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2008, pp. 77-106. https://doi.org/10.56577/FFC-59.77

in:

Geology of the Gila Wilderness-Silver City area, Mack, Greg, Witcher, James, Lueth, Virgil W.; [eds.], New Mexico Geological Society 59 th Annual Fall Field Conference Guidebook, 210 p. https://doi.org/10.56577/FFC-59

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EARLY GEOLOGICAL STUDIES IN SOUTHWESTERN AND SOUTH-CENTRAL NEW MEXICO

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Abstract — Geologic studies in New Mexico commenced with the beginning of American administration of the territory in the late 1840s. In southern New Mexico, moderately accurate geographical information was largely limited to the areas along the Rio Grande, as indicated by the Parke-Kern map of 1851. The earliest geological observations were published by Topographical Engineer Lt. W. H. Emory, attached to Kearny's invading army in 1846; by Adolph Wislizenus, an independent naturalist, in 1846; and by Boundary Commissioner John R. Bartlett in 1851-52. Emory's observations mainly concerned rock types, rudimentary stratigraphy, and aspects of the Rio Grande and its valley. Wislizenus was the first to observe early Paleozoic strata in the El Paso area. Bartlett, in his "personal narrative", observed and published illustrations of several geological features, including the "Giant of the Mimbres", the Santa Rita copper mines, and Cookes Peak. More substantive geologic studies of southern New Mexico were conducted during the Pacific Railroad 32nd parallel survey (1854-1855); Pope's artesian well expedition (1855-1856); and the post-Gadsden Purchase conclusion of the Boundary Survey (1854-1856) supervised by W. H. Emory. The western branch of the 32nd parallel survey, led by Lt. John Parke, included the geologist Thomas Antisell, who described and interpreted the geology of southwestern New Mexico from the Arizona border to the Rio Grande and Organ Mountains, including geologic cross sections and a geologic map of the region he traversed. Many of his observations are detailed and accurate, and he was the first to suggest that faulting along the Rio Grande might be responsible for uplifting regions to the west. However, he erred in identifying large areas between the igneous mountain ranges of southwestern New Mexico as Permian, and in mapping Cretaceous strata in the Mesilla Valley. George Shumard, attached to Pope's artesian well expedition, made reconnaissance studies of the area between El Paso and Las Cruces; the region west of the Rio Grande (including the Goodsight-Sierra de las Uvas uplift, Cookes Range, Florida Mountains, and Santo Tomas-Black Mountain volcanic fields); the Jornada del Muerto and San Andres and Organ Mountains; and the geology along the western margin of the Jornada (Fra Cristobal, Caballo, Dona Ana, San Diego, and Robledo Mountains, and Cutter sag volcanic field). Shumard's studies are perceptive and accurate in many respects, but he missed observing the thick early Paleozoic sections in the San Andres and Caballo Mountains, and erred in interpreting the Precambrian cores of these ranges as Cenozoic intrusions responsible for their uplift. The final Boundary Survey report had little geologic information on southern New Mexico, but Emory contributed some observations of the El Paso area, and James Hall wrote an important paper, with a geologic map of New Mexico, synthesizing observations of Carboniferous and Cretaceous strata in the territory and correlating them with equivalent strata throughout the United States.

INTRODUCTION

Present knowledge of the geology of New Mexico is built upon observations and studies dating back about 160 years, to the time when New Mexico first came under American administration as a result of the Mexican-American War (1846-1848). The efforts of the earliest geologists and other observers to describe and interpret the geological features they encountered are known to only a few modern workers. As time passes, each new generation of geologists relies increasingly on relatively recent studies as the basis for their research, and the contributions of earlier workers pass into obscurity, rarely read or cited. Perhaps this is inevitable, as advances in knowledge are iterative and it is generally (although not always validly) assumed that previous research incorporates all of the relevant knowledge that preceded it. However, it is worthwhile from time to time to reflect upon the contributions of early observers who first studied the geology of an area. Not only is this of historical interest, but it broadens our appreciation of the development of our present knowledge, provides some recognition for those who laid the foundations for that knowledge, and makes us aware of the intellectual and historical climate in which earlier geologists worked.

This contribution briefly summarizes early geologic studies of southwestern and south-central New Mexico from the beginning of American administration through the 1850s. The area covered here extends from the Fra Cristobal and northern end of the San Andres Mountains on the north, to the New Mexico-Texas border (and including the Franklin Mountains) on the south, and from the Sacramento Mountains on the east to the Arizona border on the west (Fig. 1). This paper complements a similar paper on southeastern New Mexico, particularly the Guadalupe Mountains, by Kues (2006).

The history of geological studies in south-central New Mexico (and indeed, in New Mexico in general) begins with the American occupation because, as far as I have been able to determine, no published observations (aside from the names of some ores and minerals in mining areas) were made under the Spanish colonial and Mexican administrations of New Mexico. The Spanish were certainly interested in the natural history of their American domains, for major expeditions, such as the Royal Scientific Expedition to New Spain (1785-1800) were carried out during the 18th century (see Engstrand, 1981), resulting in large zoological, botanical, geological and paleontological collections. However, none of these natural history-intensive expeditions reached New Mexico. These essentially ended in the late 18th century, owing to the ascension of a less enlightened and supportive Spanish king (Carlos IV), political crises in Spain, the Napoleanic Wars, and finally, the wars for independence in the Spanish American colonies in the early 1800s. A few exploring expeditions were mounted during this time, and some reached New Mexico (see Goetzmann and Williams, 1992), but these were of a military

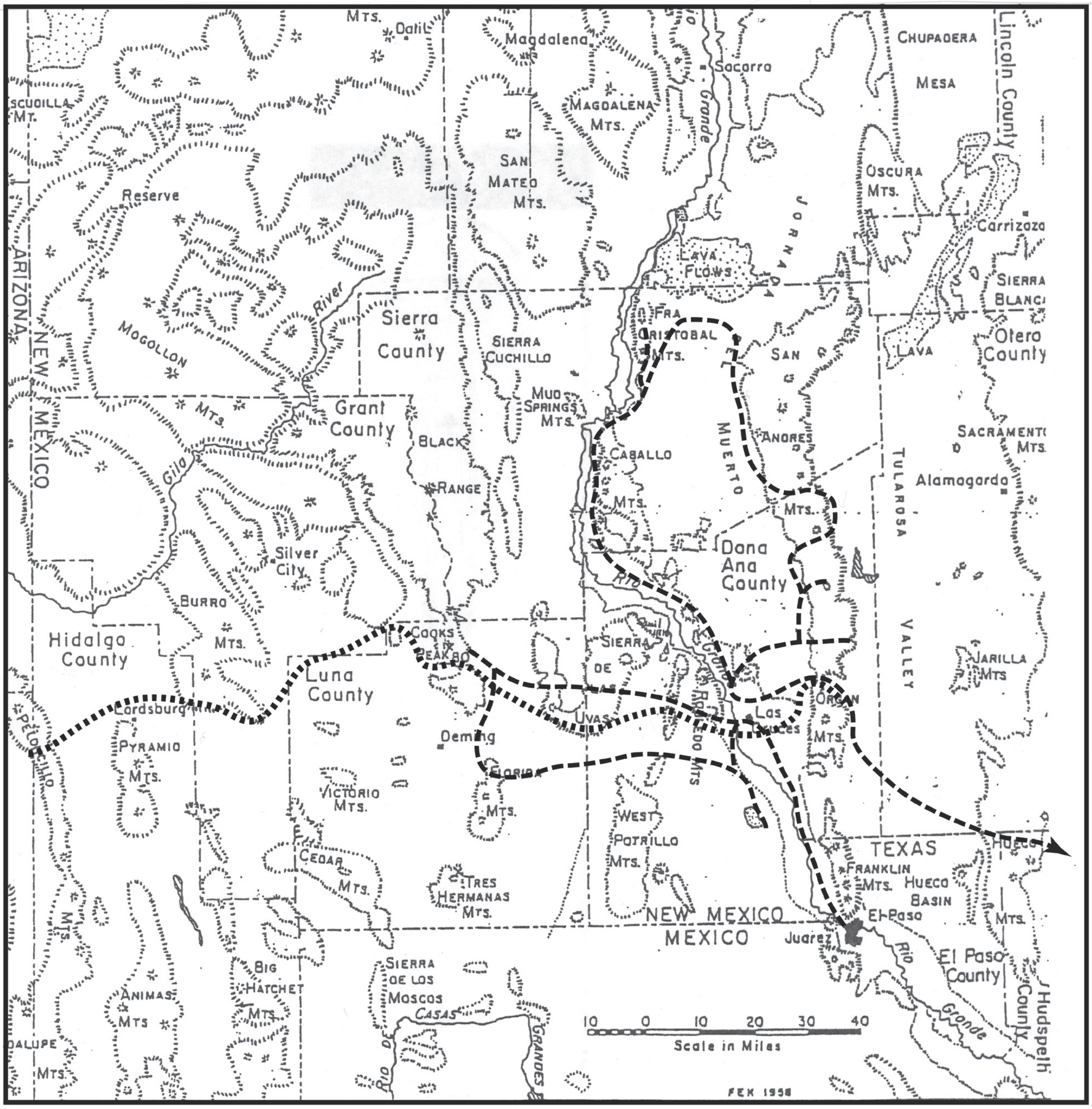


FIGURE 1. Reference sketch map of southwestern and south-central New Mexico (from Kottlowski, 1960), showing routes of Thomas Antisell in 1855 (square-dash line) and G. G. Shumard in 1855 and 1856 (long-dash lines).

and political nature, designed to block the perceived westward encroachment of Americans, especially after the Louisiana Purchase of 1803.

During the Spanish period, New Mexico, at the northern margin of the Spanish American empire, and neglected (and indeed, intentionally kept isolated) by the central government in Mexico City, languished in extreme poverty (see for example Bustamante and Simmons, 1995). No Spanish explorers with an interest in natural history reached this remote region, and New Mexico itself, with virtually no schools, printing presses, doctors, lawyers, or other educated citizens, produced no individuals with the interest, training, or means to study the geology or other aspects of the natural history of the territory.

Economic conditions improved after Mexican independence in 1821, in association with increased commercial activity initiated by the opening of the Santa Fe Trail, but New Mexico still lacked an infrastructure conducive to scientific studies of its natural history. Some American naturalists (especially botanists), and other American observers began to enter New Mexico during this time, but their numbers were few and the geological information they recorded was minute. Even significant mining activity, at Santa Rita (for copper) and east of the Sandia Mountains (for gold), was conducted at a very primitive level and led to no real record of geological data, such as the nature of the rocks from which the minerals were being extracted. The Mexican government did mount a major expedition to its northern frontier in 1827-1829, commanded by Manuel de Mier y Teran (see Jackson, 2000). Teran was a graduate of the Mexico National College of Mines, and his expedition reported on some aspects of the geology of the regions it explored. However, its focus was the unruly province of Texas, and the expedition did not enter New Mexico.

This all changed in 1846, for the military parties that invaded New Mexico during the war included officers of the elite Army Corps of Topographical Engineers, who were trained in the sciences and recorded and published their observations. Once the territory came under American administration, expeditions that included geologists and biologists poured into New Mexico and immediately began to describe its natural history. Thus, substantial knowledge of the geology of southern New Mexico, as for the entire territory, began to be amassed and recorded around 1850.

GEOGRAPHY

The geography of the new American territory of New Mexico was not well known, and one of the main tasks of the military and scientific expeditions of the late 1840s and 1850s was to clarify its geographic and topographic features, as well as to ascertain the location and nature of roads and the kinds of useful resources, such as minerals, water, and lumber, that would aid the military occupation and eventual settlement by Americans. Pre-invasion maps published by Americans display only generalized and rudimentary knowledge (often incorrect) of the geography of southern New Mexico (see Martin and Martin, 1984, for examples); many of the smaller mountain ranges are not shown at all on these maps. Indeed, the map chosen as the authoritative reference for drawing the Mexico-U.S. boundary after the war (Disturnell's map of 1847) was later found to show the Rio Grande 2^{o} of longitude too far east and El Paso [El Paso del Norte, the present Ciudad Juarez, Mexico] 30' of latitude too far north. This severely complicated the drawing of the southern boundary of New Mexico, as these two features were important reference points in the Treaty of Guadalupe Hidalgo. These pre-invasion maps were cobbled together from many sources of highly variable reliability, including the few existing Spanish-era maps.

Much of the information about New Mexico geography available to the Spanish was derived from a well-documented survey of New Spain's northern frontiers conducted in 1766 to 1768 by the Marques de Rubi ("Military Inspector of the Borderlands"), and recorded in a narrative diary of the expedition by Nicolas de Lafora (translation by Kinnaird, 1958; see also Reinhartz, 2005). This remarkable expedition covered about 7600 miles and surveyed the northern part of New Spain from the Colorado River in Arizona to the Red River in Louisiana, with the purpose of inspecting every site of Spanish settlement in the region and evaluating frontier defenses. It is the most thorough and detailed description of what is now the southwestern United States accomplished before the arrival of the Americans, rivaled only by the journal of the Dominguez-Escalante expedition (1776-1777) from northern New Mexico across the Great Basin.

The de Rubi expedition progressed from Durango to Chihuahua to El Paso in the spring of 1766, and in August and September journeyed up the Rio Grande Valley along the Camino Real through the Jornada del Muerto to Socorro, Albuquerque, and Santa Fe before returning to El Paso. In the New Mexico part of the expedition, Lafora, a captain in the Spanish Royal Engineers, recorded in detail the landscapes and topographic features he observed each day, together with camping places and distances traveled, and information about sparse villages. This is the best source of geographic and topographic information, as well as the names in use for these features, for its time. Unfortunately no reference was made to the geology of the topographic features, such as rock types or structures, that he encountered.

In south-central New Mexico, Lafora briefly described many of the prominent mountain ranges, including (moving northward from El Paso) the Organ (Los Organos) Mountains (which included the San Andres and Sandia-Manzano-Los Pinos uplift as well), the Dona Ana and San Diego Mountains, the Roblerito (Robledo) Mountains, and Aleman and El Muerto playa lakes in the Jornada del Muerto. The names El Perrillo and El Muerto sierras were applied to portions of the Caballo Mountains, with the San Cristobal (or Fra Cristobal) Mountains just to the north. Nearing Socorro, the party passed San Pascual (Little San Pascual Mountain), with the "Apache Woods" (Bosque del Apache) to the north. Across the river, Lafora noted a "high, central range called Los Ladrones", which joins the Mimbres range; this is probably the San Mateo Mountains, but the same name was also used for the small uplift north of Socorro that presently bears the name Ladron Mountains. The party found the settlements of Luis Lopez, Socorro, and Alamillo vacant and in ruins. The map produced by Lafora in 1771 (but not published; see Kinnaird, 1958, for a reproduction) is longitudinally compressed, pictorial, and cartographically primitive, but does portray a good amount of topographic detail and accurately locates the villages and towns of New Mexico, as far north as Taos.

The most detailed map of New Spain produced before Mexican independence (1821) was that of the great German scientist and geographer Alexander von Humboldt, who spent nearly a year in Mexico (1804), traveling widely and researching the colonial archives in Mexico City. Humboldt (1811) wrote a comprehensive account of New Spain, especially its mining industries, and included a detailed map of the province, which included New Mexico (reproduced by Martin and Martin, 1984). However, as von Humboldt did not travel anywhere near New Mexico, his short commentary on the territory and the New Mexico part of his map were compiled from sources available to him in Mexico City.

Humboldt's description of New Mexico was mainly geographical, although so little information was available that he could not even give the elevation of topographic features. Rather than being a large and prosperous colony, he noted, New Mexico was limited to "only a strip along the banks" of the Rio Grande between Albuquerque and Taos, "inhabited by poor colonists", whose situation was in some ways equivalent to that of Europeans in the Middle Ages. He stated that New Mexico was a fertile but depopulated land, and "as one now believes, devoid of mineral riches", isolated by deserts, empty of colonists south of Socorro, and occupied by Indians.

Humboldt's map represents an outstanding cartographic achievement for its time, with topography indicated in remarkable detail via carefully hachured lines. For New Mexico, however, topographic detail is shown only in the region near the Rio Grande, and much of this is inaccurate, although virtually all of the settlements of the region are included.

A few examples from von Humboldt's map provide an indication of just how limited geographic knowledge of New Mexico was at the time. El Paso is shown considerably north of the 32nd parallel of latitude instead of south of it. Few of the uplifts in New Mexico are accurately shown; instead the main topographic features portrayed are a pair of nearly parallel, virtually continuous, north-south uplifts running just west and east of the Rio Grande. A smaller range, labeled Sierra Obscura [sic] to the north and Sierra del Sacramento to the south, is situated a little farther east. The mesa upon which Acoma Pueblo is located is on the map, but overlooks the Rio Grande about at Isleta. Tributaries of what is called the Red River (actually the Canadian River, a separate river system) are shown near Taos and Santa Fe, and the Red River is depicted running southeast and joining the Mississippi River north of New Orleans. There were some improvements in geographic knowledge of New Mexico during the next 35 years, but most of the territory was essentially *terra incognita* at the time of the American invasion.

The American military parties that entered New Mexico during and immediately following the 1846-1848 war were very much concerned with assembling detailed information about the geography of the new territory, as this was essential to the occupation, administration, settlement, and utilization of natural resources in New Mexico. Several topographic maps prepared with the reports of Topographical Engineers James W. Abert, William G. Peck, William Emory, and James H. Simpson, together with information from other sources, were combined in the first detailed American map of New Mexico, completed in April 1851 by the young topographic engineer Lt. John G. Parke and the artist Richard Kern. The portion of this map that covers south-central New Mexico is reproduced here (Fig. 2), to illustrate the state of knowledge of the area shortly after American administration began.

Inspection of this map indicates fairly accurate knowledge of the uplifts along the Rio Grande and the well-traveled Camino Real, but extensive areas where information was vague or lacking (much of the region east and west of the central corridor is labeled "unexplored"). Limited information accounts for the long, narrow, strongly curved line of mountains representing the massive Sacramento-Sierra Blanca uplift, and its curious intersection with the center of the Guadalupe Mountains. All of the major north-south trending mountains along the Rio Grande valley are portrayed as uniformly narrow, which reflects ignorance of the true spatial extent of some ranges. The Organ Mountains (Sierra de los Organos) are shown as an arcuate, sinuous uplift ending just northeast of El Paso, apparently including the Franklin Mountains. However, the Franklins actually trend due north from the western outskirts of El Paso, and are not continuous with the Organ Mountains. It is surprising that they are not more accurately portrayed, given that the region around the town of El Paso was among the most frequently observed in the south-central New Mexico area. The range now called the San Andres Mountains is labeled the Sierra Soledad and Sierra de Caballo, and a northern northeast-trending extension, called the Sierra de Jumanes, appears either to be an inaccurate and exaggerated portrayal of the northern end of the San Andres range and the Sierra Oscura, or the large mesa in southwestern Torrance County presently called Mesa de los Jumanos.

Near the Rio Grande, the Fra Cristobal Mountains are accurately shown, separated by a low area to the south from an unnamed range now called the Caballo Mountains. Farther south, the San Diego, Dona Ana, and Robledo Mountains are portrayed, but only the former is named. North of the Fra Cristobals and west of the river are three parallel, unnamed, narrow ranges extending north of Socorro. These represent the San Mateo, Magdalena, and Chupadera-Socorro-Lemitar uplifts, but only the last of these is shown approximately accurately. East of the river, the (unnamed) Los Pinos uplift and an attenuated "Manzana" Mountains extend northeastward from the Socorro area. Most of the southwestern portion of the region is blank, but a roughly circular area of short ridges is shown, and "copper and gold mines" and "copper mine Apaches" are indicated. These represent the area of the Santa Rita copper mines, worked by the Spanish and Mexicans from the early 1800s, but largely *terra incognita* to Americans; it has been placed nearer to the Rio Grande than it actually is.

Despite the inaccuracies, the Parke-Kern map was a creditable attempt to portray the geography of New Mexico as then known, and it was a distinct improvement over previous maps. Subsequent exploration of New Mexico during the 1850s would rapidly increase knowledge of the geography of the territory and begin to fill in some of the blank spaces.

EARLY GEOLOGICAL OBSERVATIONS

Prior to the entry of trained geologists into New Mexico in 1853, some accurate geological observations of south-central New Mexico were recorded by individuals who traversed the territory during the Mexican-American War and during the boundary survey that followed. Notable among these earliest contributors to geologic knowledge of this area were the Army topographic engineer William H. Emory, the independent scientist Adolph Wislizenus, and John Russell Bartlett, the fourth U. S. Boundary Commissioner. Their contributions are discussed below.

William H. Emory

Following the outbreak of war with Mexico, General Stephen W. Kearny's Army of the West invaded New Mexico on August 7, 1846, across Raton Pass. The main record of this expedition, which continued on to California, was written by First Lieutenant William H. Emory, a graduate of West Point (Class of 1831), 34 years old, and a veteran in the Army's elite Corps of Topographic

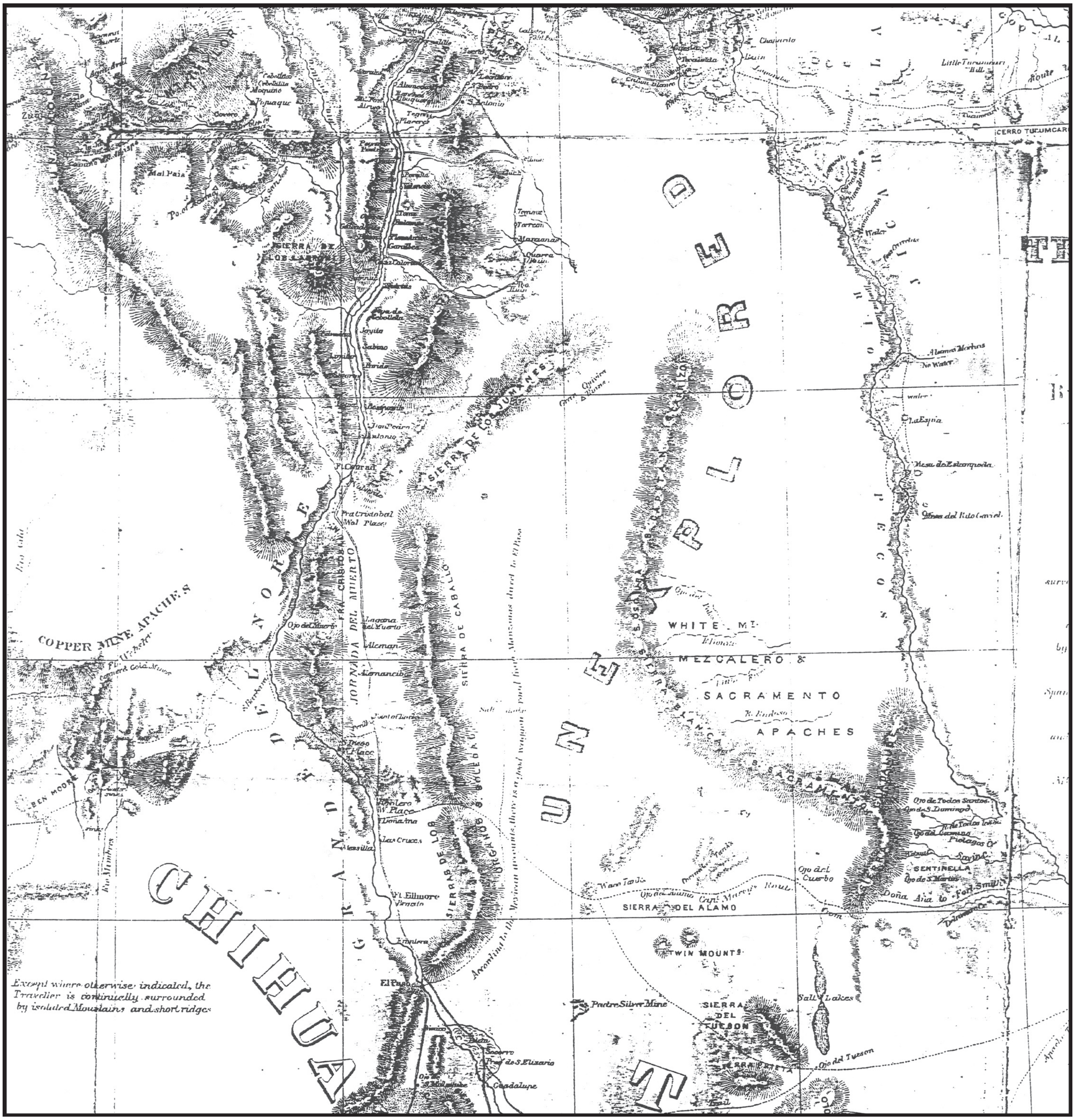


FIGURE 2. Part of Parke-Kern map of 1851, showing geographic features recognized at the time of the early geological surveys.

Engineers. As he traveled through New Mexico, Emory performed a detailed reconnaissance of the areas traversed by the Army. He made observations on geological and topographic features, collected geological and biological specimens (giving the scientific names of most of the animals and plants he collected), charted and evaluated roads, measured streams, determined altitudes and latitudes and longitudes of landforms, commented upon mineral and agricultural resources, explored Indian ruins, and surveyed the site of the first American fort in New Mexico (Fort Marcy, in Santa Fe). Emory's journal (1848; reprinted with annotations by Calvin, 1951; see also Goetzmann, 1959) contains a wealth of information, clearly and literately communicated, that provided

Americans their first detailed picture of the newly won territories. As he traveled he made topographic sketch maps, which were later combined into a single map of the Army's route that surpassed in detail and accuracy any previous map of these regions. Quotations concerning the geology Emory observed given below are referenced with page numbers from Calvin (1951).

Kearny's army was in and around Santa Fe from August 18 to September 25, 1846, establishing American control over New Mexico, and then continued south down the Rio Grande Valley. Near Socorro, Emory inspected Sierra Socorro, and pronounced it "a confused mass of volcanic rocks, traversed by walls of a reddish colored basalt and seams of porphyritic lava and metamorphic sandstone", and noted specimens of galena and copper ore. Surveying the area across the river with his field glass, he reported "the Sierra Grande, which commences at Zandia [Sandia Mountains] with such towering heights, here tapers down to moderately sized hills. The formation is apparently of different colored sandstone, and wherever stratification shows itself, dipping about 25 degrees to the south and east; but in some places it is horizontal, and in others showing great disturbance. With the glass may be seen walls of light colored stone, basalt or trap, running off for miles in a straight line, nearly north and south" (p. 86). This type of observation is typical of Emory's journal. Because he had to stay close to the route of his army, he generally could not venture off to examine geological features closely, nor had he the time to work out age relationships of the rocks he observed. Thus, his observations were limited to descriptive lithology, but these were literally the first such observations made in south-central New Mexico.

The army continued south along the west bank of the Rio Grande, and by October 9 had reached a position opposite the Fra Cristobal Mountains. Emory described the geomorphic features of the sediment cover at the western base of the range and the hydrologic aspects of the Rio Grande, noting that here the river was 118 ft wide, averaged 14 ft deep, and flowed over large round pebbles. On the west side of the Rio Grande, Emory found the sloping terrain cut "by deep arroyos, crowned on their summits by basalt, underlayed by sandstone" (p. 90). The Army of the West then moved southwestward away from the river, and entered what Emory called the Mimbres Mountains (the Black Range of modern usage). The valleys of the Rio Mimbres and its tributaries were described as truly beautiful, with rich, fertile soil. Emory (p. 97) described these mountains as …" formed chiefly of a reddish amygdaloid and a brown altered sandstone, with chalcedonic coating. In places, immense piles of conglomerate protruded [Gila Conglomerate]; disposed in regular strata, dipping to the south at an angle of 45^{o} . There was also one pile of volcanic glass brittle, in strata about half an inch thick, dipping 45^{o} to the south."

Crossing the Black Range through the pass that today bears his name, Emory traversed the resurgent dome of one of the largest and best exposed mid-Tertiary cauldrons (appropriately named Emory cauldron, 55 km by 25 km in approximate dimensions) in southwestern New Mexico (Elston et al., 1975). The "reddish amygdaloid" he reported is the caldera-fill facies of the Oligocene Kneeling Nun Tuff, and the volcanic glass is probably part of one of the ring-fracture domes of the cauldron, a member of the Mimbres Peak Formation (Elston, written commun., 2008).

By October 18, the party dropped into "the valley of what is supposed to be an arm of the Mimbres [River], where there are some deserted copper mines. They are said to be very rich, both in copper and gold, and the specimens obtained sustain this assertion." (p. 97). These, the Santa Rita copper mines, were deserted, with the remains of 20 or 30 adobe homes and numerous shafts visible. "The entire surface of the hill in which they are sunk is covered with iron pyrites and the red oxide of copper. Many veins of native copper were found…" (p. 98). Although Emory did not know how long the mines had been worked (the miners had been driven out by Apaches in the mid-1830s), he was aware that the ore was rich and fortunes had been made, noting that "the gold found in the ores of these mines paid all the expenses of mining, and the transportation of the ore to the city of Mexico, where it was reduced" (p. 98).

The following day (October 19), the men reached the spring of San Lucia, 13.5 mi from the copper mines, "in a beautiful valley, surrounded, at the distance of fifteen miles, with high mountains" (p. 99). This spring, also called San Vicente, eventually supported a village of the same name, which around 1870 became the town of Silver City, as American miners moved into the area. After a conference with the Apache inhabitants, Kearny's army continued westward, and the next day encountered the Gila River for the first time. "Clear and swift, it came bouncing from the great mountains, which appeared to the north about 60 miles distant," (p. 102), and to the men's pleasure, was filled with fish. The surrounding country was described as very broken, " … traversed by huge dikes of trap and walls of basalt." From one of the peaks, Emory could see the topography in all directions: the "…mountains run from northwest to southeast and arise abruptly from the plains in long narrow ridges, resembling trap dykes [sic] on a great scale. These chains terminate at a certain distance to the south…" (p. 103). He described the mountains as "…of volcanic rock of various colors, feldspathic granite, and red sandstone, with a dip to the northwest, huge hills of a conglomerate of angular and rounded fragments of quartz, basalt, and trap…" (p. 103). The party was in the northwestern foothills of the Big Burro Mountains, and seeing Precambrian granite overlain by a variety of Paleogene intrusive and extrusive igneous rocks. He also noted, in the canyon of the Gila, layers of sandstone and limestone, which may refer to the limited outcrops of Cretaceous sedimentary rocks in that area. The army camped on October 22 within view of a prominence Emory named Steeple Rock, the name it bears to this day, about 6 mi east of the Arizona border.

Here we will leave Kearny's Army of the West, and Emory's record of the country through which it passed. The army crossed the deserts of Arizona and southern California, and on December 6-10, north of San Diego, fought the bloody Battle of San Pascual, in which many officers and men were killed or injured (including Kearny; Emory saved his life by killing a Mexican lancer who was about to run the general through), but which secured southern California for the Americans. On December 12 the army marched into San Diego and Emory's cross-country reconnaissance was completed.

The importance of Emory's record and maps of his journey, from Fort Leavenworth, Kansas, to the Pacific cannot be overestimated. The geographic/topographic maps he prepared, with locations based on 2000 astronomical observations and more than 350 altitudes determined by barometer, is a landmark of western cartography, and immediately made all previous maps of New Mexico and the other areas he surveyed obsolete. His report provided an immense amount of detailed information, in many cases the first available to Americans, concerning the geography, terrain, resources, biology, geology, Indian ethnography and archeology, and Hispanic culture and peoples of what had just become the southwestern United States. It also produced information relevant to the practicality of a transcontinental railroad; Emory specifically recommended that the Mexican-American boundary line from El Paso to the Pacific be drawn at 32^o north latitude so as to include a possible southern route within the boundaries of the U. S. As Goetzmann (1959, p. 137-138) also noted, Emory's observations led him to two other important conclusions about the potential settlement of the West. First, he realized that natural rainfall could not sustain agricultural settlements, and thus that settlement would have to be restricted by governmental authority to areas near sources of water such as streams, not based simply on acquisition of land. In this he anticipated the philosophy of John Wesley Powell more than 30 years later. Second, he argued that for several reasons, slave labor would never succeed in the Southwest, an issue of great import in the decade leading up to the Civil War.

Adolph Wislizenus

About one month after the report of Emory (1848) was published, the account of another perceptive observer of New Mexico natural history and culture appeared in print. This was written by Adolph Wislizenus, a St. Louis doctor and partner of the eminent botanist George Engelmann, who on his own initiative embarked upon a scientific expedition through New Mexico in 1846. He traveled with a caravan that left Missouri in late May and after a month on the Santa Fe Trail, arrived in Santa Fe on June 30, where they heard for the first time that a state of war existed between the U. S. and Mexico. Wislizenus's account of his travels (1848) was reprinted by Rittenhouse (1969) and his geological observations in northeastern New Mexico were discussed by Kues (1985). His journal is filled with detailed observations on New Mexico natural history; he collected plants, kept meteorological tables, determined elevations by barometric measurements, and contributed many lengthy and perceptive observations of the life, customs, and society of Hispanic New Mexicans. Because he had no military duties, Wislizenus was able to spend more of each day en route observing and recording. A 10-page essay in his report concerning the geography, agriculture, minerals, climate, population, history, culture, and government of New Mexico, at the end of the Mexican administration, is arguably the most detailed and authoritative to come out of the Mexican War and its aftermath.

Wislizenus left Santa Fe on July 8, about 6 weeks before Kearny's army arrived there. He reached Albuquerque three days later after a tour of the Old and New Placers mining district east of the Sandia Mountains, of which he gave an extremely detailed account, the best that exists concerning Mexican mining in New Mexico in the 1840s. The caravan he was accompanying left Albuquerque on July 17, and traveled through Isleta, Valencia, Tome, Joyita, and La Joya, to Socorro, a journey of 11 days. In Socorro, Wislizenus employed a guide to escort him to some nearby copper mines, noting that the mountains near Socorro consist mainly of porphyritic rock. The supposed copper ore proved to be "but a green trachyte rock" (Wislizenus, 1848, p. 37). Traveling south on the east bank of the Rio Grande, the party passed Valverde ruins and encountered some "black-looking hills between our road and the river [consisting] of amygdaloidal basalt" (p. 37), the Black Mesa area opposite San Marcial. Travel through the Jornada del Muerto produced only cursory comments on the mountains in view (Fra Cristobals to the west, and the Sierra Blanca 30 mi to the east), soil quality, sparse vegetation, and sources of water. By August 5 the Organ Mountains were in sight, and on August 8 Wislizenus, traveling in advance of the caravan, rode into El Paso, where he remained a week.

Wislizenus was much impressed with the El Paso area, particularly the extensive cultivation of fruits and vineyards and its potential as a military base. He noted that El Paso's elevation was about 1000 ft lower than Albuquerque, and calculated, allowing for the circuitous route of the Rio Grande, that the southward gradient of the river is about 2.5 ft per mile. He also spent a day examining the geology of nearby mountains (p. 42):

"To examine the geological character of the surrounding country, I made, one day, an excursion into the mountains, southwest of the town. I was astonished to find them to consist almost entirely of limestone, the first I saw in the valley of the Rio del Norte. Below the limestone at the foot of the mountains were horizontal layers of compact quartzose sandstone, such as I have seen for several hundred miles in the prairie towards Santa Fe, underlying the [late Cenozoic] basaltic and granitic rocks [he had observed in northern New Mexico]. The limestone rose upon it to the height of the mountain chain, but on its sides granitic and porphyritic rocks seemed to a small extent to have burst through the limestone and overflown it. After a long search I was lucky enough to find near the top of the mountain some fossils in the limestone, belonging to the Silurian system".

This paragraph requires some comment. This identification of lower Paleozoic strata was the first for New Mexico and neighboring regions. However, Wislizenus's statement that he found Silurian fossils in mountains southwest of El Paso is perplexing. The mountains (Sierra Juarez) southwest of El Paso are composed entirely of Cretaceous and Cenozoic sedimentary rocks (Strain, 1958). Harbour (1972) suggested that Wislizenus's identification of the fossils was in error for that reason. However, Wislizenus earlier had correctly identified Cretaceous fossils from the Las Vegas area, so it is unlikely that he would have confused Cretaceous with Silurian fossils. Instead, I believe it is likely that Wislizenus rode east or northeast from El Paso into the Franklin Mountains, and simply made an inadvertent error in reporting the direction he traveled. The western and southern faces of the Franklin Mountains, overlooking El Paso, have a thick sequence of Ordovician limestones (El Paso and Montoya Formations).

Fossils from these formations would have been identified as Silurian; the Ordovician Period would not become part of the geologic time scale for another 30 years. Further, the Ordovician limestone cliffs are underlain by Cambro-Ordovician Bliss Sandstone and by Precambrian granites, porphyries, and other igneous rocks, which accord with Wislizenus's reports of those rock types associated with the limestones. The next man with geological training to inspect the Franklin Mountains (G. G. Shumard in 1855) verified the occurrence of "Silurian" fossils (see below). Wislizenus's comparison of the underlying sandstones with (Cretaceous) sandstones of the Santa Fe region appears simply to have been a guess. His comment that these were the first limestones he had seen in the Rio Grande Valley suggests that even though he had reconnoitered the Pecos, Santa Fe, and Albuquerque areas he had missed the exposures of Pennsylvanian limestones that are a prominent feature of the geology of those areas. Although his observations in the El Paso area are somewhat confusing, Wislizenus deserves credit for first recognizing the presence of lower Paleozoic strata there. Wislizenus also included a "geological sketch map" of his route through New Mexico. This is mainly a topographic sketch map, with very little actual geological information, and was not as detailed as Emory's map

Wislizenus left the caravan at El Paso and proceeded southward to Chihuahua. Unfortunately while there (late August, 1846) the news arrived of Kearny's army taking control of Santa Fe. Wislizenus was attacked by an angry mob, taken into protective custody by Mexican officials, and exiled in a small town 90 mi west of Chihuahua. He was eventually freed in March 1847 by Colonel Doniphan's forces, and returned to the U. S. as an army medical officer, arriving in New Orleans on June 20, 1847. He never returned to the Southwest, but his account of his travels through New Mexico on the eve of the Mexican-American War remains as one of the most important documents of New Mexico history.

John Bartlett and the Boundary Survey, 1850-1852

The Treaty of Guadalupe Hidalgo, ending the Mexican War in February 1848, stipulated the establishment of a new boundary between the two countries. This boundary would run about 2000 miles, from the mouth of the Rio Grande, northwestward along the river to a point near El Paso, and then westward to the Pacific, just south of San Diego. The task of surveying the boundary and marking it in the field fell to American and Mexican boundary commissioners and their surveying teams. The first of several American commissioners was appointed late in 1848 but by a year later only part of the California boundary had been surveyed. John Bartlett, the fourth commissioner, was appointed in June 1850, and arrived in El Paso in November 1850, after a long trek from the Texas Gulf Coast, to begin surveying the New Mexico part of the boundary.

Bartlett was a man of many interests and traveled extensively in the West to areas far from the U.S.-Mexico boundary region, such as deep into northern Mexico and to San Francisco and the Napa Valley. Because of inaccuracies in Disturnell's map (mentioned above) Bartlett was forced to work a compromise with the Mexican commissioner in establishing the boundary between Mexico and New Mexico. This began at the Rio Grande near Dona Ana and struck westward into Arizona, thus giving up most of the rich Mesilla Valley and (his critics charged) the best route for a transcontinental railroad, while retaining the Santa Rita mines in the U. S. When the compromise boundary was announced, most of the population of Dona Ana moved south to what they believed would remain Mexican territory, and founded the town of Mesilla. However, his surveyor refused to sign the agreement, the boundary survey stalled, and the compromise boundary agreement was ultimately repudiated by the U. S. government. Bartlett was dismissed early in 1853 when he returned to the East. The U. S. purchased the strip that Bartlett had "given away" and a large additional area to the south (the present southern parts of New Mexico and Arizona) for $10 million (the Gadsden Purchase, 1853). A new survey commenced and was finally concluded in 1856 under the direction of (now) Major W. H. Emory. The official report of the Boundary Survey, including several lengthy scientific reports (geology, paleontology, botany, zoology), was compiled by Emory (1857-1859); information pertaining to New Mexico geology is discussed later in this paper. Detailed accounts of the Boundary Survey have been published by James (1969), Emory (2000), and Rebert (2001), among others.

This bit of history would be irrelevant to an account of early geological observations in southern New Mexico except for the fact that Bartlett (1854) produced a best selling, two-volume, "personal narrative" of his travels and activities while Boundary Commissioner. This book includes some descriptive information as well as illustrations of geological features (Fig. 3) in southern New Mexico. Bartlett himself was an accomplished artist, who produced many sketches and paintings, and another artist, Henry Cheever Pratt, also accompanied the Boundary Survey, producing a rich visual record of the Southwest. Many of these images are reproduced in Hall (1996). Geologically important are Bartlett's illustrations and descriptions of the Guadalupe Mountains (see Kues, 2006), the "Giant of the Mimbres" (reproduced by James, 1969, and comprehensively discussed by Mueller and Twidale, 1988), the Santa Rita copper mines (where Bartlett spent several weeks and provided the best contemporary history of their operation, which ended because of Apache attacks in 1838), and the Organ Mountains (several sketches and paintings made by Bartlett and Pratt were reproduced, with extensive commentary, by Mueller and Mueller, 1998).

Because Bartlett's observations on southern New Mexico have been so well documented by several recent authors they will not be repeated here. Although he was not trained in geology, Bartlett was an acute observer, a fine recorder of what he saw, and able to illustrate unusual geological features accurately. He therefore deserves mention in any survey of early geological observations in southern New Mexico.

THE PACIFIC RAILROAD SURVEYS

Introduction

Even before the Mexican War, the idea of a transcontinental railroad had attracted much interest, and with the acquisition of

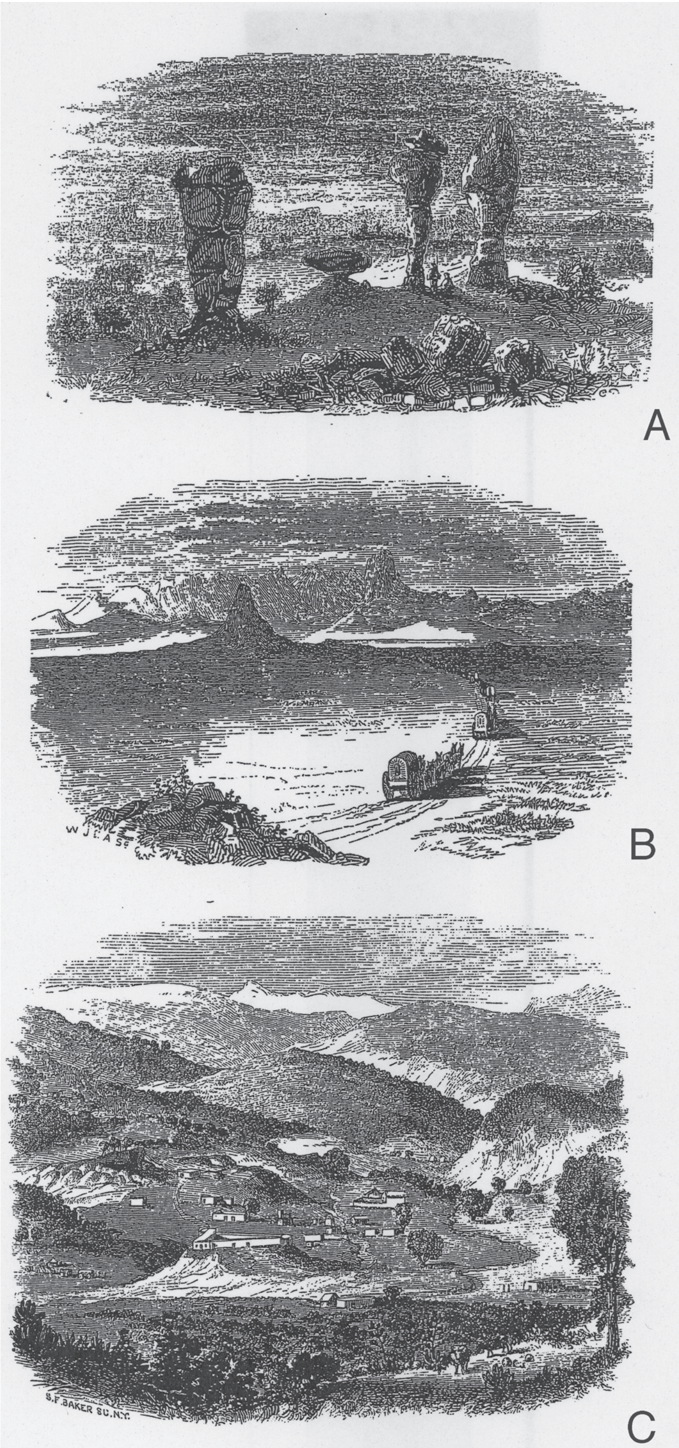


FIGURE 3. Woodcuts of southern New Mexico from Bartlett (1854). A, “Sandstone rocks, Rio Mimbres” (Giants of the Mimbres); B, “Approaching Mule Spring, Picacho de Mimbres” [Cookes Range]; C, “Valley of the [Santa Rita] copper mines from the west.” The depiction of the Cookes Range in 3B is rather fanciful, but the profile of the Cookes Range is shown accurately in 3C as the white ridge on the skyline. Outflow facies of Kneeling Num tuff supports the rugged cliffs capping the fault blocks beyond the buildings in the middle ground, and the white areas beneath the Tertiary volcanics and on the mine dumps forming a crescent around the settlement are the copper-bearing, 56 Ma porphyry, hydrothermally altered to sericite and kaolinite (Elston, written commun., 2008.

the new southwestern territories several potential routes began to be seriously discussed. Competing sectional (North-South) and regional plans were debated, as cities in the Mississippi Valley area, from Vicksburg to Chicago, vied to become the eastern terminus of the railroad, which would vastly increase their importance and economic prosperity. As many as eight different routes were advocated, but factional interests in Congress prevented a decision on a single route. Finally, in March 1853, Congress decided to fund detailed surveys of several potential routes, hoping that the information would indicate a clearly superior route that could gain wide support. These surveys were commanded by officers of the Corps of Topographical Engineers, and most included a variety of scientists in various disciplines, including geologists. Although primarily motivated by politics, the Pacific Railroad surveys together turned out to be the first great scientific survey of the American West.

Two potential railroad routes crossed New Mexico. The first, along the 35th parallel (roughly Tucumcari-Santa Fe-Albuquerque-Zuni), was surveyed in 1853 by a party under the command of Lieutenant Amiel Whipple and included the Swiss-born geologist Jules Marcou. The second survey, along the 32nd parallel, was something of an afterthought, as some powerful Southern politicians and influential army officers believed that previous surveys, such as that of Emory in 1846 and another by Marcy in 1849, had clearly shown this to be the best route. This survey was completed in two segments. The western segment, surveyed by Lt. John G. Parke (who had helped produce the 1851 map of New Mexico mentioned above) in 1854-1855, began in San Diego, crossed the Mojave Desert, Arizona and southwestern New Mexico, and ended in Dona Ana. The eastern segment, commanded by Captain John Pope, departed from Dona Ana early in 1854, traveled eastward through the Guadalupe Mountains, and then through Texas to southeastern Oklahoma.

Parke and Antisell

Parke surveyed the region from central Arizona to the Rio Grande on two separate expeditions. The first, a party of 58 men, set out from San Diego in January 1854 and reached the Pima villages north of Tucson, Arizona, in mid-February, where detailed surveying began. In early March it entered New Mexico and arrived in Dona Ana on March 13. About a week was spent reconnoitering south-central New Mexico, as far southwest as the Florida Mountains. Parke returned the following year, in July-August 1855, to assemble additional information on mountain passes, grades, and other subjects relevant to a potential railroad route. It was this expedition that included a geologist. Parke’s (1855, 1857) reports provide a good overview of the physical geography encountered from central Arizona to the Rio Grande, and include lengthy analyses of the many advantages of the 32nd parallel route for a railroad.

The geologist attached to the second Parke expedition was Thomas Antisell (1817-1893). Antisell was trained as a surgeon and was a political exile from Ireland who immigrated to the U. S. in 1848. Before leaving he had published on the geology of Ireland, and in the U. S. practiced as a surgeon and lectured on chemistry at several colleges. He was a somewhat unusual choice for geologist on a Pacific Railroad expedition; apparently the support of the botanist John Torrey at Princeton was influential in gaining him the position. His work on the 32nd parallel Pacific Railroad survey would be his first and only geological investigation in the U. S. Antisell later served in the U. S. Patent Office, and then as a medical officer in the Civil War. Afterwards he was chief chemist for the U. S. Department of Agriculture, and spent 6 years as an expert chemist in Japan before returning to the patent office in 1877 for the remainder of his career (Merrill, 1924). Most of his geological report (Antisell, 1856) concerned California, where he spent most of his time, but his observations and interpretations of the geology of southwestern and south-central New Mexico form the first detailed account of the geology of this region, going far beyond the abbreviated observations of the Mexican War and Boundary explorers. Unfortunately, Antisell's work has been unknown to most modern geologists working in southern New Mexico. His report is rarely cited; Bartlett's much less significant geological observations seem to be much better known.

Antisell's observations of the rocks exposed along his route through southwestern New Mexico are quite detailed. Seemingly all significant outcrops were examined; types of rocks were reported, dimensions and orientation of dikes, and dips of sedimentary and volcanic units measured, and simple stratigraphic sections at several localities were given. Likewise, he also paid close attention to the geologic structures he observed, and to the composition of the soils and alluvium in the playa lakes and stream valleys. Beyond mere description, Antisell also sought to recognize the geologic processes responsible for the features he observed, and to synthesize his observations into a larger picture of the geologic history they represented. To this end, his report included several geological cross sections, some of which are reproduced here (Figs. 4, 5) to show how he interpreted the geology of this area. Some of the outcrops he described are difficult to interpret because their locations were not precisely given, and because few of his geographic reference points had names. In general, however, his route can be followed with fair accuracy (Fig. 1) and the features he described related to rock units and structures recognized by modern geologists. The following account is not intended to exhaustively document all of his observations, but to indicate how he described and interpreted the major geologic features of the areas of southwestern and south-central New Mexico he viewed.

Antisell entered New Mexico across the northern part of the Peloncillo Mountains, through what is now called Steins Pass, along the present route of I-10, descended into the Animas Valley ("Valle de los Playas"), and traveled eastward to the western foothills of the Big Burro Mountains, a short distance north of the present town of Lordsburg. He interpreted the Peloncillo and Pyramid Mountains as mainly of volcanic origin (p. 153; see also Fig. 4):

"They are not protrusions of primary rock which have carried up their superimposed strata…but they are injections of plutonic rocks, which, rising in a fluid condition, has forced itself through the fissures formed by the subterranean force, and spread over the summit level of the plain…Trachyte and porphyry are the two species of rock erupted most abundantly; the former forming the crest of many of the hills…and spreading itself over the surface like a stratum, while the porphyries are found in dykes, and do not appear to have been as fluid as the trachytes…" He also noted "a dyke of dense augitic basalt" cutting through a trachyte on the eastern side of the Peloncillos

Summarizing, Antisell (p. 153) noted "…that there have been three distinct volcanic oupourings in these ranges…1st, that of the porphyries; 2d, that of the trachytes; and 3d, that of the basalt, the antiquity of which were in the order indicated, and the earliest of them subsequent to the deposition of reddish sandstone and whitish grit, which overlie…carboniferous limestone [which he had observed in the Chiracahua Mountains of southeastern Arizona]." He also noted that this igneous activity had served to elevate the region, with associated faulting. Antisell's interpretation of the sequence of volcanic episodes in southwestern New Mexico was remarkably accurate. Until relatively recently (including Dane and Bachman's 1965 geologic map of New Mexico), workers viewed this succession in terms of an early pre-Datil Formation porphyritic andesite (Antisell's "porphyries"), the Datil Formation (rhyolites; "trachytes" in Antisell's terminology), and post-Datil "basalts" (mostly black rhyodacite and basaltic andesite). With more recent study, including detailed mapping and radiometric dating, it has become apparent that this succession should be doubled, with the upper "basalt" of the lower section correlating to the basal andesite of the upper section. These complexities, however, would not have been apparent along Antisell's route (Elston, written commun., 2008).

This part of the Peloncillo range and neighboring areas has been geologically mapped by Gillerman (1958), Hudson (1984), and Richter et al. (1990). Antisell's observations were accurate. Steins Mountain, on the north side of the pass, is of rhyolitic pyroclastic rocks ("trachyte") on porphyritic andesite ("porphyry"), cut by prominent dikes. The term rhyolite as a rock type was not introduced until the 1870s (Elston, written commun., 2008). The trachytes Antisell referred to, belonging to a complex association of Eocene to Oligocene rhyolitic lavas and tuffs, also compose much of the central and southern Pyramid Mountains (e.g., Geologic Map of New Mexico, 2003). Older Cretaceous to early Paleogene intrusive porphyries and andesitic eruptive flows, are especially well exposed on the north end of the Pyramid Mountains; these may be seen on Antisell's cross section (Fig. 4A). In the 1850s, of course, it was not possible to determine absolute ages for rock units, but Antisell's estimate of their relative ages was essentially correct.

Approaching the western foothills of the Burro Mountains (now called the Gold Hills), Antisell (p. 154) noted "…that they have not a central igneous nucleus around which the strata are inclined, but are rather a series of waves, upraising great breadths of land", a series of "porphyritic chains" oriented north-60° west. Most of the Gold Hills and Big Burro Mountains are composed of large-grained Precambrian granites, which probably appeared porphyritic to Antisell. However, neither in his text nor in his figures (Fig. 4B) did he indicate an awareness that the dominant igneous rocks of these mountains were of what he would have called Primary (Precambrian) age.

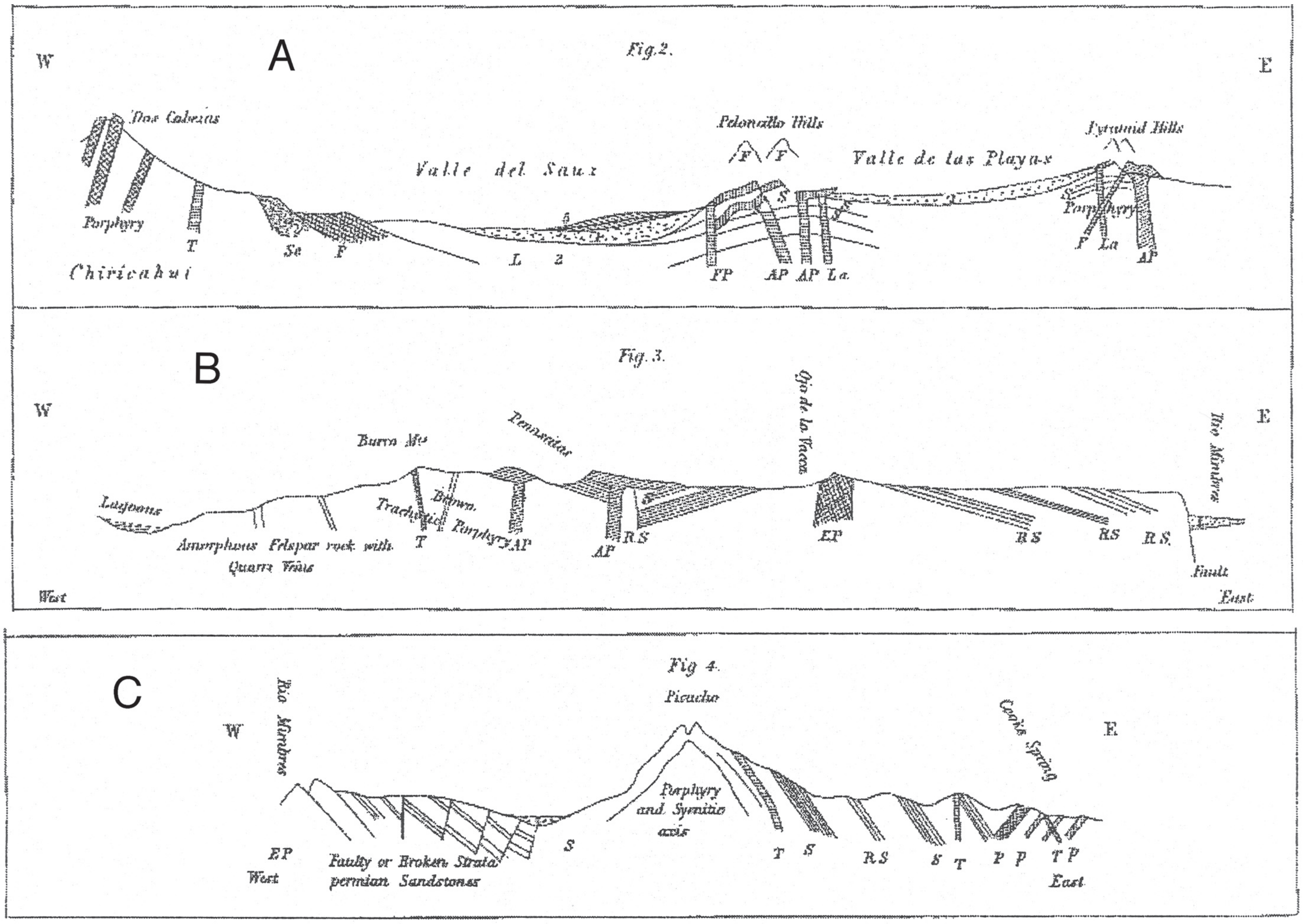


FIGURE 4. Thomas Antisell's geologic cross sections in southwestern New Mexico. A, From the Chiricahua Mountains (Arizona) to the Pyramid Mountains (pl. 12, fig. 2); B, From the Burro Mountains to the Rio Mimbres (pl. 12, fig. 3); C, From the Rio Mimbres to Cookes Spring (pl. 13, fig. 4). Abbreviations: L, Carboniferous limestone; FP, feldspathic porphyry; AP, trachytic rocks; S, Permian sandstone; F, feldspathic dikes; La, basaltic lava; RS, red Permian sandstone; Picacho, Cookes Peak.

Antisell's route took him from the west to the east side of the Gold Hills. Along this route, the Tertiary volcanics of the Steeple Rock area to the northwest, and of the Knight Peak graben separating the Gold Hills from the Big Burro Mountains, would have been conspicuous. However the Precambrian core of the Gold Hills is mostly covered by grus and partly buried by a large bajada, and could easily have escaped Antisell's attention. Some of the quartz veins shown on the west side of the Burro Mountains by Antisell are indeed visible from a distance to a modern traveler (Elston, written commun., 2008). Apparently he did not inspect them closely enough to observe that they do contain gold, which later gave the Burro Mountains its modern name.

In the Big Burro Mountains, and eastward to the Mimbres River and beyond, Antisell reported several types of sedimentary rocks, including yellow and red sandstone, white sandstone "grit", and a thick (200+ ft) unit of feldspar conglomerate that capped the local section west of the Rio Mimbres. The conglomerate is clearly part of the Gila Conglomerate, which is widely exposed in this area. The "yellow sandstone", reported as locally hardened into an enamel-like material or converted into agatized layers, are exposures of Paleogene ash-flow tuffs, which crop out extensively around the north end of the Big Burros and along parts of the Gila River to the north. Throughout his report Antisell identified ash-flow tuffs and volcaniclastic beds as sandstones, understandable in view of the granular nature of tuffs and the fact that the concept of ash-flow tuffs and their genesis from volcanic activity had not been recognized in the 1850s.

Antisell considered the beds of red sandstone, well exposed around the "Ojo de la Vaca" (Cow Spring, in the extreme northwestern corner of Luna County) and dipping east towards the Rio Mimbres as Permian (Fig. 4B), based on a perceived similarity to red sandstones he observed in ranges along the Rio Grande. He described these sandstones (p. 155) as a "brick-red, homogeneous rock" with "whity feldspathic clay and nodules, and cavities sparingly scattered through it", and noted that it formed the road bottom across which his party was passing. No Permian or

Triassic red beds occur in this area; the beds of red sandstone he was seeing are probably reddish ash-flow tuffs units and/or Miocene and younger sedimentary beds.

Antisell's identification of red sandstones in this area and elsewhere west of the Rio Grande as Permian was explained in a separate section of his report (p. 168-169). He had observed red sandstones conformably overlying Coal Measures (Pennsylvanian) strata (mainly limestones) in the Dona Ana and Caballo Mountains areas. Because of lithological differences he decided not to include these younger red strata within the Carboniferous, but instead correlated them with the "new red sandstone" of Great Britain, which had been assigned to the recently established (1841) Permian System, believing them to be older than the Triassic red beds that Marcou had observed on the 1853 Whipple expedition. In support of this assignment he noted that beds of gypsum and rock salt were associated with the sandstones in some places. Although he had no fossil evidence to support a Permian age, Antisell's reasoning was valid and his age assignment was correct. Red sandstone units in the Dona Ana and other ranges near the Rio Grande are tongues of the Abo Formation, of Early Permian age. However, Antisell miscorrelated these Permian sandstones with (to his eyes) similar sandstones in the igneous terranes of the Burro Mountains, Rio Mimbres, and Sierra de las Uvas areas. He correctly recognized that these sandstones were (p. 168) "…derived from the decomposition of the red, felspathic [sic] igneous rocks, which constitute the axis of the upheaved districts west of the Rio Grande…" He failed to recognize that these Cenozoic sandstones, which nowhere were in contact with Carboniferous limestones, were different from the red sandstones east of the river, which conformably overlay them. This is the main conceptual error in his report.

Antisell's party then crossed the Rio Mimbres, which he noted (p. 156) lies in "a depression or fault in the strata, which have been upraised immediately east of the river…" Near the Rio Mimbres "is spread out a great expanse of whitish and red sandstone, broken through by porphyritic amygdaloid [vesicular volcanic rock]". His position near the southern termination of the perennial reach of the Rio Mimbres puts him in the large area of Eocene-Oligocene lavas and pyroclastic ash-flow tuffs and flow breccias through which the Rio Mimbres has cut for a distance of more than 10 mi, just north of the Luna-Grant County line (see Elston, 1957, for a modern map of this area between the Mimbres River and the Cooks Range). The red and white sandstones of this area are a bedded, sandy, volcaniclastic member of the Sugarlump Formation (Elston, written commun., 2008).

Just west of the Rio Mimbres he stopped at the (p. 156) "remarkable warm spring known as "Agua Caliente", the present Faywood Hot Spring, visited four years earlier by Bartlett. Antisell described the spring as issuing from a mound of tufa 20 ft above valley level and 2.5 ft above the level of the water of the spring, "showing that the spring, by the deposit of carbonate of lime from its waters, has formed a basin wall for itself, and allowed its level to be raised above the surrounding valley." This basin was said to be 25 ft across, but Antisell did not mention the dimensions of the entire tufa mound, which is several hundred feet across (J. E. Mueller, written commun., 2008). Antisell measured the temperature of the spring water at 130^{o} and said it was "agreeable to the taste." More than a century later (1965 and 1974) Summers (1976, table 20) found the temperature to be 131^{o}. Bubbles of gas lacked a sulfurous odor and extinguished a flame, and the gas "was therefore carbonic acid." Antisell concluded (p. 157) that "there is nothing to justify the conclusion that there is at the present time any volcanic forces in action…" Instead, the carbonates deposited by the spring were probably due to the "…spring passing through the strata of carboniferous [sic] limestone…" below the surface, with the high temperature possibly due to the "depth from which the water has risen to the surface." This is likely to be true, as Elston (1957) mapped a band of Pennsylvanian rocks around a rhyolite dome about 1.5 mi to the northeast of the spring.

A short distance northeast of "Agua Caliente" the party encountered (p. 157) "…an upheaval of felspathic porphyry, which has carried up the sandstone strata on each side…", and an area nearby where "…immense blocks and loose masses of sandstone rock lie heaped together in the most grotesque forms;…seen from a distance…now they resemble trees, and now men; least of all could they be taken for what they really are, distintegrated sandstones. They are now known as the Giants of the Mimbres."

Antisell's description suggests that he was seeing the more extensive boulder/pinnacle field now called City of Rocks, 3 mi west of the isolated pinnacles overlooking the Rio Mimbres that Bartlett had first called the Giants of the Mimbres. The latter name apparently disappeared from usage quickly. William Bell, a member of a railroad surveying party, visited this area in 1867, and referred to a "city of rocks," without mentioning "Giants of the Mimbres." Bell (1869) applied the name "city of rocks" also to a lithographic figure of what appears to be Bartlett's "Giants of the Mimbres." The name City of Rocks also appears on an early (1879) Land Office Map of New Mexico, and has been a State Park since 1952.

The City of Rocks and Giants of the Mimbres "sandstones" are Oligocene ash-flow tuffs eroded along fractures. They were originally mapped by Elston (1957) as part of the Sugarlump Formation but are now regarded as erosional remnants of the Kneeling Nun Formation, the outflow sheet of the Emory cauldron (Elston, written commun., 2008). Antisell was well aware of the influence of erosion in creating these unusual structures (p. 157): "The wearing away of [these sandstones] show what a loose texture these rocks have; every heavy shower denudes them to some extent, and after some years they have no longer the same appearance or outline which they formerly showed." Mueller and Twidale (1988) comprehensively studied the geology, geomorphology, and origin of the City of Rocks and Giants of the Mimbres.

Leaving the "Giants of the Mimbres" area on August 10, 1855, Antisell's party traveled eastward the 10 mi to the "Picachos de los Mimbres," now known as the Cookes Range, through (p. 157) "rolling land, not broken through by any extensive outcrop of volcanic rock…" The Picachos de los Mimbres was accurately described as a prominent landmark, standing 2500 ft above the plain, about 10 mi long, and unconnected to any other range. Antisell (p. 157-158) stated that its axis, constituting the main mass of the range, was composed of "reddish granite and syenitic rock" (Fig. 4C), the latter containing slender crystals of actinolite. Dikes composed of feldspar porphyry, greenstone, and augite were observed cutting through the granitic core.

Antisell noted that the dikes appear mostly on the west side of the mountain and run nearly north-south. He especially remarked upon (p. 158) a dike of greenstone "…running northeast and southwest, about forty feet wide, accompanied by porphyritic feldspar [sic]. This dyke can be traced northwest into the mountain, up its sides, and almost to the summit; it is not vertical but appears to take the shape of the sandstone strata, which it covers up, and does not apparently cut across. Southward, this augite dyke can be traced to the Sierra Florida, into which it enters." This description, probably of one of the flows within the Rubio Peak Formation along the southeastern end of the Cookes Range, demonstrates the remarkable detail of Antisell's field observations.

Antisell's observations are essentially accurate, allowing for a considerable refinement in igneous rock terminology in the past century and a half. The core of the Cookes Range is a granodiorite porphyry stock, characterized locally by concentrations of hornblende (not actinolite) crystals, and cut by latite, diorite, and basalt dikes (e.g., Jicha, 1954). Antisell observed more beds of red and yellow sandstone and white "grit" dipping steeply to the east on the eastern flanks of the range (Fig. 4C), as the party traveled through a canyon (now called Rattlesnake Canyon) just south of Cooks Peak. Some of these strata probably are beds of the Lower Cretaceous Sarten Sandstone, and others may be bedded tuff and volcaniclastic units of Eocene age (the overlying Rubio Peak Formation), both of which crop out along the canyon and the southeastern flank of the Cookes Range (e.g., Elston, 1957; Geologic Map of New Mexico, 2003). Other "sandstone" beds, especially those at some distance from the range, may be younger beds within the Gila Group or within pre-Pleistocene pediment and alluvial deposits.

From Picacho de los Mimbres Antisell traveled southeastward to Cooke's Spring, the largest and most reliable source of water between the Rio Grande and Rio Mimbres along Cooke's wagon road, a route across southern New Mexico opened by a detachment from Kearny's army in 1846, and dangerous because of frequent Apache attacks. Fort Cummings, a short distance to the north, was built in 1863 to protect travelers. Cooke's Spring is located about 8 mi southeast of Cookes Peak, in close proximity to "a series of porphyritic and trachyte dykes" (p. 159). From the springs, the party moved eastward (Fig. 5A) across a valley lacking rock exposures, and skirted the southern edge of (p. 159) "a broken ascending country, very rocky, made up of reddish porphyry, amygdaloid protrusions, and basaltic overflows. Looking from the west, this region presents a long line of trappean [volcanic] hills, conical porphyry, and trachyte pyramids towards the north, raised from 600 to 1,000 feet above the plain…" These are the Goodsight Mountains and Sierra de las Uvas, entirely of igneous origin, and their route was just north of present Interstate 10.

Antisell noted that a large trachyte mass, Monument Hill (Fig. 5A), marks the eastern margin of this volcanic uplift; from there the plain sloped down to the Rio Bravo [Rio Grande] some 150 to 300 ft through mesas and bluffs cut by small canyons. West-dipping white, yellow, and red sandstone beds, which rapidly disintegrated into sand along the trail, were again reported; these are Pliocene to early Pleistocene units included in the upper Santa Fe Group, and possibly, nearer the river, beds of the older volcaniclastic Palm Park Formation. I have been unable to trace the name Monument Hill forward to determine its present name, if it has one, but it likely was the site of one of the boundary markers established by the Boundary Survey under Bartlett a few years earlier (J. E. Mueller, written commun., 2008). Judging from its location and other information given by Antisell it may be one of two isolated buttes composed of Eocene-Oligocene pyroclastic deposits located at the southern end of the Sleeping Lady Hills. One of these is named Reichey Butte and the other appears to be unnamed. Alternatively, as suggested by Mueller, it may be a large hill at the northern end of the Sleeping Lady Hills, just south of Rough and Ready Pass.

Approaching the Rio Grande, Antisell noted just to the north (p. 159) "…a conical hill about 800 feet high, opposite the town of Dona Ana, called the Picacho. This is an upheave of compact quartz and trachyte porphyry, which is connected to the hills to the north and on the opposite side of the river." The name Picacho Peak is still applied to this dome of flow-banded rhyolite, about 35 million years old, at the south end of the Robledo Mountains.

Antisell, in summarizing the structure of the country north of his route (Goodsight Mountains/Sierra de las Uvas) noted (p. 159-160) that the "basaltic overflow, which upraises the belt of country between Cook's spring and the river so many hundred feet above the level of the Mimbres and Rio Bravo, is about 12 or 15 miles wide [actually it is more like 25 mi wide]. In its upheaval it has elevated the sedimentary beds in opposite directions, so as to form a synclinal axis, running north and south, the strata dipping east and west toward the middle of the disturbed region [Fig. 5A]." This was a perceptive observation. Modern geologists consider the thick, faulted, late Eocene-Oligocene volcanic/volcaniclastic pile of the Goodsight-Sierra de las Uvas uplift to have filled an elliptical, north-south trending volcano-tectonic depression (Goodsight-Cedar Hills depression), which has also been characterized as a synclinal trough (Seager., 1986, p. 42), and an east-tilted half-graben (Mack et al., 1998, p. 146). Antisell also suggested (p. 160) that the volcanic "disturbances" that raised the Goodsight/Sierra de las Uvas uplifts also dropped the Mesilla Valley and the bed of the Rio Bravo, which "…probably lie in the angle of a fault produced by such dislocation." This seems to be the first suggestion that the valley of the Rio Grande, at least locally, has dropped along a fault as an adjacent area immediately to the west was being "upheaved". Probably too much should not be read into this interesting conclusion, as it probably reflects Antisell's reluctance, noted by Merrill (1924), to accept that rivers operating slowly over long periods of time could cut deep canyons, and his tendency to explain such features catastrophically, such as by movement along a fault.

Antisell also introduced a little geohydrology into his discussion of the region west of the Rio Grande (p. 160): "This rupture of the sedimentary crust and the dislocation of the strata dividing the latter into so many minor areas, bounded by trappean dykes

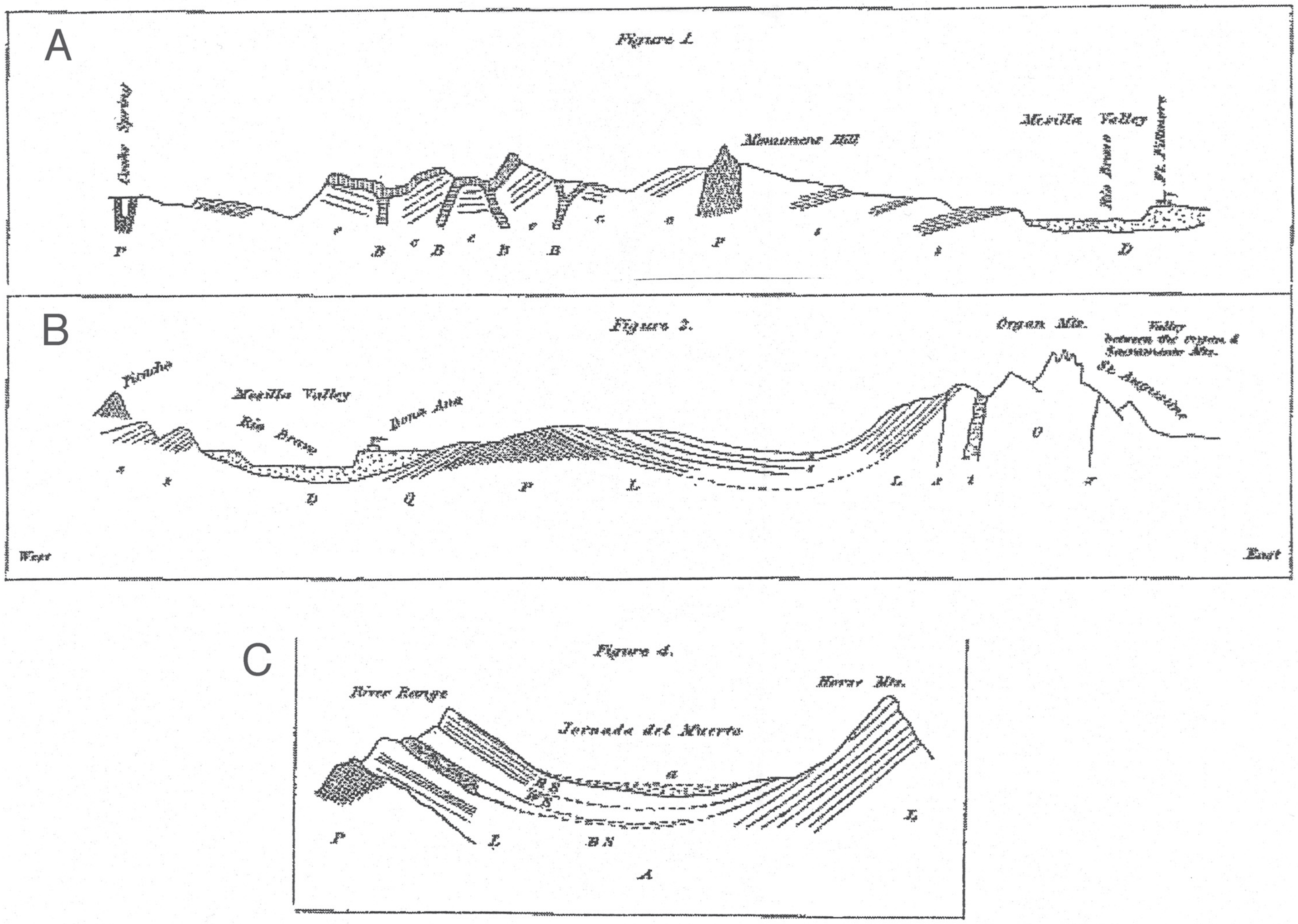


FIGURE 5. Thomas Antisell's geological cross sections. A, Cookes Spring to the Mesilla Valley (pl. 14, fig. 1); B, Picacho Peak to Organ Mountains (pl. 14, fig. 2); C, Jornada del Muerto ("River Range" = Caballo Mountains; "Horse Mountains" = part of San Andres Mountains). Abbreviations: B, dikes and overflows of basalt; e, contorted and dislocated Permian grits and sandstones; P, feldspathic porphyry and trachyte; D, Quaternary alluvium of Rio Grande Valley; L, Carboniferous limestone; Q, Cretaceous greenish-gray sand with silicified wood; t, trap dikes; x, veins of argentiferous galena; O, axis of Organ Mountains, granitic porphyry and leptinite; B.S., thin band of black shale; W.S. and R.S., overlying white and red sandstones; a, synclinal axis of Jornada del Muerto.

and overflows, renders the district unprofitable as a means for obtaining water from deep sources, inasmuch as each minor district is thus fed only by the fall of water in its own area; in other words, artesian well borings are not likely to be successful in their result" (see below for more on artesian wells). Later in his report, Antisell (p. 170-177) analyzed rain- and snowfall, amount and sources of surface water supply, including rivers, springs, and playa flats, and evaluated in more detail the potential for artesian wells. This section of his report is worth reading by anyone interested in the history of water studies in New Mexico. He recognized that sources of surface water in southern New Mexico are limited, and that water runs in most streams only a few weeks a year. He recommended damming some streams, such as the Rio Mimbres, and storing water in reservoirs and covered tanks to restrict evaporation.

Having reached the Mesilla Valley, Antisell (p. 160) devoted several paragraphs to the flow, sediments, and soils of the Rio Grande and its valley. He recognized sediment input from several sources, transportation of some sediments across flood plains during high water, and the continuous shifting of the river channel owing to variations in the force of the current and the volume of water it contained. He observed that the soil of the valley was mainly light sandy clay with some carbonate of lime, and was remarkably fertile. Brief mention was made of the geologically young alluvium extending from the base of the mountains to the east to the river valley, which was cut by arroyos. More information was provided by Parke (1857), who was viewing the terrain from the perspective of road and railroad construction. Parke noted (p. 22) two major terraces along the west side of the river, "…one averaging about 40 feet above the alluvial bottom of the

Rio Grande, west of Mesilla; the other, about one and a half miles further west, rises about two hundred and fifty feet above the former." The latter terrace is probably the La Mesa geomorphic surface, occupied by the ancestral Rio Grande about 0.780 Ma, before downcutting to its current level began.

Antisell also (p. 160) made reference to "…a layer of greenish sand with silicified wood, belonging to the cretaceous [sic] period," towards the north end of the Mesilla Valley. This is shown on his plate 14, fig. 2 (Fig. 5B), and discussed (p. 169) as being exposed in a creek bed on the upper terrace east of Dona Ana. As no Cretaceous strata are known in the Mesilla Valley, it is difficult to say what this bed actually is. The fragments of silicified stems, up to 6 in. wide and 2 ft long, were said to resemble "equisetum" (the modern scouring rush, a sphenophyte), but were unfortunately "lost in subsequent transportation." Silicified and opalized Pleistocene plant stems are known from several locations along the Rio Grande, and it is likely that Antisell's specimens were another occurrence of the same kind.

Antisell's responsibilities as geologist of the Parke expedition presumably ended when it reached Fort Fillmore (6 mi south of Las Cruces, established in 1851). However, he also conducted a geological reconnaissance of the Organ Mountains, and provided the first reasonably detailed account of the major features of the geology of this range. Dunham (1932) and Seager (1981), in their important studies of the Organ range, cited Antisell but provided no indication of his geological observations. Antisell's observations are discussed in detail here, because they are important in the history of New Mexico geological studies, and because they indicate that he gained a reasonably accurate view of Organ Mountains geology (Fig. 5B) in the few days that he examined it on horseback.

First, Antisell noted (p. 161) "…on the slopes of the Pass San Augustine quartzose felspathic [sic] rock is found, and from there to the summit syenite, having slender crystals of hornblende and reddish feldspar. This syenitic rock crosses the range and appears on the east side of the mountains, further south; on the east foot slope felspathic rock again occurs. But the great mass of the hills are made up of a felspar porphyry…, the quartz being white and sometimes crystalline, in a pale flesh-colored feldspar; the summits wear irregularly, and present the lofty broad pointed spires which have given them their name, from the fancied resemblance to a Spanish organ. From its structure it appears to be a very modern granitic rock."

Both the syenite and "felspar porphyry" he observed are phases of the 36 million year- old Organ batholith, which has a complex variety of lithologies (Seager, 1981). Most of the exposed part of the batholith, including the "needles" at the summit of the range are composed of locally porphyritic quartz syenite and quartz-alkali feldspar syenite, together with gradational lithologies such as quartz monzonite, rhyolite and monzonite porphyries, and true granites. The batholith represents magma that remained in the magma chamber after the slightly earlier eruption of the Organ caldera.

Antisell also reported that a "… large mass of augitic trap lies on the west side of this porphyritic feldspar, and appears to have come up through it. This dyke lies about three miles north of the Soldado [Soledad] canon; thence, southwards, flesh-colored porphyry is the chief axial rock." This rock may be the Orejon andesite, masses of which are prominent around Organ Peak, in contact with the batholithic rocks, north of Soledad Canyon (Seager, 1981). Conspicuous greenish epidote alteration characterizes these rocks, which may have been identified as augite by Antisell.

Antisell went on to note that east of Fort Fillmore "… the chain falls down into a range of much lesser height, the hills being made up rather of elevated sandstones and sedimentary rocks than of the igneous axis. Such are the Chinaman's cap and a few other peaks visible in travelling down the river." These are presently named the Bishop Cap Hills, which indeed are mostly composed of clastic and carbonate strata of a thick Pennsylvanian section above early and middle Paleozoic and Mississippian strata.

Antisell also mentioned "a dark blue limestone" believed to be of Carboniferous age near San Augustin Pass; "…it flanks the axis for 600 feet of elevation, with a dip of 30^{o} to the west". Probably he was referring to the extensively exposed Pennsylvanian and Early Permian limestones just north of the pass on the west side of the uplift, which are easily observed and accord with the dip and elevation figures he gave. He also mentioned "…a large vein of argentiferous galena, which is worked by Mr. Stevenson…" The Bennett-Stevenson mine still exists; it is about 2 mi south of San Augustin Pass near the western base of the mountains, in close proximity to a small exposure of the Pennsylvanian Lead Camp Limestone, although the ore is hosted by earlier Paleozoic rocks. Antisell also reported, east of Las Cruces "…a low rounded hill, standing isolated on the plain, about 500 feet high; it is of carboniferous [sic] limestone." This is an obvious reference to Tortugas Mountain, which is composed of Lower Permian Hueco Group limestones. As Permian rocks were not known in North America at the time Antisell was in the Organ Mountains, identifying these limestones as Carboniferous was reasonable and accurate.

Less easily interpreted is Antisell's observation that on the east side of the Organ Mountains are gypsiferous sandstones resting conformably on Carboniferous limestone, with evidence of gypsum quarries worked by Spanish settlers. He ventured the opinion that these were Upper Triassic strata, but the only gypsum-bearing formations in the region are of Late Pennsylvanian (Panther Seep Formation) and Early Permian (Yeso and San Andres Formations) age. The main problem, though, is that there are no exposures of strata of this age anywhere along the eastern side of the Organ Mountains (Seager, 1981). Because the name Organ Mountains was also applied to the San Andres Mountains at this time, it may be that Antisell observed gypsum beds north of San Augustin Pass, where the Panther Seep does crop out along the eastern side of the uplift.

Antisell (p. 162) also briefly discussed the Jornada del Muerto, recognizing it correctly as a syncline of sedimentary strata. His discussion is somewhat confusing; for example his statement that the "…hills north of Dona Ana [presumably the Dona Ana Mountains] …form the eastern boundary of the Jornada…close to the Rio Bravo…" is inexplicable, given that ranges along the Rio Grande are along the west side of the Jornada. The two uplifts shown on his cross section (pl. 14, fig. 4; Fig. 5C) across the Jornada ("River Range" on the west; "Horse Mtn." on the east) are not mentioned in the text. The former appears to be the Dona Ana Mountains, and the latter possibly part of the San Andres range along the east side of the Jornada (recall that on the Parke-Kern 1851 map most of the San Andres range was labeled Horse Mountains; also, there is no indication that Antisell journeyed northward to the range presently called the Caballo Mountains). If my supposition is true, Antisell's figure makes sense – a thick sequence of limestones along the western slope of the San Andres range, dipping beneath the surface of the Jornada, and emerging again close to the river in the Dona Ana Mountains. The Dona Anas not only display the same limestone (Lower Permian Hueco Group) on its northern end, but also overlying thin black shale beds and a sequence of red sandstones of the Abo tongue (e.g., Seager et al., 1976), as indicated on Antisell's diagram of the "River Range".

In a later section of his report (p. 167-168), Antisell summarized the age relationships of the rocks of the Mesilla Valley area. Following deposition of the Carboniferous limestones he observed in several areas, and the Permian red beds overlying them east of the river, he believed there were three distinct periods of "disturbances". The earliest was "the upheaval of the granites of the Organ mountains", which he thought occurred sometime between the Permian or Triassic and the Cretaceous. The second event was the emplacement of porphyries and trachytes of the Dona Ana Mountains and Picacho and Monument Peaks. Most recent was "…the trappean and basaltic lavas" west of the river (Goodsight-Sierra de las Uvas Mountains), which elevated the region and occurred between the Cretaceous and deposition of what he called "…the tertiary [sic] conglomerates and sandstones, which contain many pieces of these volcanic rocks." We now know that all of these stages are Cenozoic, and that there is little difference in the late Eocene to Oligocene ages of his first two stages. Nevertheless, this was a creditable attempt to work out the regional sequence of events based on the physical relationships of the rock units he observed during his necessarily brief travels through the area.

Antisell included a hand-colored geologic map of the areas he surveyed, from central Arizona to the Organ Mountains (Fig. 6), which also showed his route. This is one of the earliest geologic maps published of any part of New Mexico. Most of the uplifts he crossed (Peloncillo and Burro Mountains, unnamed Goodsight Mountains/Sierra de las Uvas) he showed as parallel ridges of "feldspathic rock and porphyry" surrounding "trap and basalt". The "Sierra Mimbres" (Cookes Range) is cored by "granite and primary rock", as is the southern part of his Organ Mountains and the (unnamed) Dona Ana range to the northwest. Permian strata were shown on the surface between the uplifts across wide areas between the Peloncillos and the Rio Grande, covered by "alluvium" along the Rio Mimbres and between the Cookes Range and the Goodsight/Sierra de las Uvas uplift. The long "dyke" of "trap and basalt" he discussed can be seen extending far to the southeast from the Cookes Range (labeled Sierra Mimbres on the map), and terminating in twin ridges of "granite and primary rock". Because Antisell had noted that this "dyke" connects the Cookes Range to the Florida Mountains, and because there are no other geologically reasonable uplifts in the area, we must conclude that these ridges were meant to represent the Florida Mountains. However, they are shown on his map many miles too far south and east of the actual location of the Floridas.

East of the Rio Grande, Antisell's map shows a band of "Lower Carboniferous" rocks along the west side of the his Organ Mountains, comprising the entire uplift to the north (northern Organ Mountains on his map; southern San Andres range of modern terminology), and along the west face of the Dona Ana Mountains. Two long, north-south bands of Cretaceous rocks are shown, one extending from north of El Paso along the west side of the Organ Mountains, and another west of the Dona Ana range. All of the so-called Permian exposures west of the Rio Grande, and all of the Cretaceous east of the river (except for a small area north of El Paso and the Love Ranch area at the southwestern edge of the San Andres range), are based on misinterpretations; rocks of those ages do not exist in those areas. A Lower Carboniferous age for the strata east of the Rio Grande is also incorrect, and possibly was based on Marcou's view (from the 1853 Whipple survey) that all of the Pennsylvanian rocks he saw farther north were of Early rather than Late Carboniferous age. Antisell did not use "Lower Carboniferous" in his text, but rather simply referred to these strata as Carboniferous.

In summary, although it is virtually unknown to modern geologists, Antisell's report is the first detailed description and interpretation of the geology of southwestern and south-central New Mexico. Given the constraints under which he worked – only a few weeks in the field to examine, on horseback, the geology across an approximately 250 km-wide transect – he recorded a wealth of detailed observations on rock types, relationships, and structures, prepared geologic cross sections and a geologic map to integrate his observations over large areas, and proposed explanations of the geologic history and structural evolution of the regions he examined. Many of his conclusions have been supported by later studies, having held up, albeit with expansion and refinement, for a century and a half. Antisell's report was an important contribution to early knowledge of the geology of New Mexico..

Pope's reconnaissance

Captain John Pope surveyed the area along the 32nd parallel eastward from the Rio Grande. His party left Dona Ana on February 12, 1854, traveled east through San Augustin Pass and thence southeast to the Hueco, Cornudas, and Guadalupe Mountains, and across Texas. Pope did not have a geologist attached to his party, and he collected few specimens and presented no new geological observations in his report (Pope, 1855). Two geological reports were written for this part of the 32nd parallel survey, by Marcou (1855) and Blake (1856), but both suffered from the fact that neither geologist had actually been to southern New Mexico to see the features he was attempting to characterize (see Kues, 2006, for extended discussion of these reports). Because Pope's party quickly passed out of south-central New Mexico, little of the geological results are relevant to the area considered in this paper.

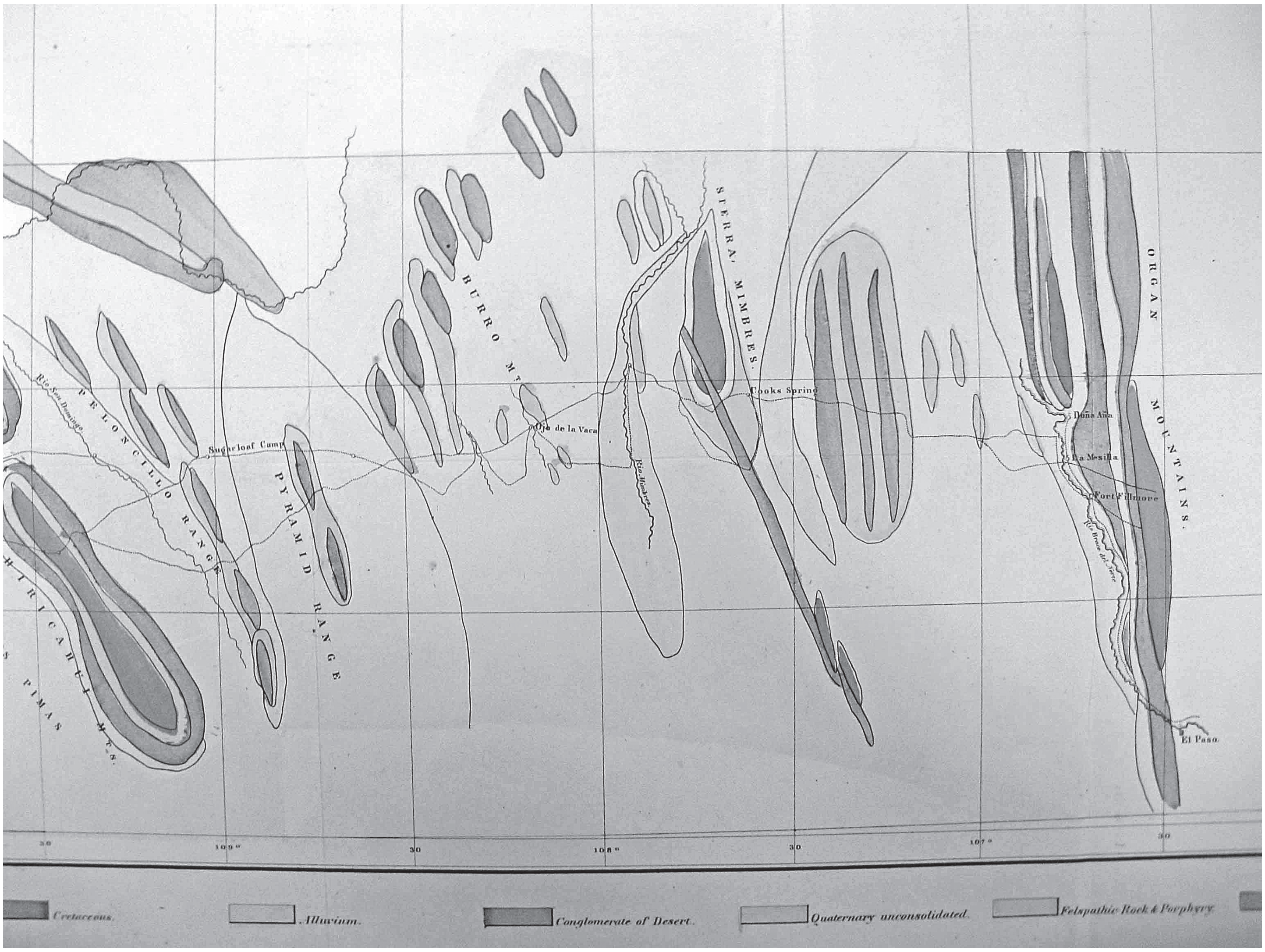


FIGURE 6. East part of Antisell's (1856) geologic map, entitled "Geological plan & section, Rio Grande to the Pimas villages", from the Chiricahua Mountains (southeastern Arizona) in the extreme southwest, across southern New Mexico to the Organ Mountains on the east. See Plate 7 on page 67 for a color reproduction of this map. Rock types referenced in legend (only part of which is shown) are Granite and primary rock (red); Devonian Sandstone (pink); Lower Carboniferous (deep blue); Permian (pale pink); Cretaceous (green); Alluvium (yellow); Conglomerate of desert (gray blue); Quaternary unconsolidated (light gray blue); Feldspathic rock and porphyry (light pink); and Trap and basalt (blue).

Blake (1856) had little to say about the Organ Mountains, noting only that it is granitic, with Carboniferous limestone. His rudimentary geologic map shows four mountain ranges near the Rio Grande: 1) Organ Mountains, extending north from El Paso and including the Franklin, Organ, and San Andres ranges of present usage; 2) Dona Ana Mountains, shown as a narrow elongate uplift extending north from Dona Ana town; 3) a small unnamed range west of the river and south of Dona Ana, presumably the Robledo Mountains; and 4) a narrow range extending north from Fort Thorn (north of present Hatch), roughly in the location of the Caballo Mountains. The geology of these ranges is portrayed simply – granitic/metamorphic cores, with Carboniferous limestone along the west (Organ Mountains), east (Dona Ana Mountains), or both (Robledo Mountains) sides. The Caballo Mountains are shown entirely as granitic/metamorphic. All of the areas between these ranges east of the Rio Grande are portrayed as Cretaceous, a conjectural and erroneous extrapolation based on Cretaceous fossils found in west Texas and near El Paso by the Boundary Survey. This map, severely deficient in accurately portraying the geography, much less the geology of the area, contributed nothing to an increased understanding of the geology of south-central New Mexico.

ARTESIAN WELLS AND GEORGE G. SHUMARD

Introduction

John Pope was enthusiastic about the possibility of large amounts of ground water below arid southeastern New Mexico, that would flow easily to the surface when drilled. Following his 32nd parallel survey he was sent back to west Texas and New Mexico to "pursue experiments in sinking artesian wells on the

Llano Estacado and Jornada del Muerto" (Goetzmann, 1959, p. 365), which might provide water for a potential railroad and for eventual settlement. Pope was assigned geologist George G. Shumard to supervise the drilling operations and study the geology of the region. Camp was initially established in May, 1855, near the Pecos River, about 40 mi east of the Guadalupe Mountains, close to the New Mexico-Texas border. Shumard had time to examine the local geology and later, in September, the geology of the Guadalupe Mountains after Pope gave up on further drilling after a single unsuccessful well (Shumard, 1858; see also Goetzmann, 1959; Kues, 2006). The party traveled to El Paso, arriving on October 5, and in November Pope, against Shumard's advice, began drilling a second well about 10 mi from Fort Fillmore, west of the Rio Grande. By early February, 1856, the well was only about 300 ft deep, with no sign of water, and the effort was abandoned. (Goetzmann, 1959). Meanwhile Shumard, from mid-October, 1855, to February, 1856, explored widely through south-central New Mexico, carefully examining the geology of the region. He published a short paper (Shumard, 1859) on the geology of the Jornada del Muerto area; a more complete report was published (Shumard, 1886) long after his death. The artesian well experiment was a dismal failure, and finally ended in 1858.

George Getz Shumard (1823-1867) was trained in medicine but found a greater interest in geology, and participated as surgeon and geologist in two of Marcy's expeditions through Texas and Oklahoma. Following his service with Pope's artesian well expedition in 1855-1856 he was appointed by his brother, B. F. Shumard, as assistant geologist with the first Texas Geological Survey, serving in that capacity from 1858 to 1861. In 1861 he moved to Cincinnati, Ohio, and served as Ohio State Surgeon General until his death (R. Shumard, 2001).

Shumard surveyed four areas in detail during the year he spent working with Pope on artesian wells. At El Paso, he examined the geology of the "El Paso" (Franklin) Mountains, and northward as the party moved to Fort Fillmore. A short time later, in mid-October, he explored a large area west of the Rio Grande from Las Cruces in connection with a search for a suitable location for drilling the second artesian well mentioned above. His third survey, in December, took him through the Jornada del Muerto and neighboring mountain ranges. And finally, he examined the Organ Mountains as Pope's party was heading back to west Texas in March, 1856.

El Paso to Las Cruces area

Shumard noted that the southern part of the El Paso Mountains consists of much granite, which he described as hard, light gray to deep vermilion in color, and potentially an excellent source of building material. Smaller areas of what he described as deep red, quartzose and feldspathic porphyry were said to mainly be confined to the summit of the mountains. Shumard did not venture an age for these igneous rocks, but seems to have viewed them as "upheaving" and metamorphosing the limestones along the western side of the range. These are of Precambrian age; the massive granites are widely exposed along the Franklin Mountains and grade into porphyritic textures locally (Harbour, 1972). The crest, especially to the south, is a Precambrian red porphyritic rhyolite, with feldspar and locally abundant quartz phenocrysts, as Shumard accurately reported.

Along the western side of the Franklins Shumard (1886, p. 103) "was much interested in finding here, near the base of the exposure, well marked strata of the Inferior Silurian System [much later to be named Ordovician], corresponding to the Blue Limestone of Cincinnati…" and he reported several characteristic brachiopod and coral taxa from the thick sequence now known as the El Paso and Montoya Formations. He also correctly noted (p. 104) that the "Lower Silurian" limestones so prominent at the south end of the Franklins disappear to the north and are replaced by Carboniferous strata, although he grossly underestimated their thickness at 300 ft (the Pennsylvanian sequence of the northern Franklins exceeds 2500 ft; Harbour, 1972).

Continuing north along the east side of the Rio Grande, Shumard reported, about 30 mi north of El Paso, that (p. 104) "… the mountains change in appearance and structure…and consist chiefly of highly inclined strata of dark blue to gray Carboniferous limestone, dipping west…" and he estimated the thickness of these strata at 3000 ft. "In a couple of miles", he continued, "the limestone disappears, and is replaced by eruptive rocks…". Shumard was passing the Bishop Cap Hills, a small isolated uplift just south of the southwestern corner of the Organ Mountains, which along their western side are composed mainly of Pennsylvanian strata, dipping westward at about 25^{o}. The total thickness of Carboniferous strata in the Bishop Cap Hills is about 1300 ft (Seager, 1981). About a mile to the north, the southwestern edge of the Organ Mountains, with its thick sequence of gray to reddish-brown, late Eocene ash-flow tuffs, would have presented an abrupt and visible contrast with the Carboniferous limestones, even from a distance of several miles as Shumard rode by. Continuing north on the road from Fort Fillmore to Dona Ana, about 3 mi east of Las Cruces, he again noted Carboniferous limestone, …exposed to a thickness of about six hundred feet," and containing prolific crinoid and other fossils (Tortugas Mountain, with its Lower Permian Hueco Group limestones).

Rio Grande to the Cookes Range and Florida Mountains

On October 15 Shumard, accompanied by a topographer and a small escort of mounted soldiers, started westward from their camp near Fort Fillmore, forded the Rio Grande, and began a geological reconnaissance of the area between the Rio Grande and Rio Mimbres valleys. This was only two months after Thomas Antisell had passed through the same area as he completed his geological observations for the 32nd parallel survey, but I have found no evidence that he and Shumard communicated with each other.

Shumard's party moved across the Rio Grande flood plain, then ascended the 200 to 400 ft-high bluffs onto the older Quaternary alluvium of the table lands west of the river, and passed Picacho Peak. Shumard described it as (p. 106) "…a conical peak rising abruptly to the height of [850 ft]. It forms the most elevated part of a broad dyke that extends…from the Dona Ana

Mountains…", and stated that this dike was 5 or 6 miles wide, but mostly buried or cut through by the Rio Grande. The Picacho, he noted "…is composed principally of dark red and slate colored porphyry, greenstone, and claystone…", the porphyry being soft and easily eroded. Modern interpretation of Picacho Mountain regards it as the root of a flow-banded rhyolite dome rather than a dike, but similar to other such domes and some dikes on the south end of the Dona Ana Mountains (Seager et al., 1987; Mack et al., 1998), and in both cases associated with eruption of the 36 Ma Organ caldera. Shumard was perceptive in recognizing a genetic relationship between the rocks of Picacho Mountain and others 15 mi away in the Dona Ana Mountains.

Shumard also examined the south end of the Robledo Mountains, immediately to the north of Picacho Mountain, describing it (p. 106) as "…a bold, rugged escarpment, about [1000 ft] in height, and…consists of hard gray and blue crystalline limestone of the Carboniferous System," as indicated by several species of brachiopods and gastropods he collected. These limestones, which compose most of the Robledo Mountains, are in the Lower Permian Hueco Group, but their fossils would have appeared as Carboniferous to paleontologists of that time, just before the announcement of the first Permian fossils in North America being discovered in Nebraska.

Shumard's party proceeded westward into what he called the "Valley of the Boundary Station", about 9 mi from Picacho Mountain. This put him approximately in the area of the Sleeping Lady or Rough and Ready Hills, but his exact route cannot be determined from the information in his report. Chains of ridges and hills several hundred feet high were reported, and these and the valley floor were said to be (p. 107) "…composed of eruptive rocks, which are traversed by nearly parallel dykes of hard red and purple porphyry, basalt, and vesicular amygdaloid. One of these dykes rises abruptly above the general surface as high as [600 ft], forming what is denominated the Boundary Station." This may be the same feature Antisell referred to as "Monument Hill", probably the site of an early marker placed by Bartlett's boundary survey in 1851. As noted above the terrain of this area is Eocene-Oligocene tuffs and pyroclastic units.

Continuing westward, close to Antisell's route but in reverse, Shumard crossed an elevated plateau about 20 mi wide (p. 107) "…composed principally of highly metamorphosed sedimentary strata, the continuity of which is frequently interrupted by dykes from a hundred yards to a mile wide…" – the lower southern part of the Sierra de las Uvas. The varied tuffaceous and volcaniclastic units, clearly showing indications of having been affected by heat, probably prompted Shumards's use of the term metamorphosed. The western side of the plateau, he continued, "…terminates abruptly in a long line of bold and precipitous escarpments in places upwards of [500 ft] high. These exhibit near their bases rude projecting masses of dark red and purple porphyry, and other varieties of eruptive rocks." We can visualize Shumard on the western edge of the Goodsight Mountains; his estimate of their height above the plains to the west is accurate, and they are formed primarily of lavas and tuffs of the Bell Top Formation.

Continuing westward for another 13.5 mi brought the party to the Picacho de las Mimbres (Cookes Range), which Shumard described as consisting of (p. 108) "…a very compact purple porphyritic granite, containing a large proportion of quartz and a deficiency of mica. On either side occur dykes of greenstone, red and dark porphyry, and amygdaloid", a characterization of the central granodiorite stock that was similar to Antisell's.

Shumard also described another feature at some length: "From near the eastern base of the mountains, and several miles north of the southern extremity, a broad dyke rises to a height of six or eight hundred feet, bearing south 12 degrees west. It extends a distance of twenty-five miles, and intersects the Sierra Florida near its southern extremity. This dyke consists of compact red porphyry, greenstone, quartz, and amygdaloid. The extremities only are seen projecting above the surface, its central portion having apparently been removed by erosion." It will now have become apparent to readers that Antisell and Shumard used the term "dyke" in a much broader sense than modern geologists, essentially for any linear, elevated structure, like a ridge, composed of igneous rocks. Shumard's description echoes that of Antisell's description of a large augite dike traceable into the Florida Mountains, but is much larger in scale, a major topographic feature. However, exactly what Shumard was referring to is difficult to discern, as no specific indication of any structure fitting his description appears in later works on the geology of the ranges, such as Darton's (1916) detailed study of the geology of Luna County. One can only surmise that Shumard was referring to the entire southeastern projection of the Cookes Range, which is composed of a variety of Eocene volcanic lithologies, and connecting it in his mind southward across 8 mi of desert flats to the Little Florida Mountains. However, the trend of both of these uplifts is southeast, not southwest.

This also raises the question of what, if any reliance Shumard placed on Antisell's report. Antisell's report was published in 1856, while Shumard was still in the field, so we must presume that his observations of the area between the Rio Grande and Rio Mimbres were made independently. However, it is almost certain that he would have had Antisell's report available as he was writing up his own observations, probably in 1857 (recall that some of the results of Shumard's reconnaissance were published in 1858 and 1859), although no mention of Antisell's work appears in Shumard's reports. Considerable similarity exists between the geological descriptions of Antisell and Shumard for the areas where their routes approximately coincided. This may simply be a consequence of the fact that they were observing the same geological features and describing them within the prevailing geological paradigms and terminology of the mid-19th century. One can't help wondering, though, whether Shumard may have combined or adapted some of Antisell's observations with his own field notes in writing his report.

Shumard's party rode south from the Cookes Range and on October 19 entered the Sierra Florida. Shumard provided the first description of the geology of this range (p. 109):

"[The Sierra Florida is] a short detached range which rises abruptly from the gently undulating and ascending plain, and like the Mimbres range, presents a number of rugged peaks. The highest of these attain an elevation above the base of near two thousand feet. The direction of the main axis or line of eruption is north 55 degrees west. The rocks are compact trachyte porphyry and cellular quartz, both of which appear to be yielding rapidly to the weather, and present externally a dirty ferruginous brown color. Black iron sand occurs in great abundance in the neighborhood, and among the loose detritus near the base of the mountains some fine agates and carnelians were collected." The last statement strongly indicates that he was on the western slopes of the Little Florida Mountains, where, in Rockhound State Park, similar specimens may be collected today.

He ascended to the crest of the Sierra Florida and described the view: "From the summit…a good view may be had of the valley of the Mimbres, which stretches many miles to the west, and is surrounded on all sides by rugged mountain chains, whose sharp and jagged peaks seem in the distance to rise one above the other in almost endless succession, while through the center of the valley long lines of low somber looking hills and ridges indicate the existence of numerous dykes. In fact the whole of the valley appears to have been the theater of intense igneous action, and no evidence of the existence of sedimentary strata are visible upon the surface." Shumard apparently did not survey far enough to the south in the Floridas to encounter the widespread exposures of Paleozoic strata that comprise much of the central and southern part of the range (e.g., Clemons, 1998).

From the Sierra Florida, Shumard's party turned east, towards the Rio Grande, and traveled along a gentle slope across (p. 109) "…thick deposits of coarse silicious [sic] and feldspathic sand, with fragments of eruptive rocks disseminated through it." Their route was approximately that of present Interstate 10. To the south he viewed "…a range of detached hills, which extend from the valley of the Rio Grande to within a short distance of the Sierra Florida. These hills appear to be from two to six hundred feet high, and consist of igneous rocks of a dark and very rough appearance." These are the West Potrillo Mountains, a Quaternary volcanic field of numerous basalt flows and more than 130 cones that covers an area of about 400 mi^2 from I-10 to the Mexican border. The age of eruptions ranges from about 262 to 916 ka (Hoffer, 2001)

Approaching the Rio Grande, a few miles south of Mesilla, the party turned south, and after 5 mi (p. 110) "…we came to a heavy deposit of black basaltic lava, projecting abruptly above the surface to the height of a hundred and twenty feet, with an average width of about a mile. This is composed near its base of heavy compact basalt with a vitreous luster, containing small green particles of chrysolite; but as we approached the summit of the lava stream it gradually assumes the character of a vesicular basalt, and finally that of highly vitreous scoria. This stream is about two miles long and appears to have proceeded northeast from an abrupt truncated cone known as the *Picacho de las Mesa*. Its surface is for the most part flat, totally devoid of vegetation, and seems to have undergone but little or no alteration since the period of its eruption. On nearly every side it terminates abruptly."

"The "*Picacho*" is also composed of lava, and projects above the lava stream at its base to the height of about two hundred feet. At the summit is a shallow basin-shaped depression [where] the scoria is light, friable, and resembles highly burnt cinder."

This cinder cone is most likely now called Santo Tomas, the most northerly in a line of four small basalt fields that overlook the west side of the Rio Grande valley, midway between Las Cruces and the Texas border. Ten miles south, Shumard described "…a second cone, about six hundred feet high, from which a broad sheet of lava proceeds in an easterly course for the distance of about ten miles, where it terminates abruptly. This stream, as well as could be determined at a distance, has an average breadth of about two and a half miles, and does not differ in general appearance from that of the "*Picacho"*. From the character and general appearance of these cones and lava streams, I am disposed to ascribe their origin to a comparatively recent geological period." The greater extent and higher cone of this second field, and its distance from the "Picacho", suggest that it is Black Mountain, the southernmost in this line of volcanic cones. Shumard was correct in thinking these basalts were young; radiometric dates range from about 79 to 137 ka (Hoffer et al., 1998).

Jornada del Muerto and adjacent mountain ranges

On December 11, 1855, Shumard again departed Pope's artesian well operations, this time to explore northward into the Jornada del Muerto and its bounding mountain ranges, accompanied by a topographer, a guide, six laborers, and a mounted escort of nine soldiers. The record of his daily observations and geological conclusions was published as a separate paper (Shumard, 1859). Two main conclusions were discussed at the beginning of this paper. Concerning the Jornada del Muerto, Shumard (1859, p. 342) stated: "Geologically speaking…, the Jornada del Muerto may be considered as nothing more than a simple trough, composed mainly of limestone, sandstone, and shale, and covered to the depth of five or six hundred feet with loose detritus. It is the upheaved edges of these strata that constitute the mountains on either side, their synclinal axes being everywhere strongly marked by the central depression of the plain."

Further, Shumard noted that the Jornada was free of "igneous protrusions" and believed that it would therefore be a good potential source of artesian waters. He perceptively noted that the depth to which wells would need to be drilled to reach water, would not only have to penetrate the loose sediments near the surface, but also a thick sequence of Cretaceous sandstones, which he knew rested upon Carboniferous strata from his observations of surface exposures along the west side of the Jornada, near the Fra Cristobal and Caballo Mountains. The entire depth to water (presumably in the Carboniferous limestones) he estimated at 1000 to 1500 ft. In reality the depth to Pennsylvanian rocks in the center of the Jornada del Muerto is considerably greater than he thought, but his reasoning based on limited observations was valid.

A second conclusion regarded the mountains that border the Jornada to the east. This range, he stated (p. 341-342) "…varies in width from five to fifteen miles, and forms a nearly continuous range extending north and south the entire length of the "Jornada"…Although these mountains have the same direction and are apparently continuous with the Organ range, with which they have been hitherto classified, their general conformation and structure are totally distinct. In no respect is there the slightest resemblance between them, one being composed almost entirely of sedimentary strata, and the other mainly of eruptive rocks." Despite this clear distinction between the San Andres and Organ Mountains he continued to call the northern range the Organ Mountains. Exactly when the name San Andres Mountains began to be used is unclear, and Julyan (1996) does not say. They are labeled "Sierra Solidad or San Andres" on Carleton's 1864 map of the territory. On the authoritative General Land Office maps of 1876 and 1879 the name San Andres is applied only to the northern part of the range, north of Hembrillo Pass, with the southern part plus the Organ Mountains referred to by the latter name. By the 1880s, San Andres (or San Andreas) was used for the entire range.

Much of Shumard's time on this Jornada expedition was spent in and around the San Andres Mountains, and he provided the first geological description of the range (summarized below). However, his explanation of the process responsible for the uplift of the range was in error (p. 342): "The cause of the upheaval of [the San Andres range] is rendered fully apparent by a chain of low igneous hills which have been traced extending along the eastern base for the distance of nearly 90 miles, and which towards the south appear to be continuous with the eruptive rocks of the Organ Mountains." Shumard failed to recognize that the igneous rocks along the eastern base of the San Andres range are Precambrian in age, and missed the overlying thick sequence of early and middle Paleozoic strata that would have demonstrated them to be "Primary", rather than the result of relatively recent igneous activity. The fault system on the east side of the San Andres Mountains, along which the range was uplifted, would not have been obvious during a brief reconnaissance, but identification of the basal igneous rocks as Precambrian might have led Shumard to think in terms of faulting rather than igneous activity as the cause of uplift.

Shumard's route from Dona Ana town was due north towards the Dona Ana Mountains. He noted, across the river, "Robledo Mountain", composed almost entirely of Upper Carboniferous [actually Lower Permian] stratified rocks, dipping 10º to 20º to the southwest, and rising to a height of nearly 1000 ft, with a steep eastern face but sloping more gently to the west and southwest. Striking the southern end of the Dona Ana Mountains, which he characterized (p. 343) as "…composed of a number of conoidal peaks, the highest of them about one thousand feet above the general level of the plain", Shumard entered a deep canyon, consisting of (p. 344) "…gray and purple porphyry, mica-schist, greenstone, compact quartz, and feldspar [sic], most of which appear to be undergoing rapid distintegration…". The following day the party progressed through (p. 344) "…deep and rugged canons, some of which presented nearly vertical sides, exhibiting here and there tortuous veins of greenstone and quartz. As we progressed, the rocks became harder and more granitic in their character until we arrived at the eastern base of the range, where coarse gray porphyritic granite was alone observed."

From this description, it is likely that Shumard traversed the canyon region just southwest of Dona Ana Peak and followed it around to its northeast slopes. He would have crossed exposures of the Eocene Palm Park Formation near the entrance to the canyon, which consists of a variety of volcaniclastic lithologies and some flow units, and northeast of the peak would have encountered extensive exposures of the intrusive gray monzonite porphyry mapped by Seager et al. (1976) as part of the Dona Ana caldera (considered part of the northern end of the Organ caldera by Chapin et al., 2004). His party then headed northeast across the Jornada del Muerto, thus missing the central and northern parts of the Dona Ana range and the thick Lower Permian sequence there.

Shumard crossed the Jornada in less than a day, and his direction of north 70º east brought him to the mouth of a deep gorge (called Bear Canyon today). Following the canyon to the eastern side of the mountains, he reported mostly (p. 344) "…dark gray and bluish sub-crystalline limestone of the upper division of the Carboniferous system [Lower Permian Hueco Group] and porphyritic granite. The limestone unit was estimated at 2000 ft thick (an accurate estimate, as the Hueco is about 2200 ft thick in this area; Bachman and Myers, 1969), and highly fossiliferous. As noted above, Shumard believed the granites, encountered only near the eastern side of the range, were the same as compose most of the mass of the Organ Mountains, rather than Precambrian.

Leaving Bear Canyon, the party traveled north along the west side of the range, encountering only more of the highly fossiliferous upper Carboniferous limestones, which here and in several other locations in the San Andres Mountains provided good collections that were ultimately turned over to his brother, B. F. Shumard, for identification. Shumard observed (p. 346) that, looking east, "…the edges of the upheaved strata are found overlapping each other in quick succession, presenting abruptly to the east, with a continuous slope to the west, which corresponds very closely with the general inclination of the strata, so that the mountains present the appearance of having been cleft through their centres."

During a pause in the party's travel, Shumard busied himself in exploring a rugged canyon through the mountains that terminated in gray porphyritic [Precambrian] granite (probably Ash Canyon), and the party eventually again moved northward, to a canyon identified as San Andres Canyon. "As this afforded an easy passage through the mountains, and it being desirable to ascertain as minutely as possible the character of the rocks along their eastern base, we here concluded to change our course and enter the canon" (p. 347). Shumard noted that the "…limestone is here of a much darker color and far more compact than any previously observed. When struck with a hammer it emits a sulphurous odor, but does not differ, paleontologically, from that seen [previously]. In a few places, hard yellowish and brownish quartzose sandstone…were found intercalated."

This lithological description suggests that Shumard was sampling the Late Pennsylvanian Panther Seep Formation, which stratigraphically underlies the Hueco Group along the western length of the range, but crops out higher on its slopes, dipping westward beneath the Hueco towards the base of the range. The Panther Seep features dark, organic-rich limestones as well as numerous clastic beds.

Nearing the eastern mouth of this canyon, Shumard began reporting (p. 347) "…thick beds of mica and hornblende schist, which continued to be largely exhibited until we arrived at the eastern extremity of the canon. Here the granite was again observed in the form of low conical hills, the highest of them not exceeding four or five hundred feet." Near the mouth of San Andres

Canyon, large exposures of dark Precambrian hornblende-plagioclase amphibolites and gneisses begin appearing among the prevailing coarse-grained granites along the eastern base of the San Andres range (Seager et al., 1987); these metamorphic rocks are largely absent south of the canyon. Looking to the east, Shumard observed the "…"Valley of the Salt Lakes," which is here about thirty miles broad, and is abruptly terminated on the east by the Sacramento Range, whose highest point, the Sierra Blanca, was seen towering far above the rest, its summit mantled with snow." The gypsum dune field of White Sands is visible from this point, and it is curious that Shumard failed to mention it.

The party now traveled north along the eastern side of the mountains, "…over beds of hornblende and mica-schist and porphyritic granite. The first two reposed upon the last, and were thickly marked with veins of quartz and greenstone." Arriving after a day's journey at a canyon called "Pina Blanco", the party ascended this canyon through thick Carboniferous limestones to the summit of the range. Pina Blanco Canyon is not shown on any recent maps or mentioned in any other sources I am aware of, but given the 15-mile breadth of the San Andres range here and its distance from San Andres Canyon, it is probably either Lost Man or Hembrillo Canyon. Shumard's party spent a day and a half laboriously traveling northwest, through richly fossiliferous Coal Measures limestones (the Pennsylvanian Lead Camp and Panther Seep Formations), "…mostly over rough peaks and through deep canons…" before coming into sight of the Jornada and descending to the western side of the mountains. This portion of the San Andres Mountains is cut by a maze of deep canyons, whose names – Lost Man, Dead Man, Hospital, Howinahell Canyons – give ample indication of the difficulties experienced in traversing them.

The party proceeded due north along the western base of the range, traveling (p. 349) "…over thick deposits, principally of coarse silicious sand and angular blocks of limestone and sandstone, often firmly cemented with calcareous matter. The surface of the country is hilly, and frequently divided by long narrow ravines, and presents a gentle slope to the west." The sandstone, Shumard noted, was light yellow to gray in color, attained a thickness of 300 ft and wherever seen was "…resting conformably upon the limestone and with the whole dipping west at an angle of about 30°." These sandstones are likely part of the Lower Permian Yeso Formation, which is exposed in a line of low hills along the western base of the central part of the San Andres range, and overlies the Hueco Group limestones.

Turning west across the Jornada del Muerto on December 17, Shumard looked back and observed (p. 349) that the mountains could "…be traced northward as far as the eye could reach. For the first twenty or twenty-five miles, they appeared not to differ in general composition or character from those already examined; the slope being uniformly to the west. Beyond this, they were seen for the first time sloping east, while the abrupt cliffs faced the west." Shumard was seeing in the far distance the northern end of the San Andres range, and beyond, the southern end of the Sierra Oscura, which indeed display a steep western slope. On the following day, they reached the Camino Real and passed Laguna del Muerto, one of the few watering places on the centuries-old main route through the Jornada, north of Engle and east of the gap (Cutter sag) between the Fra Cristobal and Caballo ranges. Their route passed over (p. 350) "…thick beds of volcanic rocks, consisting of dark colored scoriae, basalt, greenstone, and other eruptive rocks, most of these apparently undergoing rapid disintegration, and encrusted frequently with a chalky substance. The surface of the ground is thickly coated with coarse reddish sand, and fragments of porphyry, basalt, and other eruptive rocks." This is the Cutter Sag basalt field, an area of Pliocene basaltic lava flows, with small vents and cones, which covers several square miles at the south end of the Fra Cristobal Mountains.

Leaving most of the party in camp, Shumard turned northeast to examine the Fra Cristobal Mountains, some 10 mi distant, crossing the volcanic field noted above. His description of the geology of this area (p. 350-351), reveals a close attention to detail."…we came to thick beds of black scoriaceous lava, which continued to be largely exhibited until we reached the base of the "Fra Cristoval Mountain". This lava stream is about nine miles broad, from four to five hundred feet thick, and appears to have proceeded westward from several distinct points of eruption. To the east, it is everywhere abruptly terminated by a chain of low conical hills that stretch many miles to the north-east, and consist of scoriae and compact basalt; the former bearing marks of having been subjected to a much more intense heat than any hitherto observed, being light, friable, and resembling highly burnt cinders. From these hills the lava stream was observed gradually descending and branching, it being in a number of places cut through by the Rio Grande, which here winds a tortuous course over volcanic rocks, and affords, by its smooth shining surface and grassy borders, a pleasing contrast to the otherwise barren and gloomy character of the scenery."

Later, viewing this volcanic terrain from the summit of the Fra Cristobal Mountains, Shumard (p. 352) commented that it "…has been, and that too, at no very remote geological period, the theatre of intense igneous action. With the exception of the portion constituting the river valley, the surface is everywhere rough, black, and almost wholly devoid of vegetation. The lava appears to have undergone but little change since the period of its eruption." Shumard's observations were qualitatively quite accurate. This area is one of basalt-capped mesas, with the lavas being remnants of extensive flows originating from narrow, north-south trending fissures during the Pliocene (probably from 4.5 to 2.9 Ma), possibly related to faults. Somewhat later eruptions (about 2.1 Ma) from cinder cones to the east (noted by Shumard) covered much of the earlier fissure lavas (Lozinsky et al., 1986; Mack, 2004); these are the flows that Shumard crossed. Remnants of these Pliocene eruptions, including small cones, are also visible within Palomas Formation (Santa Fe Group) sediments along the west flank of the Fra Cristobals, and, as noted by Shumard, severely constricted the Rio Grande (and later, Elephant Butte reservoir) east of the Mitchell Point exit on I-25.

Shumard had little to say about the geology of the Fra Cristobal Mountains, beyond that they were principally composed of hard, blue and gray Carboniferous limestones. The following day, December 19, Shumard's party traveled south to the Horse Mountains [Caballo Mountains], and he noted the steep western face, composed of (p. 352) "…upheaved, and in places, highly folded strata of sandstone, shale, and limestone, dipping E., from 30º to 70º." At the north end of the range he noted an upper sandstone bearing Cretaceous fossils (as identified by his brother), underlain by "…a dark bituminous shale, which we regard as forming the superior part of the Coal Measures". The Cretaceous sandstone could be in one of several Upper Cretaceous units (most likely the Tres Hermanos or Gallup Formations) that bear marine fossils (Seager and Mack, 2003). The identity of the bituminous shale is uncertain, but is more likely Cretaceous in age, as both the Tres Hermanos and Crevasse Canyon Formations in the area include dark gray shales and even thin coal beds. The Permian strata underlying the Cretaceous units in the Caballo Mountains (which Shumard would have considered Carboniferous) consist of entirely different lithologies (Seager and Mack, 2003). Beneath the dark shale, Shumard reported thick-bedded, light gray limestones with Coal Measures (Pennsylvanian) fossils.

Shumard had this to say concerning the rocks below the Carboniferous limestones (p. 353): "Near the western base of the mountains, the limestone of the Coal Measures presents a highly metamorphosed appearance, and here also the cause of the upheaval of the mountains is fully apparent by a chain of low igneous hills, against which the limestone rests, and which are observed extending in a southerly direction for many miles. Wherever examined, they were found to be composed principally of compact reddish granite, mica-schist, and hornblende rocks." As was the case along the eastern side of the San Andres Mountains, Shumard failed to recognize that the igneous rocks forming the core of these mountains are Precambrian, not some relatively recent intrusion that uplifted the overlying Carboniferous strata. Because of this, the faulted nature of the Caballo uplift escaped him. The steep western slope of the Caballos displays a full complement of Cambrian through Mississippian strata, around 1300 ft thick, below the Coal Measures limestones, but apparently Shumard never closely inspected these units for age-diagnostic fossils and assumed the entire sedimentary sequence was Carboniferous. On the other hand, his observations of the igneous rocks were lithologically accurate; the Precambrian of the Caballos includes several plutons composed mainly of reddish granite, and also hornblende-rich amphibolites, gneisses, and schists (Seager and Mack, 2003).

For the next two days, Shumard's party moved along the east side of the Rio Grande, along the western base of the Caballo uplift, and his observations are cursory, as the party was nearly out of provisions and was hastening back to Dona Ana. He did notice, towards the south end of the uplift, that the "igneous hills" were increasing in height, the composition of the rocks was changing, and that dikes of greenstone, basalt, and porphyry were becoming common. He was now in the highly faulted region south of the main Caballo uplift, characterized by small faulted uplifts (e.g., Red Hills, Red House Mountain) and widespread exposures of Eocene-Oligocene ash-flow tuffs, volcaniclastic deposits, and some lavas.

On December 22, the party emerged onto the Jornada again, passing San Diego Mountain as it continued southward. Shumard (p. 355) briefly characterized this uplift, as follows: "[San Diego Mountain] rises in the form of a solitary peak to the height of nearly a thousand feet, and is evidently of much more recent origin than any of the other [igneous peaks] examined. Its axis runs pretty nearly north and south, and, as far as we were able to judge from a distance, is composed of granite. Near its western base we observed heavy beds of quartz, porphyry, and greenstone. Against the sides of this mountain, the quaternary [sic] deposits were seen strongly upheaved and highly metamorphosed, dipping both to the east and west, at an angle of about 70º and exhibiting shades of light yellow, red, purple, and black. The layers comprising them are for the most part firmly consolidated, and have a thickness of about five hundred feet." Modern studies (e.g., Seager et al., 1971) reveal that the core of San Diego Mountain is mainly red Precambrian granite (hardly the "much more recent" igneous rocks that Shumard claimed), which is bordered to the west along a major fault by steeply dipping facies of the Oligocene-Miocene Hayner Ranch Formation, a thick sequence of mainly tan and red conglomerates and finer-grained clastics.

Organ Mountains

Pope's expedition, with Shumard, returned to the Pecos country and the Llano Estacado in March, 1856, for more artesian well drilling, which continued there until September, when operations were shut down and the men headed east for the winter. Departing Dona Ana on March 8, the party skirted the southern end of the Dona Ana Mountains and entered San Augustin Pass, at the northern end of the Organ Mountains, along the route of present US 70/82. Shumard (1886, p. 111) described the rocks at the western end of the pass as "…compact red porphyry and light gray porphyritic granite, in which feldspar greatly predominates," and noted that the latter lithology also forms the main mass of the mountains to the south. The walls on either side of the pass were, in places, "…almost vertical cliffs from one to two thousand feet high." These rocks, observed by Antisell a few months earlier, are part of the Organ batholith, a complex of 35-36 Ma plutonic rocks. The outcrops observed by Shumard along the pass are the Sugarloaf Peak quartz monzonite porphyry, described by Seager (1981, p. 63-64) in terms similar to those of Shumard, "…a gray to pinkish-gray, coarse-grained rock of granitic appearance," with prominent crystals of feldspar. Shumard also noted highly fossiliferous, steeply dipping Carboniferous limestone near the western entrance to the pass, "…and where it is in immediate contact with the eruptive mass presents a highly metamorphosed appearance." Here, Shumard was correct in his interpretation of the Carboniferous limestones being distorted and altered by younger igneous acitivity; Seager (1981) noted that Paleozoic sedimentary rocks around the northern and western margins of the batholith have been variably altered by thermal metamorphism.

Continuing through San Augustin Pass, Shumard could see the Sacramento Mountains and Sierra Blanca in the distance to the east, and nearer, a range of "eruptive rocks" that are now called the Jarilla Mountains. The expedition then turned south along the east side of the Organs and paused at the Ojo de la Soledad, "a clear stream of running water one or two feet deep, which originates from springs that issue from the igneous rocks" (p. 113), shown on modern maps as Salado Arroyo, the eastern drainage of Soledad Canyon. Shumard observed a rugged topography of deep, tortuous canyons through coarse, feldspar-rich granites, part of the same Organ batholith (of later geologists) that he had first seen entering San Augustin Pass Continuing southward, he noted (p. 113) that "…the eruptive rocks decrease rapidly in elevation, and are finally succeeded by upheaved strata of hard crystalline limestone of the Carboniferous Period, which increases rapidly in thickness and soon constitutes almost the entire bulk of the mountains." He reported many species of Pennsylvanian fossils from these strata. This report is confusing at best, both because there are no Carboniferous strata exposed along the southeastern side of the Organ Mountains (only limited outcrops on the west side of Rattlesnake Ridge, which it is highly unlikely that he inspected), and because a little later in his report (p. 114) he stated that the route south of Ojo de la Soledad for 8 or 10 mi revealed only "eruptive" and metamorphic rocks. I suspect that the thick Carboniferous strata he mentioned here actually refer to Pennsylvanian strata observed in the Bishop Cap Hills as he was proceeding north along the Rio Grande several months previously (see p. 104).

Shumard's fossils

The fossils collected by George Shumard on the Pope artesian well expedition were given to his older brother, B. F. Shumard, who at this time was Assistant Geologist and Paleontologist with the Missouri Geological Survey. The elder Shumard first reported on fossils from the Guadalupe Mountains, which he identified as Permian in age, one of the earliest reports of Permian fossils from North America (B. F. Shumard, 1858, 1859; see also Kues, 2006). Less attention was given to the other collections, which were all believed to be of "Coal Measures" or Pennsylvanian in age. These included a few new species of gastropods from 4 mi west of Sierra Hueco, just south of the New Mexico-Texas state line (B. F. Shumard, 1859); it is uncertain if these actually came from Pennsylvanian strata or the more extensively exposed Lower Permian Hueco Group. Besides providing identifications of all the "Carboniferous" fossils George Shumard had collected in New Mexico, B. F. Shumard (1863) also described a new brachiopod as *Spirifer organensis*, from the Coal Measures of the Organ Mountains, not far from Fort Fillmore. As the Fort was about 6 mi south of Las Cruces, it is likely that George Shumard collected this species from the restricted exposures of Lead Camp Limestone that crop out intermittently along the west side of the Organ Mountains. This species has only been reported once since then, by Greger (1934), who redescribed and illustrated the type specimens, giving their locality as the Organ Mountains northeast of Mesquite, Dona Ana County.

B. F. Shumard transferred the bryozoans in his brother's collections to Hiram Prout, a St. Louis physician, who (1858) described seven new species of *Fenestella* and two new species assigned questionably to *Eschara*. All of these were reported to be from "Carboniferous Limestone" in the Organ Mountains. However, because George Shumard used the name Organ Mountains for the Organ plus San Andres ranges, the localities and strata from which these specimens came cannot be identified with any accuracy. With one exception (*F. norwoodiana*) none of these fenestrate species has subsequently been identified in the paleontological literature, and so should be regarded as "forgotten names", not to be used in modern studies.

Summary

George G. Shumard's explorations as part of Pope's artesian well expedition produced the first reasonably detailed surveys of the geology of many parts of southern New Mexico. His most noted accomplishment concerned the stratigraphy of the Guadalupe Mountains and neighboring areas, and the collection of fossils recognized by his brother as being of Permian age – the initial studies of the great Permian reef complex (Kues, 2006). However, his geological observations in south-central and southwestern New Mexico are also important, in that they provided the first information on the geology of numerous mountain ranges and the areas between them. To Shumard goes the credit for the first descriptions of the geology of the Little Florida, Robledo, Dona Ana, San Diego, Caballo, Fra Cristobal, San Andres, and West Potrillo Mountains, and the Cutter sag and Santo Tomas-Black Mountain basalt fields. His geological observations of the Cookes Range, and Sierra de las Uvas-Goodsight and Organ Mountains supplemented and amplified those of Antisell, made a few months earlier.

This information is typically limited to the most conspicuous geological structures and rocks of these ranges, but given the short periods of time he had for field studies, it could not be otherwise. Much of this information is accurate and perceptive, providing an initial framework for later, more detailed studies that in most cases would not come until the early 20th century, when the U. S. Geological Survey turned its attention to southern New Mexico. However, several deficiencies in his observations and interpretations prevented him from arriving at a more accurate picture of the geological history of the region; one that would have been of more fundamental importance than the view he did provide. He failed to recognize thick sequences of early and middle Paleozoic strata above granitic and metamorphic rocks in the San Andres and Caballo ranges, believing them to be of the Carboniferous age indicated by fossils higher in the section. He believed the igneous rocks at the cores of these mountain ranges to be relatively recent (Cenozoic) intrusions rather than of Precambrian age. And because he believed these igneous rocks to be geologically young, he attributed the uplift of these ranges to igneous activity, rather than considering that uplift along faults might be responsible.

FINAL REPORT OF THE BOUNDARY SURVEY, 1857

Introduction

The final American Commissioner of the Boundary Survey, Major W. H. Emory, was appointed on August 15, 1854, a few months after the Gadsden Purchase treaty was ratified by the U.S. Congress. Under Emory's direction, the surveying of the new U. S.-Mexico boundary, including the present boundary between

New Mexico and Chihuahua, was conducted expeditiously and harmoniously in coordination with his Mexican counterpart, Jose Salazar y Larregui. The final marking of the Gadsden line was completed on October 15, 1855, details of field work were wrapped up by December, and the final maps of the boundary were exchanged between the two commissions in June, 1856. To Emory fell the task of producing a comprehensive summation of the work and results of the Boundary Survey. This report was published in 1857 to 1859 in two volumes. The first volume included much of the technical information; a description by Emory of the country along the boundary and a few geological observations; and the geological and paleontological reports. The second volume, in two huge parts, contained the descriptions of the botanical and zoological specimens collected.

For the New Mexico portion of the boundary, the report included exquisitely rendered, detailed topographic maps of the terrain along the boundary (see Rebert, 2001, for examples) but little information on the geology of that region. This is perhaps not surprising, as the New Mexico part of the boundary was only a small fraction of its entire length, and the emphasis was on getting the boundary surveyed, not studying its geology in detail. The two geologists on the survey, C. C. Parry and Arthur Schott, did produce chapters dealing in fair detail with parts of the boundary, especially along the Rio Grande southeast of El Paso and from central Arizona through southern California, but wrote nothing about the geology of the New Mexico part of the boundary. Instead, it was Emory (1857) who, in his notes on the general features of the boundary region, included some discussion of the geology around El Paso. Emory's contribution also included much technical information (longitude and latitude determinations, astronomical, geodetic, meterological, and magnetic data), and 32 detailed topographic sketches (by artist John E. Weyss) that illustrated critical areas along the boundary (e.g., Fig. 7). All of the geological specimens collected were given to James Hall, who wrote a general geological summary (Hall, 1857), not only of the boundary, but of the entire western United States (see below). All of the fossils collected were turned over to paleontologist Timothy Conrad, who described them (Conrad, 1857) in another chapter of the Boundary Report.

Emory's observations around El Paso

Emory's (1857) summary account of the boundary region included what is probably the first stratigraphic section of Pleistocene deposits of the "tablelands" forming bluffs along the Rio Grande (near El Paso and westward into New Mexico; Fig. 8). He viewed these young, unconsolidated sediments as (p. 6) "…representing basins filled up with alluvial and diluvial depositions, concealing, as it may be, older tertiary [sic] strata below." He also attributed to subsequent drainage across this "tableland" (or geomorphic surface, in modern terms) the various terraces visible along the Rio Grande. Emory also commented on the sediments, channel, and flow of the Rio Grande.

A short distance above El Paso, Emory noted that the Rio Grande constricted between rocky walls, which exposed (p. 8) "…disturbed strata of limestone, characterized by frequent fossils as belonging to the *Cretaceous* period…while on either side of the river tower up to a height of 500 to 1,000 feet rugged igneous rocks, having a granitic texture…" The fossils Emory collected were given to Conrad, who, in two papers (Conrad, 1855, 1857) described the fossils from this locality, reported only as "between El Paso and Frontera". Frontera was an ephemeral settlement in the early 1850s, about 8 mi north of El Paso and on the western (New Mexico) side of the present New Mexico-Texas border (Julyan, 1996). Given the proximity of Emory's Cretaceous locality to towers of igneous rocks, it is almost certain that they came from Cretaceous strata exposed around the igneous intrusion now called Cerro de Cristo Rey (formerly Cerro de Muleros). In addition, the initial marker monument for the boundary was established on the Rio Grande opposite Cerro de Cristo Rey, and the boundary went through the peak just to the west (Fig. 7). Fossils are so abundant in some beds around this peak that Emory could hardly have failed to notice them. Conrad described a total of one coral, 10 bivalves, one gastropod, and the large foraminiferan *Cribratina texana* from this locality, including several new species, all now known to be of late Early Cretaceous age. This was among the earliest published studies of New Mexico fossils.

Emory also discussed the geology of (p. 8-9) "a conspicuous high mountain range" on the American side of the river (Franklin Mountains), thought mainly to be composed of stratified limestone, dipping 45^{o} WSW, with evidence of various "igneous outbursts", associated with disturbed Cretaceous beds. The limestone was considered to be Carboniferous, and about 1500 ft thick, although he noted Wislizenus's report of Silurian fossils nearby and suggested the lower strata might be of this age (Shumard's report of Lower Silurian fossils in the Franklins had not been written yet). He included a geological sketch of the mountains as seen from El Paso (Fig. 9). The tilted beds labeled Carboniferous are actually a thick sequence of Ordovician limestone and dolomite (El Paso and Montoya Formations). The peaks behind the sedimentary strata said to be composed of granite and porphyry (B, D), are parts of the Precambrian igneous core of the range, mostly granites and granite porphyries (see Harbour, 1972). Along the crest, the diagram portrays (no. 38) "…outweathering masses of siliceous rock, [which] frequently assume grotesque forms and positions, representing various tower-shaped prominences." This unit is either the Precambrian Lanoria Quartzite or part of a thick Precambrian rhyolite sequence, both of which are extensively exposed along the crest and eastern slopes of the range north of the lower Paleozoic limestones that form the south end of the Franklins.

James Hall

The most important geological contribution to the Boundary Report was a paper by James Hall (1811-1896). In the mid-1850s Hall, the State Paleontologist of New York, was unquestionably the most influential paleontologist in North America, and one of a few Eastern scholars who dominated American geology as well. Because of the lengthy time it took to complete the Boundary Survey, and his wide connections with geologists and governmental agencies, Hall was able to incorporate observations and

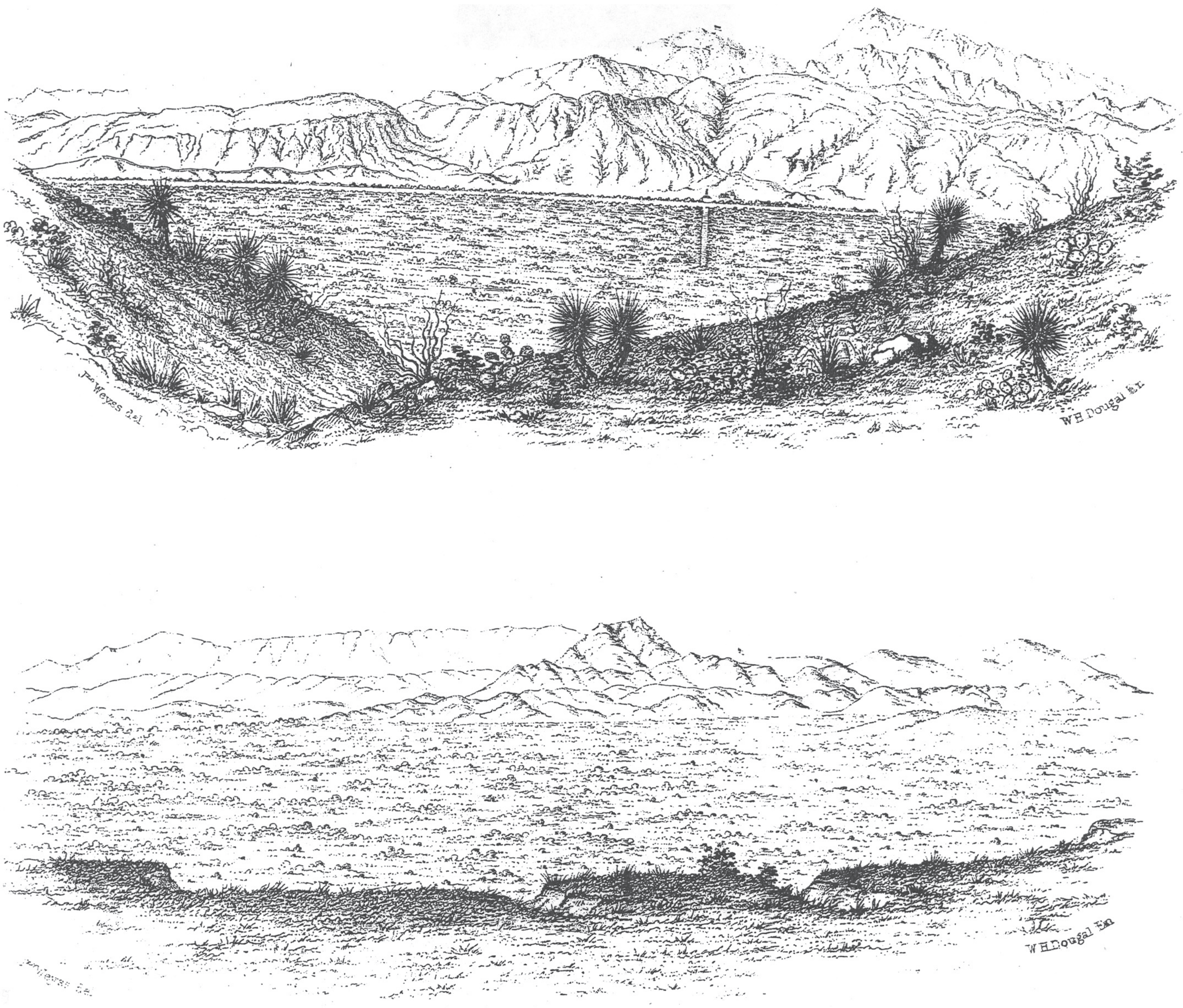
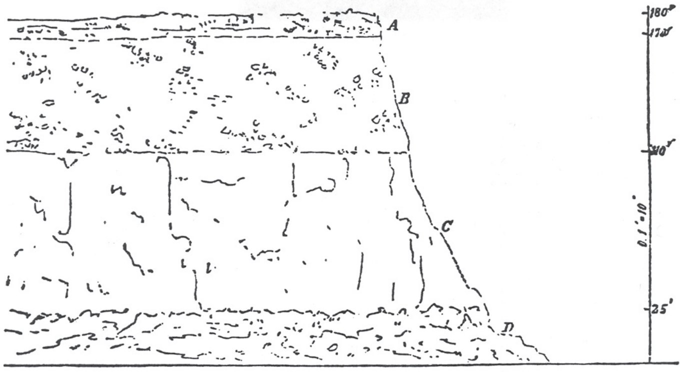


FIGURE 7. Topographic sketches 1 and 2 of Emory (1857). Upper , “view of the initial point of the boundary line on the Rio Bravo del Norte looking west” towards Cerro de Cristo Rey. Lower, “view along the boundary line looking east from Monument 3 on parallel 31° 47’”; west side of Cerro de Cristo Rey rises in background, with Franklin Mountains beyond.

data from the Boundary Survey, the Pacific Railroad surveys, and other expeditions in the mid-1850s, into an ambitious attempt to synthesize the geology of the entire western United States and to relate it to that of the midwestern and eastern parts of the country. His paper for the Boundary Survey focused on correlating Carboniferous and Cretaceous stratigraphy across the continent, and included a geological map of the entire western U. S., including New Mexico. Although his map, especially, is rudimentary and generalized because of too little available information and extrapolations not supported by evidence, this paper was a remarkable intellectual achievement for its time. Here, only a brief summary of the major ideas is given.

Concerning Carboniferous stratigraphy, Hall first noted that, in contrast to the thick Lower Carboniferous (later to be called Mississippian) limestones of the Mississippi Valley, there is no evidence of such strata in the Rocky Mountains or New Mexico, thus challenging Marcou’s identification of Lower Carboniferous limestones widely across New Mexico in the 35th parallel report. Second, Hall noted a pronounced change in Upper Carboniferous (Pennsylvanian) sedimentation from east to west across the continent, from shale- and sand-dominated strata bearing numerous coal beds but minor limestones east of the Mississippi River, to “a vast limestone formation” without coal in New Mexico and the other western territories. He pointed out that during the time



A. Highly calcareous marl, chalklike, with occasional pebbles.
B. Brownish gray sand, with nodules of clay.
C. Yellow ferruginous marl.
D. Debris of drifted sand and washed clay.

FIGURE 8. “Section of earthy table-land forming bluffs of the Rio Bravo above El Paso, corresponding with that forming the “Jornada del Muerto” to the north” (Emory, 1857).

marine conditions prevailed in the West, environments conducive to growth of the land plants from which coal is derived dominated the East. Further, he postulated that what thin limestone beds do occur in the Upper Carboniferous of the Midwest and as far east as Ohio were the result of eastward transgressions of marine environments during oscillations of the sea, a very early suggestion of cyclothemic sedimentation caused by eustatic sea level changes.

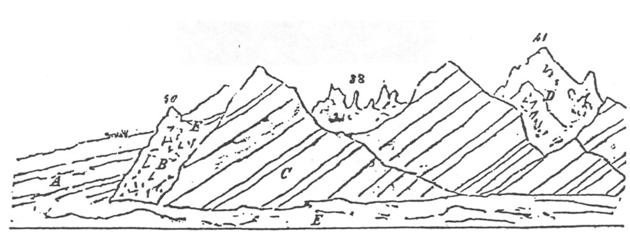
Hall’s discussion of the Cretaceous for his Boundary Survey report amounted to a broad synthesis of Cretaceous deposition in the U. S., involving correlation of Cretaceous sequences from New Jersey, the Gulf Coast, and Nebraska, to New Mexico. Briefly, he recognized three “divisions” of the Cretaceous. Most Cretaceous fossils then known from North America were assigned to an “upper division” (these are typical Late Cretaceous faunas). The Cretaceous fossils collected during the Boundary Survey from west Texas and the El Paso/Frontera area were different, leading Hall to conclude (p. 127) that they indicated “a different epoch of the cretaceous [sic] period from those beds further east.” Hall believed correctly that these fossils, and those that Marcou had described from the Tucumcari area and considered to be Jurassic, represented an interval below the main fossiliferous New Jersey/Gulf Coast/Nebraska strata, and he assigned them to a “middle division” of the Cretaceous (now known to be late Early Cretaceous in age). Finally, Hall assigned strata lacking marine fossils below the “middle division”, to a “lower division” of the Cretaceous. These strata are now known to include rocks of Triassic to Early Cretaceous age.

Hall had much more to say about New Mexico’s Cretaceous fossil record than is relevant for this paper. What is important is that Hall’s synthesis of the Cretaceous stratigraphy of the United States, incorporating substantial data from New Mexico, represented a bold initial hypothesis concerning the subdivision of the Cretaceous Period. This hypothesis would be much tested and refined in the next few decades, as large amounts of new information became available from work in the Midwest and the Texas-New Mexico regions.

CONCLUDING COMMENTS

Although the military campaigns of the Mexican War yielded the first geological observations of southern New Mexico, geological knowledge of this region increased vastly during the 1850s, as the American government mounted major efforts to explore and survey its new territories. These expeditions – the Boundary Survey, the 32nd parallel Pacific Railroad expeditions, and Pope’s artesian well experiments – were all conducted for pragmatic reasons relating broadly to the expanded national interests of the U.S., and all were either led by or involved the strong participation of the scientifically trained Army Corps of Topographical Engineers. However, each of these surveys also included scientists as essential participants. Certainly part of the reason for the scientific expertise was practical – the zoologists, botanists, and geologists were needed to evaluate the natural resources, such as timber, soil, water, topography and minerals, that would determine the suitability of southern New Mexico for settlement, agriculture, rail- and wagon-roads, and economic development in general.

For scientists, these surveys also represented an unprecedented opportunity to conduct pure research, from broad field studies to the systematic study of collected specimens, from large areas about which very little was known. The scientific establishment at the major eastern universities and the Smithsonian Institution recognized this, and were instrumental in emphasizing to the federal government the importance of the scientific information these expeditions would produce. The complementary benefit to the advance of American natural sciences was that the government was paying, both for the scientific staff on these expeditions, and for the publication of their studies after the expeditions were completed. The latter was not insignificant; the purely scientific parts of these survey reports include hundreds of colored engravings and wood-cuts, at a total cost of more than a hundred



A. Cretaceous rocks resting on granite, and diping at an angle of 10–15°.
B. Granite.
C. Carboniferous limestone.
D. Porphyry peak.
E. Drift.

FIGURE 9. “Mountains east of Rio Bravo seen from El Paso” (Emory, 1857).

thousand dollars – "real money" in the mid-19th century. The scientific portions of the expeditions of the 1850s can be viewed as the first large examples of "big science" being supported in the national interest by the federal government.

The geological studies of Antisell and Shumard provided the first real information on the geology of southern New Mexico. They were reconnaissance studies to be sure, and some important features were overlooked or misinterpreted, but they established the general geological framework of this area, with some of the details accurately portrayed. For much of this region, these studies were the only ones extant until the first decade of the 20th century. The only significant 19th-century study of part of this area, following Antisell and Shumard, was conducted by G. K. Gilbert, with the Wheeler Expedition, in 1873 (Gilbert, 1875). He examined southwestern New Mexico as far south as the Gila country, the Peloncillo, Pyramid, and Burro Mountains, and the Santa Rita region. Space does not allow discussion of this work here (although such an analysis would be worth while), except to say that the geological results were significantly more advanced and "modern" than the earlier studies, as might be expected from a man who would become one of the giants of late 19th and early 20th century American geology. For example, Gilbert was the first to recognize Precambrian (then called Archaean} rocks in the Big Burro and Santa Rita ranges, as well as the occurrence of early Paleozoic strata beneath the Carboniferous in the Silver City/Santa Rita region.

ACKNOWLEDGMENTS

I am grateful to Wolf Elston and Jerry Mueller for their careful reviews of an earlier version of this manuscript, which corrected some inaccuracies and added relevant additional information. Thanks also to Georgianna E. Kues for assistance with several of the figures.

REFERENCES

Antisell, T., 1856, Report of explorations for railroad routes, San Francisco Bay to Los Angeles, west of the Coast Range, and from the Pimas villages on the Gila to the Rio Grande, near the 32nd parallel of north latitude: Geological report; *in* Reports of explorations and survey to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, v. 7, pt. 2: U.S. 33rd Congress, 2nd Session, Senate Executive Document 78, 204 p.

Bachman, G.O., and Myers, D.A., 1969, Geology of the Bear Peak area, Dona Ana County, New Mexico: U. S. Geological Survey, Bulletin 1271-C, p. C1-C46.

Bartlett, J.R., 1854, Personal narrative of explorations and incidents in Texas, New Mexico, California, Sonora, and Chihuahua…: New York, D. Appleton & Co., v. 1 and 2, 506 and 624 p.

Bell, W.A., 1869, New tracks in North America: London, Chapman and Hall, 2 vols.,236 and 322 p.

Blake, W.P., 1856, Report on the geology of the route near the 32nd parallel; prepared from the collection and notes of Capt. Pope: Explorations and surveys for a railroad route from the Mississippi River to the Pacific Ocean, U.S. 33rd Congress, 2nd Session,Senate Executive Document 78 and House Executive Document 91, v. 2, 50 p.

Bustamante, A., and Simmons, M. (editors and translators), 1995, The exposition on the province of New Mexico, 1812, by Don Pedro Baptista Pino: El Rancho de las Golondrinas and University of New Mexico Press, 59 p.

Calvin, R., 1951, Lieutenant Emory reports: Albuquerque, University of New Mexico Press, 208 p.

Chapin, C.E., McIntosh, W.C., and Chamberlin, R.M., The late Eocene-Oligocene peak of Cenozoic volcanism in southwestern New Mexico; *in* Mack, G.H. and Giles, K.A., eds., The geology of New Mexico, a geologic history: New Mexico Geological Society, , Special Publication 11, p. 271-293.

Clemons, R.E., 1998, Geology of the Florida Mountains, southwestern New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 43, 112 p.

Conrad, T.A., 1855, Descriptions of one Tertiary and eight new Cretaceous fossils from Texas, in the collection of Major Emory: Philadelphia Academy of Natural Sciences Proceedings, v. 7, p. 268-269.

Conrad, T.A., 1857, Descriptions of Cretaceous and Tertiary fossils; *in* Emory, W.H., Report on the United States and Mexican boundary survey: U. S. 34th Congress, 1st Session, Senate Executive Document 108 and House Executive Document 135, v. 1, pt. 2, p. 141-174.

Dane, C.H., and Bachman, G.O., 1965, Geologic map of New Mexico: U. S. Geological Survey, scale 1:500,000.

Darton, N.H., 1916, Geology and underground water of Luna County, New Mexico: U.S. Geological Survey, Bulletin 618, 188 p.

Dunham, K.C., 1935, The geology of the Organ Mountains, with an account of the geology and mineral resources of Dona Ana County, New Mexico: New Mexico
Bureau of Mines and Mineral Resources, Bulletin 11, 272 p.

Elston, W.E., 1957, Geology and mineral resources of Dwyer quadrangle, Grant, Luna, and Sierra Counties, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 38, 86 p.

Elston, W.E., Seager, W.R., and Clemons, R.E., 1975, Emory cauldron, Black Range, New Mexico, source of the Kneeling Nun Tuff: New Mexico Geological Society, 26th Field Conference Guidebook, p. 283-292.

Emory, D.C., 2000, Running the Line: men, maps, science, and art of the United States and Mexico boundary survey, 1849-1856: New Mexico Historical Review, v. 75, p. 221-265.

Emory, W.H., 1848, Notes of a military reconnaissance from Fort Leavenworth, in Missouri, to San Diego, in California: U.S. 30th Congress, 1st Session, Senate Executive Document 7 and House Executive Document 41, 416 p.

Emory, W.H., 1857, General geological features of the country; *in* Emory, W.H., Report on the United States and Mexican boundary survey: U. S. 34th Congress, 1st Session, Senate Executive Document 108 and House Executive Document 135, v. 1, pt. 2, p. 1-27.

Engstrand, I.H.W., 1981, Spanish scientists in the New World: University of Washington Press, 220 p.

Geologic Map of New Mexico, 2003, New Mexico Bureau of Geology and Mineral Resources, scale, 1:500,000.

Gilbert, G.K., 1875, Report on the geology of portions of New Mexico and Arizona: U. S. Geographical and Geological Surveys West of the 100th Meridian [Wheeler], v. 3, p. 503-567.

Gillerman, E., 1958, Geology of the central Peloncillo Mountains, Hidalgo County, New Mexico, and Cochise County, Arizona: New Mexico Bureau of Mines and Mineral Resources, Bulletin 57, 152 p.

Goetzmann, W.H., 1959, Army exploration in the American West, 1803-1863: Lincoln, University of Nebraska Press, 489 p.

Goetzmann, W.H., and Williams, G., 1992, The atlas of North American exploration: from the Norse voyages to the race for the pole: New York, Prentice-Hall, 224 p.

Greger, D.K., 1932, *Spirifer organensis* Shumard: American Midland Naturalist, v. 13, p. 130-132.

Hall, D. (ed.), 1996, Drawing the borderline: artist-explorers and the U.S.-Mexico boundary survey: The Albuquerque Museum, 156 p.

Hall, J., 1857, Geology and paleontology of the boundary; *in* Emory, W.H., Report on the United States and Mexican boundary survey made under the direction of the Secretary of the Interior: U.S. 34th Congress, 1st Session, Senate Executive Document 108, v. 1, pt. 2, p. 101-140.

Harbour, R.L., 1972, Geology of the northern Franklin Mountains, Texas and New Mexico: U. S. Geological Survey, Bulletin 1298, 129 p.

Hoffer, J.M., 2001, Geology of the West Potrillo Mountains: New Mexico Museum of Natural History and Science, Bulletin 18, p. 141-145.

Hoffer, J.M., Penn, B.S., Quezada, O.A., and Morales, M., 1998, Qualitative age relationships of late Cenozoic cinder cones, southern Rio Grande rift, utilizing cone morphology and landsat thematic imagery: a preliminary assessment: New Mexico Geological Society, 49th Field Conference Guidebook, p. 123-128.

Hudson, J., 1984, Geology and hydrothermal alteration of the San Simon mining district south of Steins Pass, Peloncillo Mountains, Hidalgo County, New Mexico [M.S. Thesis]: Albuquerque, University of New Mexico, 125 p.

Humboldt, A. von, 1811, Essai politique sur le royaume de la Nouvelle-Espagne; par Alexandre de Humboldt. Avec un atlas physique et geographique, fonde sur des observations astronomiques, des mesures trigonometriques et des nivellements baro-metriques: Paris, F. Schoell.

Jackson, J. (ed.), 2000, Texas by Teran: University of Texas Press, 300 p.

James, H.L., 1969, History of the United States-Mexico boundary Survey – 1848-1855: New Mexico Geological Society, 20th Field Conference Guidebook, p. 41-55.

Jicha, H.L., Jr., 1954, Geology and mineral deposits of Lake Valley quadrangle, Grant, Luna, and sierra Counties, New Mexico: New Mexico Bureau of Mineas and Mineral Resources, Bulletin 37, 93 p.

Julyan, R., 1996, The place names of New Mexico: Albuquerque, University of New Mexico Press, 385 p.

Kinnaird, L., 1958, The frontiers of New Spain: Nicolas de Lafora's description, 1766-
1768: Berkeley, CA, The Quivira Society, 243 p.

Kottlowski, F.E., 1960, Summary of Pennsylvanian sections in southwestern New Mexico and southeastern Arizona: New Mexico Bureau of Mines and Mineral Resources, Bulletin 66, 187 p.

Kues, B.S., 1985, Early geological explorations in northeastern and east-central New Mexico: New Mexico Geological Society, 36th Field Conference Guidebook, p. 103-118.

Kues, B.S., 2006, Geological studies of the Guadalupe Mountains area, New Mexico and West Texas, to 1928: New Mexico Geological Society, 57th Field Conference Guidebook , p. 127-144.

Lozinsky, R.P., Kelly, J.C., Osburn, G.R., and Kudo, A.M., 1986, Boat log for southern half of Elephant Butte Reservoir: New Mexico Geological Society, 37th Field Conference Guidebook, p. 57-65.

Mack, G.H., 2004, Middle and late Cenozoic crustal extension, sedimentation, and volcanism in the southern Rio Grande rift, basin and range, and southern transition zone of southwestern New Mexico; *in* Mack, G.H., and Giles, K.A., eds., The geology of New Mexico, a geologic history: New Mexico Geological Society, Special Publication 11, p. 389-406.

Mack, G.H., Kottlowski, F.E., and Seager, W.R., 1998, The stratigraphy of southern New Mexico: New Mexico Geological Society, 49th Field Conference Guidebook, p. 135-154.

Marcou, J., 1855, Geological report; *in* Pope, J., Report of exploration of route for the Pacific Railroad near the 32nd parallel of north latitude from the Red River to the Rio Grande: U. S. 33rd Congress, 1st Session, House Executive Document 129, p. 124-128.

Martin, J.C., and Martin, R.S., 1984, Maps of Texas and the Southwest, 1513-1900: Albuquerque, University of New Mexico Press, 174 p.

Merrill, G.P., 1924, The first one hundred years of American geology: New Haven, Yale University Press, 773 p.

Mueller, J.E., and Mueller, W.A., 1998, Early images of the Organ Mountains: artwork of the U.S.-Mexican boundary commission of 1851-1852: New Mexico Geological Society, 49th Field Conference Guidebook, p. 47-53.

Mueller, J.E., and Twidale, C.R., 1988, Landform development of City of Rocks State Park and Giant of the Mimbres: New Mexico Geological Society, 39th Field Conference Guidebook, p. 185-190.

New Mexico Bureau of Geology and Mineral Resources, 2003, Geologic map of New Mexico: New Mexico Bureau of Geology and Mineral Resources.

Parke, J.G., 1855, Report of explorations for that portion of a railroad route, near the 32nd parallel of north latitude, lying between Dona Ana, on the Rio Grande, and Pimas villages, on the Gila; *in* Reports of explorations and survey to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, v. 2, pt. 5: U.S. 33rd Congress, 2nd Session, Senate Executive Document 78, p. 1-20.

Parke, J.G., 1857, Report of explorations for railroad routes, San Francisco Bay to Los Angeles, west of the Coast Range, and from the Pimas villages on the Gila to the Rio Grande, near the 32nd parallel of north latitude; *in* Reports of explorations and survey to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, v. 7, pt. 1: U.S. 33rd Congress, 2nd Session, Senate Executive Document 78, p. 19-42.

Parke, J.G., and Kern, R.H., 1851, Map of the Territory of New Mexico: U.S. Army Corps of Topographical Engineers.

Pope, J., 1855, Report of exploration of a route for the Pacific Railroad, near the 32nd parallel of north latitude, from the Red River to the Rio Grande: U.S. 33rd Congress, 2nd Session, Senate Executive Document 78, v. 2, p. 1-95.

Prout, H.A., 1858, Description of new species of Bryozoa from Texas and New Mexico, collected by Dr. George G. Shumard…: St. Louis Academy of Science Transactions, v. 1, p. 228-235.

Rebert, P., 2001, La Gran Linea, mapping the United States-Mexico boundary, 1849-1857: Austin, University of Texas Press, 259 p.

Reinhartz, D., 2005, Spanish military mapping of the northern borderlands after 1750; *in* Reinhartz, D., and Saxon, G.D., eds, Mapping and empire, soldier-engineers on the Southwestern frontier: Austin, University of Texas Press, p. 57-79.

Richter, D.H., Lawrence, V.A., Drewes, H., Young, T.H., Enders, M.S., Damon, P.E., and Thorman, C.H., 1990, Geologic map of the San Simon quadrangle and parts of the Summit Hills and Mondel quadrangles, Arizona, and Hidalgo County, New Mexico: U. S. Geological Survey, Miscellaneous Investigations Series Map I-1951, scale 1:24,000.

Rittenhouse, J.D., 1969, Memoir of a tour to northern Mexico [by Adolph Wislizenus]: Albuquerque, Calvin Horn Publisher, Inc., 141 p.

Seager, W.R., 1981, Geology of Organ Mountains and southern San Andres Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 36, 97 p.

Seager, W.R., 1986, Third-day road log, from Truth or Consequences to southeastern Caballo Mountains and San Diego Mountain via I-25 and the Jornada del Muerto: New Mexico Geological Society, 37th Field Conference Guidebook, p. 35-55.

Seager, W.R., and Mack, G.H., 2003, Geology of Caballo Mountains, New Mexico: New Mexico Bureau of Geology and Mineral Resources, Memoir 49, 135 p.

Seager, W.R., Hawley, J.R., and Clemons, R.E., 1971, Geology of San Diego Mountain Area, Dona Ana County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 97, 38 p.

Seager, W.R., Hawley, J.W., Kottlowski, F.E., and Kelley, S.A., 1987, Geology of east half of Las Cruces and northeast El Paso 1ºx 2º sheets (scale 1:125,000), New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geologic Map GM-57.

Seager, W.R., Kottlowski, F.E., and Hawley, J.W., 1976, Geology of Dona Ana Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 147, 36 p.

Shumard, B.F., 1858, Notice of new fossils from the Permian strata of New Mexico and Texas, collected by Dr. Geo. G. Shumard…: St Louis Academy of Science Transactions, v. 1, p. 290-297.

Shumard, B.F., 1859, Notice of fossils from the Permian strata of Texas and New Mexico…with descriptions of new species from these strata and the Coal Measures of that region: St. Louis Academy of Science Transactions, v. 1, p. 387-402.

Shumard, B.F., 1863, Descriptions of new Palaeozoic fossils: St. Louis Academy of Science Transactions, v. 2, p. 108-113.

Shumard, G.G., 1858, Observations on the geological formations of the country between the Rio Pecos and the Rio Grande, in New Mexico, near the line of the 32nd parallel…: St. Louis Academy of Science Transactions, v. 1, p. 273-289.

Shumard, G.G., 1859, The geological structure of the "Jornada del Muerto", New Mexico…: St. Louis Academy of Science Transactions, v. 1, p. 341-355.

Shumard, G.G., 1886, A partial report on the geology of western Texas, consisting of a general geological report, and a journal of geological observations along the routes traveled by the expedition between Indianola, Texas, and the valley of the Mimbres, New Mexico, during the years 1855 and 1856: State of Texas, 145 p.

Shumard, R., 2001, Shumard, George Getz: Handbook of Texas Online: http://www.tsha.utex.edu/handbook/online/articles/SS/fsh57.html

Strain, W.S., 1958, Juarez Mountains: West Texas Geological Society, Guide Book, 1958 Field Trip, p. 67.

Summers, W.K., 1976, Catalog of thermal waters in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Hydrologic Report 4, 80 p.

Wislizenus, A., 1848, Memoir of a tour to northern Mexico, connected with Colonel Doniphan's expedition in 1846 and 1847: U.S. 30th Congress, 1st Session, Senate Miscellaneous Document 26, 141 p.