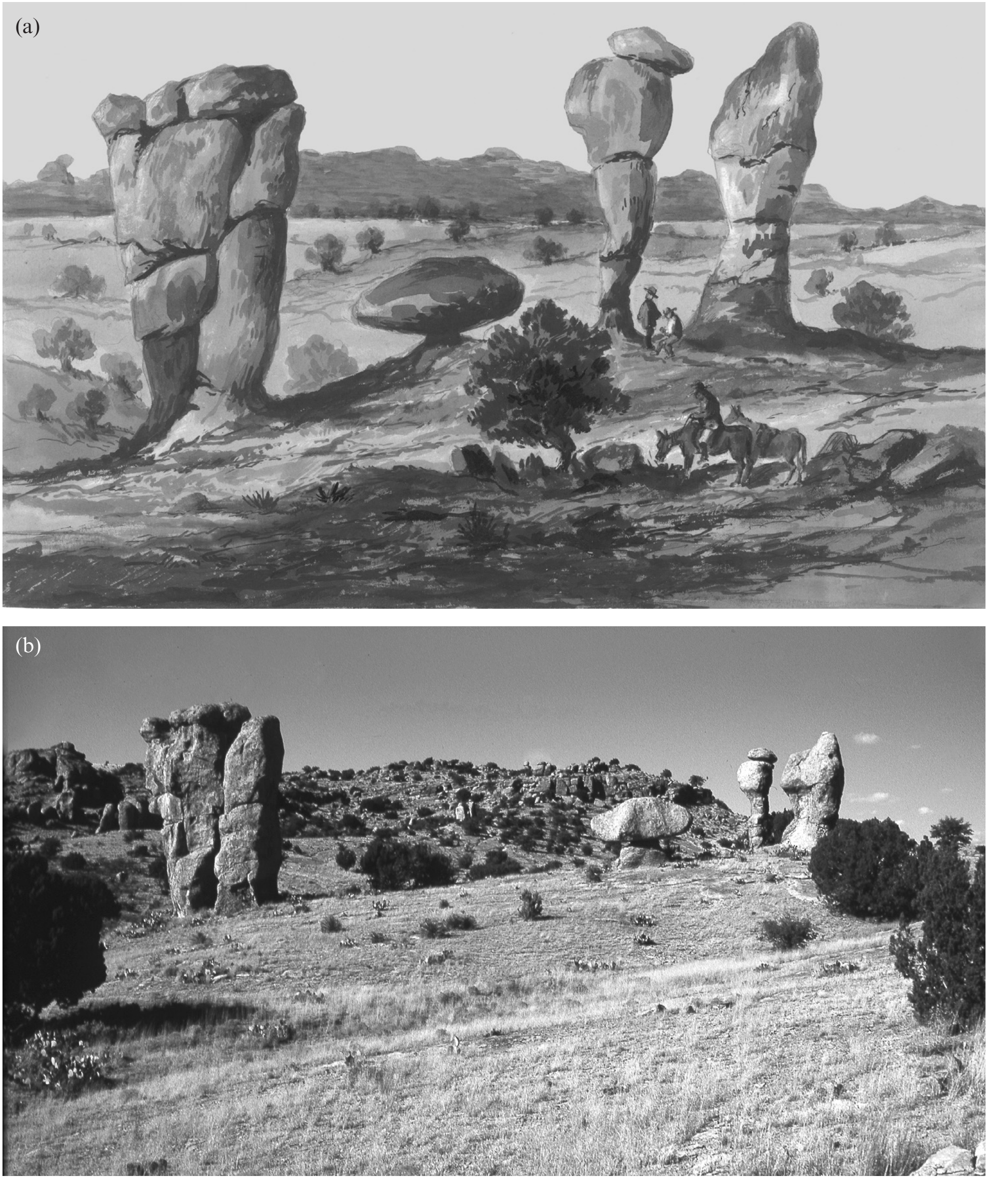

Fig. 5.
(a) Giant of the Mimbres, a sepia and wash by J.R. Bartlett, 1 May 1850, drawing no. 36 in the Bartlett Collection. There is another nearly identical sepia and wash of this scene in the Bartlett Collection, but its foreground was left incomplete. Bartlett placed the large balanced rock too far downslope of its true location.
(b) Looking NW towards the Giants of the Mimbres, a series of rock columns developed in ash-flow tuff, 40 km NNW of Deming, New Mexico. The massive column on the left, some 17 m high, is actually a double column separated by a vertical fracture and cleft. Note the balanced rock and its flaggy pedestal.

The bedrock landforms at the Giants have a two-stage origin: the first stage involves the weathering of the bedrock and the formation of a substantial soil cover; the second involves the stripping of the soil cover and the exposure of the bedrock landforms in the landscape. Thus, the major forms at the Giants are of etch origin, a process that has been identified across a broad range of climatic and bedrock conditions in other parts of the world. One of the more common minor forms of etch origin is the flared slope or basal concavity that develops below the soil surface, around the margins of blocks, boulders, and columns. Flared slopes are also common in the vicinity of the Giants, providing additional evidence that the forms at the Giants, both major and minor, are of etch origin (TWIDALE, 1986; MUELLER and TWIDALE, 2002; TWIDALE and VIDAL ROMANI, 2005).

Bartlett's drawing and the modern photograph of the Giants were taken from the same vantage point. In comparing the two figures, it is evident that Bartlett placed the large balanced rock downslope of its true location. This rock, which is 9.4 m long and 4 m thick, remains remarkably fresh, although it rests on a bedrock pedestal that is 2.7 m high and highly weathered. It is significant that the orientation of the pumice fragments in the balanced rock is nearly vertical, an indication that the boulder has been rotated some 90º from its original position in the ignimbrite sheet. Therefore, the interpretation is that the boulder toppled on to an older and higher land surface, one that has long since been removed by weathering and erosion, save for a few protected sites such as the one in which the pedestal persists (MUELLER and TWIDALE, 1988, 2002; TWIDALE and CAMPBELL, 1992).

Although overgrazing by cattle in the second half of the nineteenth century is often blamed for soil erosion and arroyo cutting in the Southwest, the evidence from the Giants suggests soil stripping occurred there at an earlier date. For example, there appears to be little or no change in the extent of either the bedrock landforms or the soil cover between the time of Bartlett's drawing (1851) and the present. This assertion is further supported by a set of photographs taken of the Giants in 1867 by William A. Bell of the Kansas-Pacific Railroad Survey (BELL, 1869). Bell's photos clearly demonstrate that there have been significant changes in the flora at the Giants (less grass and fewer yucca but more prickly pear and woody shrubs) in the past 140 years, but there are no visible changes in the extent of the bedrock landforms and the soil cover. Therefore, the evidence from both Bartlett and Bell indicates that the stripping of a major portion of the soil cover at the Giants occurred prior to 1850, perhaps related to cattle grazing by the Spanish, who controlled the area around the nearby Santa Rita Copper Mines early in the nineteenth century. Another possibility is that the stripping of the soil cover is related to the still earlier land-use practices of the American Indians, including fire and timber harvesting, as archaeologists have found the site of a former Indian village on a terrace of the Mimbres River, at the base of the hill occupied by the Giants. There remains, of course, an equal probability that the stripping of the regolith is entirely the result of natural processes (MUELLER and TWIDALE, 2002).

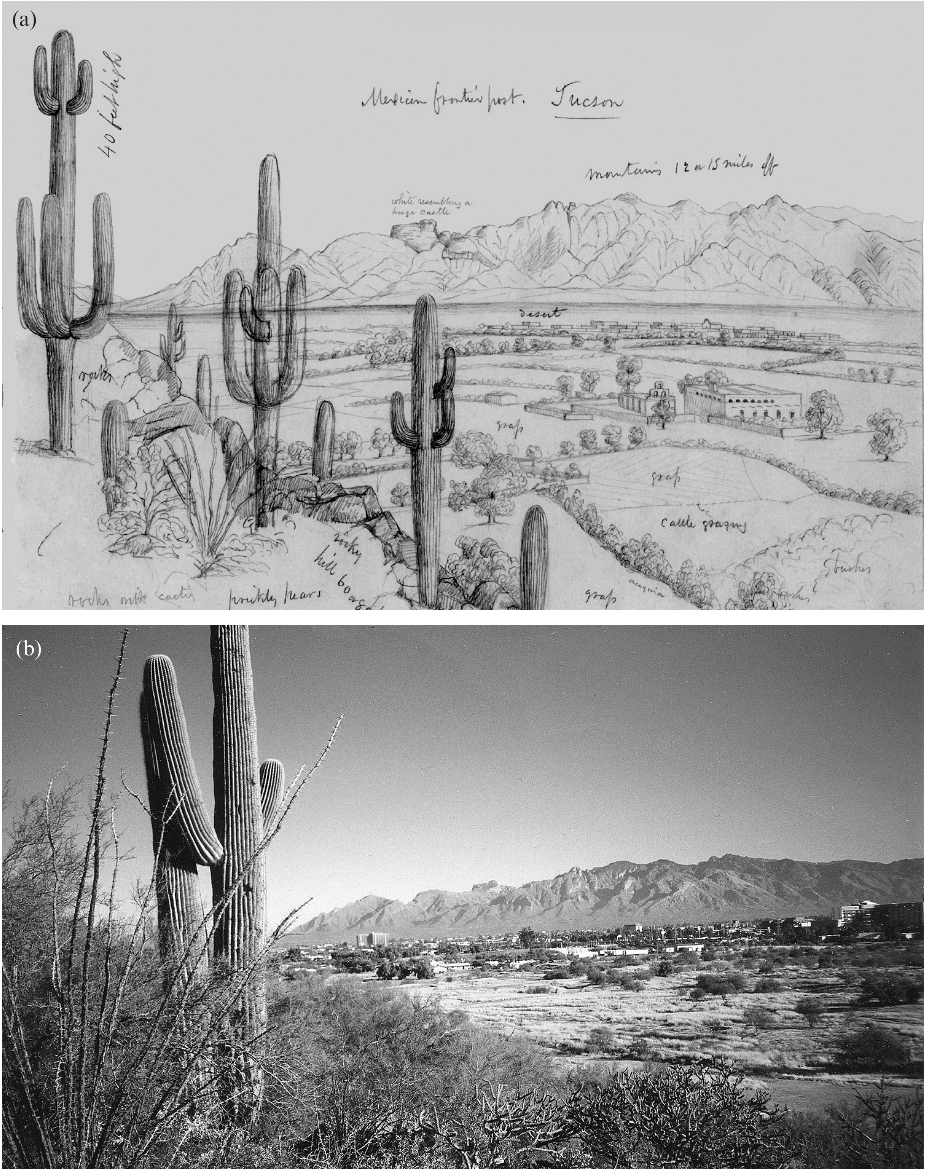

Fig. 6.
(a) Tucson, a pencil sketch by J.R. Bartlett, 17-18 July 1852, drawing no. 172w (25) in the Bartlett Collection. The Santa Cruz River and Bartlett's camp are just out of view to the right of this scene. The buildings closest to the artist are part of the ruins of the Tucson Mission.
(b) A view of Tucson, Arizona, taken from the eastern flanks of Sentinel Peak, looking NE across the city towards the Santa Catalina Mountains. Note the rather desolate floor of the modern Santa Cruz River Valley, which in places carries a veneer of city landfill.

ARIZONA

Bartlett and his Boundary Commission camped along the Santa Cruz River at Tucson, Arizona, on their return trip from San Diego to El Paso in July of 1852. Tucson at that time was still part of Mexico, and as such, it was the northernmost Mexican settlement in the State of Sonora, with a garrison of several hundred soldiers whose principal task was to protect the local population against depredations by the Apaches. In part due to the delay in having several of his wagons repaired by a local blacksmith, Bartlett took the opportunity to sketch and describe the environs of Tucson (figures 6a & 6b).

From his entry for 17 July 1852, Bartlett states: "I ascended a rocky hill . . . about a quarter of a mile from our camp, and had a fine view of the valley and surrounding country. This hill was covered with cacti of every variety. . . . scarcely a particle of soil could be seen. Below was the valley, its fields and acequias defined by the long lines of shrubbery and trees. The town is seen on the border of the plateau, where the desert begins, and stretches off to the east, to a high range of mountains about fifteen miles distant . . . Like other mountain ranges, these take a south-easterly direction and extend nearly to the San Pedro" (BARTLETT,1854, vol. 2, p. 296-297).

The hill from which Bartlett made his sketch is formed by a break in slope on the extreme eastern side of Sentinel Peak, a topographic outlier of the Tucson Mountains that are located to the west of the city. Sentinel Peak is comprised almost entirely of Middle Tertiary (23-28 Ma) volcanics, especially andesite, whereas the main Tucson Mountains are mapped as a thick sequence of Upper Cretaceous andesitic flows (REYNOLDS, 1988; SPENCER et al., 2003). In the background of Bartlett's sketch are the Santa Catalina Mountains, among the highest (2791 m) and most picturesque ranges in all of southern Arizona. The Santa Catalinas are comprised mostly of Late Cretaceous to Early Tertiary granite and Proterozoic granitoids, including gneiss. It is believed by some authorities that the andesite of the Tucson Mountains was once part of a volcano that formed the crest of the Santa Catalinas, their current separation of some 32 km having occurred along a detachment fault in Middle Tertiary. As part of the extensional tectonics that have dominated the Tucson area in recent geological time, the area between the two mountain ranges has been downfaulted, including the valley of the Santa Cruz River, which is underlain by approximately 1500 metres of basin-fill alluvium.

Much, of course, has changed since the time of Bartlett's visit to Tucson. He described the Santa Cruz River as a diminutive stream with a channel that was only 1.5–2.5 m wide. Today, the normally dry channel of the Santa Cruz is many times that width and very deeply incised, its friable bed and bank material having been excavated by a series of urban floods in the twentieth century. The peak discharge at Tucson for the 46-year period of 1915–1960 occurred in 1915 when 424.76 cubic metres per second was measured. In the subsequent 46-year period (1961–2006), the peak discharge of 1915 was exceeded six times, with the record maximum of 1492.33 cubic metres per second occurring in 1984. When Bartlett camped along the river in 1852, both water and grass were abundant; at present, both are largely absent.

Bartlett also reported that a group of springs at the base of the Tucson Mountains provided copious water to a hamlet and a large hacienda (actually a former mission, San Agustín) on the valley floor, but these springs have long since disappeared, as have the fields on his sketch that were watered by the springs and the river. At the Mission of San Agustín del Tucsón, the crumbling adobe walls of the main structures were levelled many decades ago, and only recently have excavations by archaeologists shown the size and extent of the former mission, including the chapel and the *convento*. To the south, the once productive irrigated fields of the mission and hacienda have been buried under a substantial mantle of city landfill.

While in Tucson, Bartlett also viewed and sketched the famous Tucson Ring Meteorite, which had been brought to the blacksmith shop in the 1840s from the Santa Rita Mountains some 32 km SSE of the Tucson Presidio. At the time of Bartlett's visit, the meteorite, which is approximately 1.5 metres in diameter, sat upright on the ground, with the top portion used as an anvil. Although Bartlett estimated its weight at 272 kilograms, the iron-silicate meteorite was later found to weigh 635 kilograms. The meteorite has been housed at the Smithsonian Institution since 1863.

Bartlett arrived at Fort Yuma on the Colorado River on 9 June 1852 to finish the boundary survey of the lower Gila River, which at that time entered the Colorado River directly opposite the fort. Although the Colorado River still runs past Fort Yuma, the courses of both rivers have shifted significantly since the time of Bartlett's visit, and their confluence is now 5.75 km upstream of the fort. The fort itself stands on a low hill comprised of granite breccia, material that was derived from a local quartz monzonite of probable Proterozoic age. In the vicinity of the hill is a great thickness of older alluvium, which at one time undoubtedly formed a veneer overlying the breccia (OLMSTEAD et al., 1973). This assumption is based not only on stratigraphic relationships, but also on the fact that the bedrock exposures today carry a mantle of rubble: disintegrated plates, scales, and small angular rocks that likely were weathered out of the host rock by moisture attack in the subsurface, at the interface of the bedrock and the former alluvial cap. There are also a number of rock benches cut into the hill at various levels, suggesting the probability of a genetic relationship of the benches to episodic downcutting and stabilization of the two rivers.

Shortly after leaving Fort Yuma, Bartlett's commission encountered a great northward bend in the course of the Gila River Valley. This curve, when measured along the valley floor, is some 35 km long, whereas the chord distance across the bend is approximately 25 km. The inside of the bend is occupied by the northern terminus of the Gila Mountains, a northwest trending fault-block mountain range. These mountains, including their southern extension, the Tinajas Altas Mountains, are approximately 70 km long and up to 15 km wide, with broadly flanking pediments and fans. As is true of many of the isolated ranges in southwestern Arizona, the Gila Mountains are largely the product of east-west extensional forces that have dominated this part of the Basin and Range Province during the Cenozoic.

Surprisingly, Bartlett says nothing about these impressive mountains in his field notes, but his comments a few days later from his camp at the base of the nearby Mohawk

Mountains would apply equally well here: "The mountains here are as desolate and barren as it is possible to conceive. Not a tree or shrub could be seen on them, while their bold and abrupt sides are furrowed with huge chasms and gorges. Between the base of the mountains and the bottom-land are low gravelly hills. . . . The Gila here widens considerably, and is proportionably shallow and filled with sand-bars" (BARTLETT, 1854, vol. 2, p. 197-198).

Bartlett made a sketch of the northern Gila Mountains that he later converted into a sepia and wash, the largest and one of the most fragile drawings in the Bartlett Collection (figures 7a & 7b). It is also one of the most difficult scenes to identify because the extremely dark sepia that Bartlett applied to some of the uplands does not match the tones that one observes in the field. In addition, a railroad now runs along the former south bank of the river, and canals, levees, roads, power lines, etc. have encroached on the floodplain of the Gila River in the area immediately adjacent to the site of Bartlett's former camp. Thus, the elements in the foreground of Bartlett's scene have been largely obliterated. Furthermore, and in response to the effects of upstream dams, water diversions, and irrigation withdrawals, the channel of the Gila River today is much smaller than the one depicted by Bartlett. At times it carries a substantial discharge that is contributed by localised storm runoff in the watershed immediately upstream of Dome.

The rugged Gila Mountains, which tower some 350-450 metres above the river valley, together form a natural amphitheatre that is open to the north. The highest columns on the ridge line of the amphitheatre are comprised of Late Cretaceous granitoids associated with the Blaisdell Batholith. In the middle ground of the scene, the uplands are largely developed on truncated units of older gneiss that have been downfaulted to the southeast along the steeply dipping Grey Fox fault zone. Between the base of the mountains and the floodplain is an extensive area of hills, part of a broad pediment that is cut across sandstone and conglomerate (Kinter Formation) of Oligocene to Miocene age. In places, the pediment is mantled by early to middle Pleistocene alluvium that has been derived from the erosion of the adjacent mountains (SHIPMAN et al., 2007). Significant in Bartlett's drawing is the fact that the Gila River, still in its natural state, is very broad and shallow, as evidenced by the several persons shown wading across its channel. This high width/depth ratio indicates that the river in 1852 carried mostly coarse sediment and possessed a very flashy flow regime.

Bartlett camped at or near the site of what a short time later would become Gila City, an untamed town of more than one thousand miners who worked the local gravel deposits for placer gold. As the site of Arizona's first gold rush, Gila City lasted for only a few years from the late 1850s to the early 1860s. First, the placer gold played out, and efforts to find primary gold from veins in the Gila Mountains were largely unsuccessful. Second, most of what was left of the original town site was subsequently destroyed by floods from the Gila River. The general area in the vicinity of the former Gila City is known today as Dome, the name that is also given to the adjacent curved reach of the Gila River Valley.

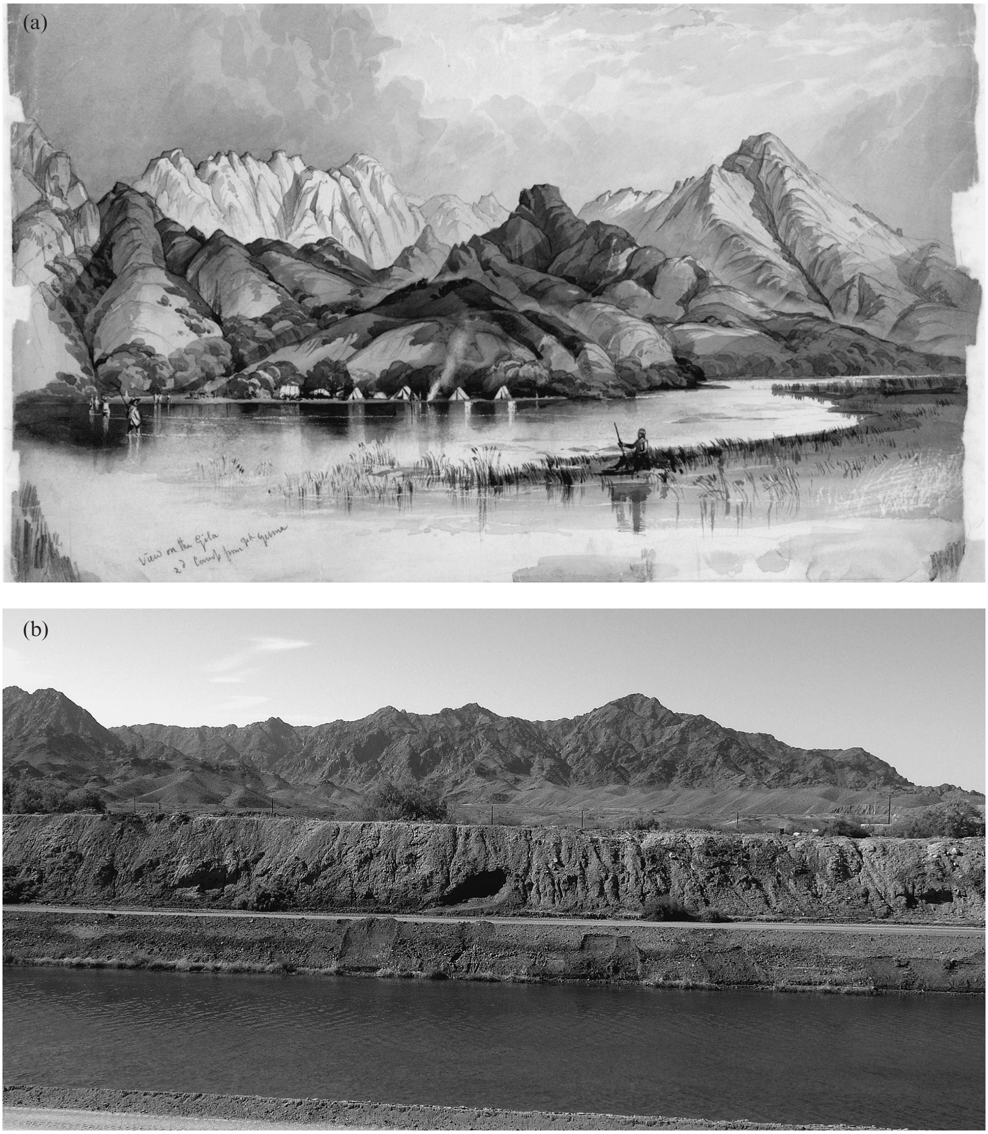

Fig. 7.
(a) View on the Gila, 2nd Camp from Fort Yuma, a sepia and wash by J.R. Bartlett, 19 June 1852, drawing no. 95 in the Bartlett Collection. Bartlett's camp is on the inside bend of the Gila River, near the eastern margin of the amphitheatre, at the north end of the Gila Mountains. Note the people on the left who are wading across the wide and shallow channel of the Gila River, which flows from left to right.
(b) Looking SW towards the northern end of the Gila Mountains near Dome, Arizona, 22.5 km ENE of Yuma. The canal and levee system in the foreground have largely replaced the former course of the Gila River in this section of the Dome Valley. The gravel hills that were worked for placer gold in the nineteenth century are visible at the base of the mountains.

CALIFORNIA

In preparation for an overland trip from San Diego to El Paso in the spring of 1852, Bartlett and several officers of his commission sailed to San Francisco to purchase supplies and equipment. There were delays in filling his orders, as he had to compete with other entities for goods and services during the hectic days of the Gold Rush. He decided to visit the goldfields of the western Sierras, but late winter rains brought floods to the rivers of the area, and he chose instead to visit the celebrated Geysers in the Mayacmas Mountains of northern California. Here, natural steam vents occur deep in the canyons along Big Sulphur Creek, a perennial stream that Bartlett referred to as "Pluton River."

The Geysers issue mostly steam, not water, and are therefore preferably called fumaroles. The rugged terrain in which these fumaroles developed is underlain by predominantly metamorphic rocks that are part of the Franciscan Group, including serpentine, below which is a shattered zone of greywacke, and at still greater depths is the heat source for The Geysers, a granite batholith that intruded the area during the Pleistocene, one million years ago, and during the Holocene, less than 10,000 years ago (BARTON, 1998). Faults are also common in this area of subduction between the North Pacific and the North American plates, and the fractured rocks are on the verge of shear failure; therefore, seismic activity, natural and induced, is common, with numerous small tremors recorded each day in and around The Geysers geothermal steam field (McLAUGHLIN and DONNELLEY-NOLAN, 1981; EBERHART-PHILLIPS and OPPENHEIMER, 1984).

At Bartlett's first stop amongst The Geysers, he encountered geothermal activity that included not only steam vents, but also sulphur fumes in the air and plates of crystallised sulphur on the ground. It was also here that Bartlett first identified, incorrectly, the weathered greywacke bedrock as decomposed granite. Next, he traversed and sketched a short tributary, Geyser Canyon, which enters Big Sulphur Creek from the north. Bartlett described his descent into Geyser Canyon: "Fumes of sulphur here met our nostrils at every step, while the rustling steam, as it spouted from a hundred cavities, completely enveloped us. The latter did not issue in one continuous column, but at short intervals, as from the pipe of a high pressure engine . . . There was no cessation to this awful roar, but one continuous noise, as though a vast workshop beneath was in full operation" (BARTLETT, 1854, vol. 2, p. 41-42).

When Bartlett and his colleagues reached the junction of Geyser Canyon and Big Sulphur Creek, they saw another area of fumarole activity upstream along the northeast bank of the latter, which Bartlett sketched as the others in his party inspected the site (MUELLER and WALTERS, 2001; figures 8a & 8b). "The scenery here was truly grand. Immense pines grew on the mountain sides and tops, while oaks and smaller trees filled the narrow valleys and ravines, which the rains had made. Just below us ran the river, dashing over rocks in its steep descent, and often concealed by the thick foliage which overhung it" (BARTLETT, 1854, vol. 2, p. 43).

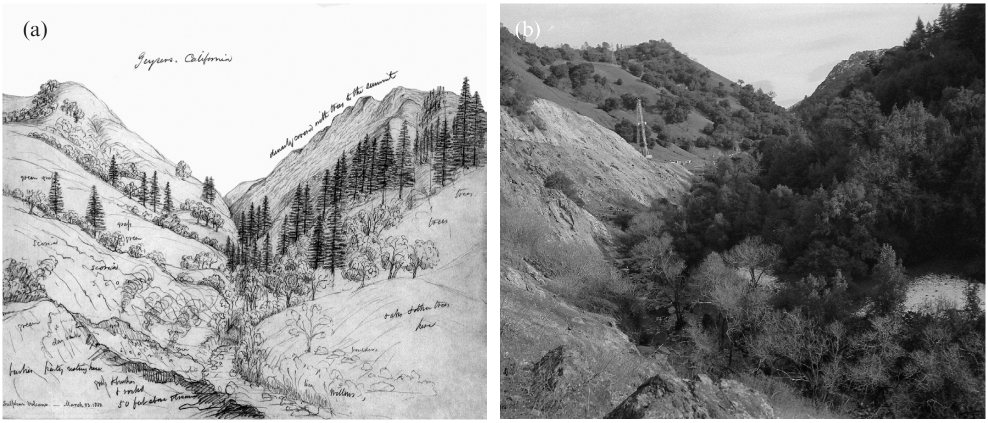

Fig. 8.
(a) Sulphur Volcano, a pencil sketch by J.R. Bartlett, 23 March 1852, drawing no. 172l (16) in the Bartlett Collection. View is to the ESE. Fumaroles issue from the steep concave slope on the left, which is underlain by a weathered greywacke. Bartlett misidentified the bedrock in his drawing as scoria.
(b) Looking upstream along Big Sulphur Creek at The Geysers, a major geothermal field in the Mayacmas Mountains, 17.5 km WNW of Middletown, California. The steep slope on the left, which at one time had active fumaroles, is now quiet, although the hydrothermally-altered surficial material remains unstable.

The Geysers have attracted visitors for millennia, beginning with several tribes of Native Americans, including the Pomo, Wappo, and Miwok tribes who inhabited this part of northern California in the middle of the nineteenth century. Shortly after Bartlett's visit, The Geysers underwent commercial development, including the establishment of the Geysers Resort Hotel on the south side of Big Sulphur Creek. In order to provide visitors with access to the fumaroles and hot springs along both the creek and Geyser Canyon, catwalks were suspended across Big Sulphur Creek, and several bath houses were also constructed. The resort flourished for a few decades in the late 1800s, but after a long period of dwindling interest in The Geysers, the facility closed, and the building was razed in 1980 (HODGSON, 1999). Natural processes in the landscape, including those of mass wasting and the invasion of scrub brush, have removed or masked much of the visual evidence for this former period of tourist activity. In more recent times, the geothermal field at The Geysers has been harnessed for steam-generated electricity, and the current total of twenty-two operating plants have a combined maximum generating capacity of approximately 850,000 megawatts per year. Along with the withdrawal of steam for electrical generation, there has been a major decrease in steam pressure in the geothermal field, causing a cessation of natural steam vent activity at the surface.

Also while in San Francisco, and with his venture to The Geysers recently concluded, Bartlett decided to visit the quicksilver mines at New Almaden, a small community southeast of San Jose. Up until the time of Bartlett's visit in April of 1852, the mining operations were small and still in their infancy, but their new owner, Baron, Forbes Company, invested much new capital, so that Bartlett witnessed a thriving and growing mercury industry that one day hoped to challenge the output at its namesake, Almadén, Spain. Baron, Forbes was an English company that also operated mines in Mexico; it utilised mining and reduction technology from both Spain and Mexico, and its early labourers were mostly Mexicans and Yaqui Indians.

New Almaden is located along Alamitos Creek, near the eastern base of the northwest-trending California Coastal Ranges. The town shared the narrow valley floor with the company's headquarters and its reduction and shipping facilities, but all of the mining operations took place in a series of high ridges and hills to the northwest of town. These uplands are dominated by Franciscan rocks of Late Jurassic to Cretaceous age, plus some younger sedimentaries. The Franciscan Group was intruded by tabular masses of serpentine, some of which were subsequently hydrothermally altered to produce a suite of silicate-carbonate rocks, and it is in the latter group that the cinnabar (HgS) and other sulfide minerals are present. Initially, the ore was mined in open cuts that followed veins of high cinnabar content, but as these richer ores played out or became inaccessible at the surface, it was necessary to dig tunnels and shafts (BAILEY and EVERHART, 1964).

Bartlett made two trips to the main mine that was located approximately 300 metres above the valley floor. In the company of the mine engineer, he descended several hundred feet below the surface to examine the extent of the passageways, the occurrence of the ore, and the miners at work. He also observed that: "the ore up to the time of our visit was transported on the backs of men in leather sacks from the bottom of the shafts to the entrance to the mine, a distance of from two hundred and fifty to three hundred feet [76.20 metres to 91.44 metres] . . . Here the ore was separated, the refuse being thrown down the hill, and the rest laid aside to be sent to the furnaces. At the same time the *mulada*, or collection of some eighty or a hundred mules, was being loaded with the ore . . . each mule carrying on an average a *carga*, or three hundred pounds [136.08 kilograms]" (BARTLETT, 1854, vol. 2, p. 62-63).

Bartlett made several drawings of sites within the New Almaden mining district, including a view of the ore reduction facilities that straddled both sides of Alamitos Creek (figures 9a & 9b). His sepia and wash rendition of the Hacienda de Beneficio (Hacienda Reduction Works) is based on a field sketch he made from a vantage point on a hillside southwest of New Almaden. The mule trains, laden with raw ore, entered the valley flat from a winding trail along the west side of a canyon, known today as Deep Gulch. Once the ore was unloaded and sorted, it was placed in a series of furnaces where the heated cinnabar released vaporised mercury, which in turn was condensed and collected in vats. From there, the liquid mercury was poured into flasks and shipped by wagon to San Francisco. Although Bartlett was well aware of the adverse health effects of mercury—he witnessed excess salivation among the men and animals at New Almaden—he took advantage of an offer to sit upon a board and float in a vat of 20 tons [18.14 tonnes] of quicksilver!

The New Almaden District produced significant amounts of mercury for many decades. Although much of the mercury

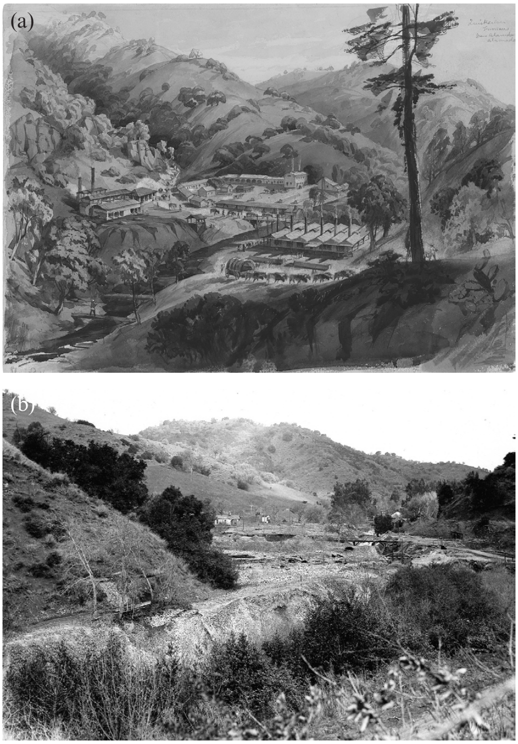

Fig. 9

(a) Quicksilver Furnaces, New Almaden, a sepia and wash by J.R. Bartlett, 3-5 April 1852, drawing no. 60 in the Bartlett Collection. In this view to the north, the valley floor on both sides of Alamitos Creek is occupied by the Hacienda Reduction Works, a processing centre for mercury ore that was brought down by mules from the high hills on the left. Towards the lower right-centre, a large wagon, presumably loaded with heavy flasks of liquid mercury, leaves the complex, pulled by a team of ten oxen. The six linear buildings with smokestacks just beyond the wagon are multi-chambered retorts. Bartlett's vantage point for this drawing is now occupied by Cinnabar Estates, a gated residential community.

(b) This 1950s photograph shows the ravaged valley floor near New Almaden that at one time was occupied by the Hacienda Reduction Works. The land has since been cleared, levelled, and reclaimed, leaving virtually no visible trace of the former mercury processing centre. In the hills above, the former mines and some 72.5 km of tunnels have been sealed, allowing Santa Clara County, the present owner, to administer the area as a county park. This mining district has long been the principal source of mercury contamination not only for the immediate area, but also for San Francisco Bay (courtesy of John Slenter and the Quicksilver Mining Museum at New Almaden).

was used for domestic purposes, including the extraction of gold in California, large amounts were also exported. However, New Almaden, beset with changing ownership and declining reserves of minable ore, never challenged the supremacy of Spain in world mercury production. All mercury mining in the New Almaden area ceased in the 1970s; the mines were subsequently closed and sealed; nothing remains of the Hacienda Reduction Works; most of the former mining district is now preserved as a public park; and mercury contamination in the soils and water remains a problem.

RHODE ISLAND

After his journey through the Southwest, Bartlett returned to Providence, where for seventeen years, he served as Rhode Island's Secretary of State. He also authored many books on a wide variety of subjects, including his *Personal Narrative*, but in literary circles, he is best known for his award winning, four-volume catalogue of the private library of John Carter Brown. He also helped to organise and direct the Sopori Land and Mining Company, an Arizona venture that for many years held a large tract of land south of Tucson, Arizona.

CONCLUSIONS

In his extensive travels through the American Southwest, from Texas to California, John Russell Bartlett was first and foremost a chronicler and illustrator of the landscape. Although he was not trained in any of the physical sciences, the eclectic Bartlett was fascinated by the rivers, mountains, mines, rocks, and geysers he saw, enough so that he made a permanent record of these images by incorporating them into his sketchbook. In addition, Bartlett compiled a field diary that he later published as his *Personal Narrative*, a book in which he describes many of his artwork sites in considerable detail. The combination of his accurate drawings and his vivid text allows one to locate these sites in the field today and to make valid comparisons of modern field conditions with those that Bartlett observed more than 150 years ago

ACKNOWLEDGEMENTS

The author appreciates the editorial assistance of Geraldine M. Mueller and Mark A. Walters. Thanks are due also to Devin G. Mueller and Mason A. Mueller for assistance in the field. Nearly all of the original drawings that Bartlett compiled from the Southwest are held in the Bartlett Collection at the John Carter Brown Library in Providence. It is with the gracious consent of the Library that several of these drawings are reproduced as part of this paper.

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