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EARLY GEOLOGICAL EXPLORATIONS IN NORTHEASTERN AND EAST-CENTRAL NEW MEXICO

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INTRODUCTION

When General Stephen W. Kearny and his Army of the West entered Santa Fe on 18 August 1846, establishing American jurisdiction over New Mexico, virtually nothing was known of the geology of this vast territory. Although mining on a small scale had been practiced for centuries, there is no evidence of any scientific effort to understand the geological history of any part of New Mexico during the Spanish and Mexican periods. The geography of some parts of the territory, especially the relatively populated region along the Rio Grande, was reasonably well known, but large areas were terra incognita to Americans and Mexicans alike. Information about the land and people of New Mexico available to the entering Americans had been gleaned largely from the sometimes romanticized accounts of travellers and traders, a few American residents and occasional American exploring parties that inadvertently or by design had penetrated New Mexico against the wishes of its Spanish, then Mexican, administrations.

Establishment of American control in New Mexico produced an immediate requirement for additional information, not only concerning the agriculture, industries and lifestyles of the Hispanic and Indian residents, but also about the roads, mineral resources, topography, climate, fauna, flora and geology of the territory. Such information was essential to the proper administration of the territory and, against a complex tapestry of abrupt, forced and sometimes antagonistic integration of Hispanic, Indian and Anglo cultures, the United States Government mounted a concerted effort to acquire it.

The growth in knowledge of the geology of New Mexico during the first decade of American administration was explosive. Although many of the observations made during this time were preliminary, generalized and in some instances erroneous, the efforts of the military men, naturalists and geologists who first examined and reported upon New Mexico's rock record represented an important first step in the understanding of New Mexico's geology. In this paper, observations and interpretations of the geology of the northeastern quadrant of New Mexico made through the first decade of American administration of the territory (Fig. 1) are described, together with some of the circumstances and consequences of these efforts. The richest sources of information about these early geological studies and the men who conducted them are their published journals and papers, and I have quoted liberally from them. A modern synthesis of the work of the U.S. Army Corps of Topographical Engineers is the excellent book by Goetzmann (1959), which I have utilized extensively in this account. Early descriptions of the geology of one important area in east-central New Mexico—the Tucumcari Mountain area—are touched on but lightly here; a companion paper in this guidebook (Kues, 1985) summarizes in detail the development of our knowledge of the geology of that area.

EXPLORATIONS PRIOR TO 1846

Introduction

Early explorations of the Southwest sponsored by the U.S. Government were hindered by the fact that this area was under first Spanish, then Mexican control, and, not surprisingly, these authorities resisted American penetration of their territory. A good example of the problems that could result from entering the Spanish–Mexican domain was the fate of the first American expedition to enter New Mexico. Led by Zebulon Pike, this expedition traversed central New Mexico, but under conditions hardly auspicious for the acquisition of scientific information. Pike's party, searching for the source of the Red River in the southern Rocky Mountains, was captured in February 1807 by a large force of Spanish cavalry, and marched under guard down the Rio Grande to Santa Fe, then to Chihuahua. All of their notes and papers were confiscated.

Stephen H. Long, 1819–1820

The first scientific exploring expedition to view parts of east-central New Mexico began as an ambitious attempt to gain information and establish a military presence along the upper Missouri River, in the Louisiana Purchase, a long way from New Mexico. Led by Major Stephen H. Long of the Army Topographical Bureau, this expedition included several scientists, such as the biologist Thomas Say, the geologist Augustus Jessup and the naturalist-painter Titian Rembrandt Peale. An extended account of the Long expedition (James, 1823), together with a discussion of the geology by Jessup (1823), was reprinted with editorial annotations by Thwaites (1905).

The scientific part of the party gathered in Pittsburgh, headed west in May 1819, and went into winter quarters with the military contingent of the expedition near Council Bluffs, Iowa. Long and Jessup returned east during the winter, where Jessup retired from exploring to be replaced by Edwin James, a young naturalist who had studied geology with Amos Eaton and botany with John Torrey. During the winter, the U.S. Congress, annoyed by the large expenditures and lack of significant results, cut appropriations and redefined the purpose of the expedition to the more modest mission of exploring the Platte River and returning by way of the Arkansas and Red Rivers to the south. Getting underway again in June 1820, the party of 22 progressed rapidly westward, reaching the Rocky Mountains in early July. After exploring Pike's Peak and Royal Gorge, the men turned southeast, and on 21 July the party divided into two. One contingent was to return east along the Arkansas River, "a trek that turned out to be aimless wandering rather than meaningful scientific exploration" (Goetzmann, 1959, p. 42). Long, James and seven others headed south to explore what was thought to be the Red River, but which actually was the Canadian.

After crossing the Purgatoire River in southern Colorado, Long's party entered New Mexico near Raton Pass about 29 July, and followed the east bank of the Canadian (it appears as the Mora River on James' 1823 map: Fig. 2) southward, reaching the area around the present Conchas Lake on 3 August. The party then followed the north bank of the Canadian eastward into Texas, which they entered about six days later. James' (1823) commentary on this part of the route contains many geological observations, but these are limited to superficial isolated descriptions of rock types, without any real attempt to synthesize these observations into a coherent picture of the stratigraphy and age relationships of the formations encountered, or to relate them to the geology of eastern North America. Jessup's (1823) discussion of the geology of the Rocky Mountain region, based on James' observations, made some attempt at synthesis, but the data base was far too limited to allow anything more than a rudimentary portrayal of the relationships of the major rock types.

Some of James' geological information may be related easily to modern geological features. Near Raton Pass, for example, he noted "sandrock" which contained "narrow beds of bituminous clay slate, which contains pieces of charcoal or the carbonized remains of vegetables"—the Cretaceous–Paleocene coal beds of the Raton basin. The party also observed the volcanic rocks east and southeast of Raton Pass, as "conic piles" of "black and porous amygdaloid" and "porphyritic greenstone," and James described the area as "a wide and elevated formation of trap rocks, resting on horizontal sandstone."

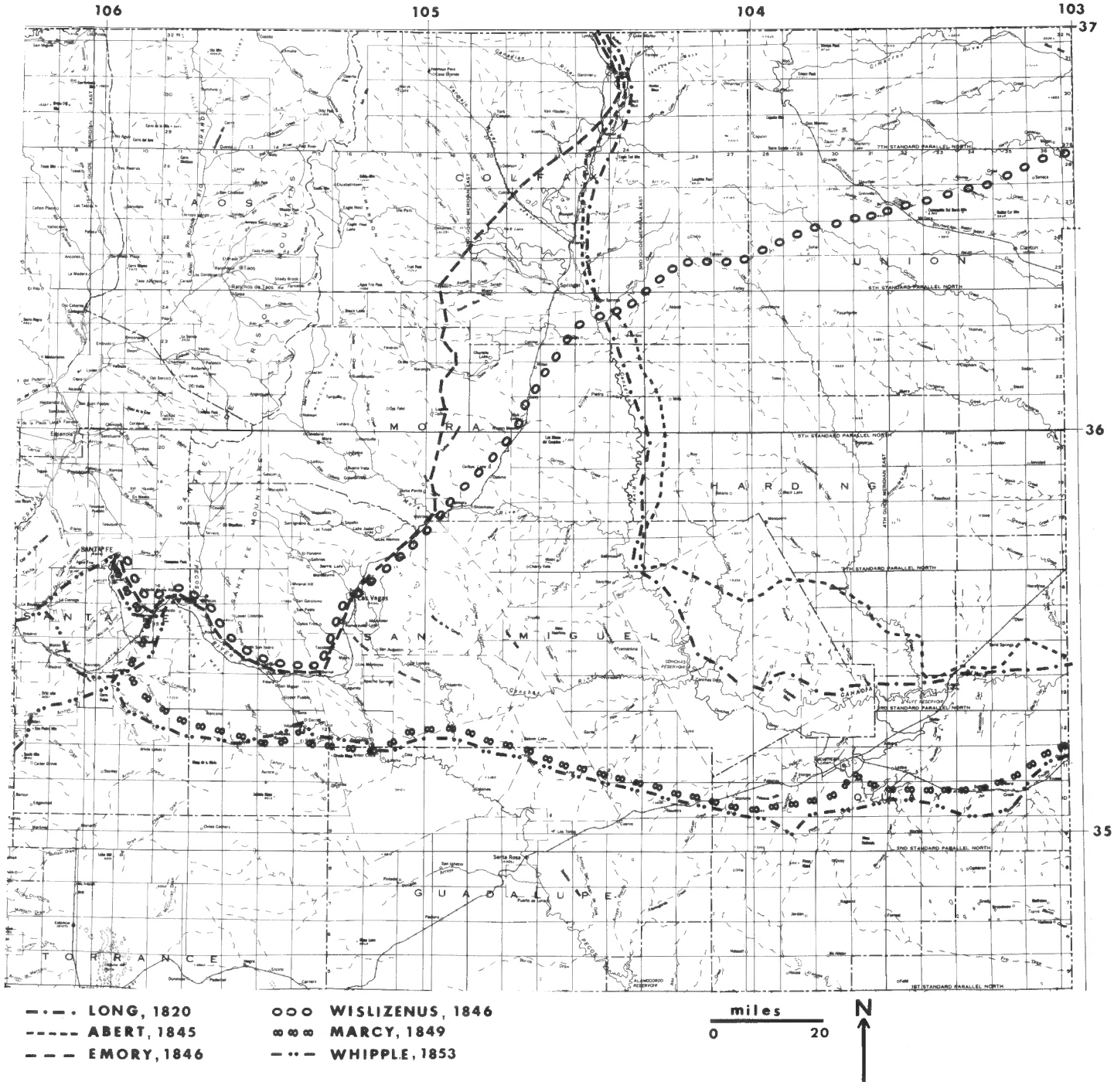


FIGURE 1. Map of northeastern New Mexico, showing routes of main expeditions that provided geological information about this area through 1853.

On 2 August the party passed the basalts exposed south of modern Sabinoso, which James (p. 91) described as follows:

> The aspect of these rocks, particularly of the amygdaloid or toad stone, is so peculiar, and its disposition so remarkably dissimilar to that of the sandstones with which it is associated, that nothing seems more natural than it should be referred to a different origin.
>
> In the midst of one of the violent storms we encountered in passing this trap formation, we crossed the point of a long and inconsiderable elevated ridge of amygdaloid, so singularly disposed as to suggest to every one of the party the idea that the mass had once been in a fluid state; and that, when in that state, it had formed a current, descending along the bed of a narrow ravine, which it now occupied, conforming to all the sinuosities and inequalities of the valley, as a column of semifluid matter would do. Its substance was penetrated with numerous vasicular [sic] cavities, which were observed to be elongated in the direction of the ridge . . . These appearances are so remarkable, that is is not at all surprising these rocks should have been considered of volcanic origin. . . .

Two sandstones were reported along this route, a horizontally bedded "fine grey sandstone" on which the trap rocks rested, and a lower, coarse-grained, yellowish-gray or light brown unit supporting a "slaty argillaceous stratum." The identity of the first unit is unclear, probably it is the Niobrara–Pierre interval, but the second sandstone is certainly the Dakota, which is widely exposed along the east side of the Canadian River and is overlain by a predominantly dark shale sequence (Graneros

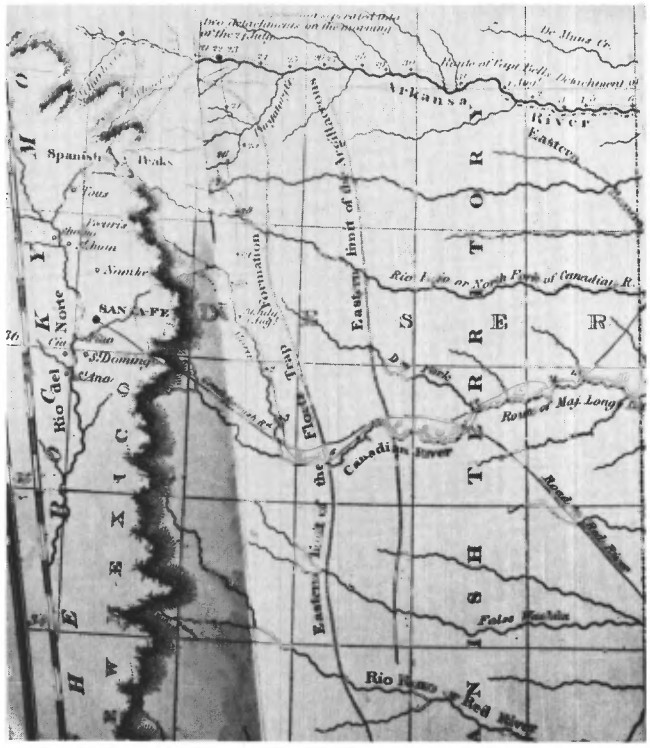


FIGURE 2. New Mexico part of James' (1823) map, showing route of the Long expedition in 1820 along the Canadian River. Note the lines showing "Eastern limit of the Floetz Trap Formation" and "Eastern limit of the Argillaceous [Sandstone]."

to Carlile part of the Upper Cretaceous). As they turned eastward, they began to encounter red soil and "precipices of red sandstone," the modern Chinle Formation, of Triassic age.

Based on James' observations, Jessup (1823) generalized about the geology along the eastern side of the Rocky Mountains, including northeastern New Mexico. The core of the mountains was recognized as granitic, with red sandstone resting directly above it. This sandstone was said to contain gypsum, iron and salt and to be different from the "old red" sandstone of the eastern United States, but Jessup did not venture a guess as to its age. At different locations this red-sandstone interval includes rocks now recognized as being from Pennsylvanian to Jurassic in age. Overlying the red sandstone was "argillaceous or gray sandstone," observed in several places along the Canadian River in New Mexico, and upon this unit rested the "Floetz [or Fletz] trap"—rocks of basaltic appearance. Two varieties of this trap rock were distinguished, a relatively light-colored, massive "greenstone" and porous or vesicular, dark-gray to dark-green rocks called "amygdaloid." Both were common along their route in New Mexico, as noted above, and were often found in the form of "conical hills" or "conic piles" (volcanic cones are never mentioned). Floetz trap was a Wernerian term for a large variety of rock types, including relatively recent basalts, that were supposed to have precipitated from the World ocean. The interpretations of the geology presented by James and Jessup are indeed somewhat Wernerian, as Merrill (1924) pointed out, but they also recognized that at least some of the trap rocks observed in places like northeastern New Mexico were far more likely to have had a volcanic rather than an aqueous origin.

James' geographic map of eastern New Mexico (Fig. 2) includes two geological generalizations. A long, north–south line running from Colorado far south into New Mexico is labeled "eastern limit of the Floetz Trap Formation." Farther east on James' map, near the present New Mexico–Texas border, is another north–south line that marked the eastern limit of the "argillaceous sandstone," representing the break between Cretaceous exposures to the west and the Tertiary–Quaternary sediments of the Llano Estacado.

Long's party encountered relatively few difficulties in New Mexico, progressing rapidly and meeting no Indians. Because game was scarce, the men were reduced to eating the fuit of prickly-pear cacti and other vegetation, and were forced to kill a horse when no deer were available. Water was also in short supply, particularly along the eastern part of their route through New Mexico, because the streams and creeks were all dry. Peale became very sick, but he was somewhat relieved "by the free use of opium and whiskey," apparently important medications of the time. After a month's journey through Texas, Long's party reached Fort Smith, Arkansas, on 13 September, where they met the northern party which had arrived ahead of them by travelling along the Arkansas River. This party had suffered the desertion of three members, who had taken most of Say's notes and manuscripts on the animals, Indians and topography, and thus much reduced the scientific data assembled by the expedition.

In retrospect, the Long expedition accomplished relatively little, considering that several legitimate scientists were along, and showed a surprising lack of initiative in determining the headwaters of either the Arkansas or the Red Rivers, one of the major goals of the expedition. Latitude and longitude measurements were carelessly made, with the result that on the map of the area traversed lines of longitude are displaced by more than a degree to the west—an inexcusable error. However, the geographic information on the course of the Canadian River in east-central New Mexico was useful in correcting some contemporary beliefs about the river systems of the Southwest, and the New Mexico part of their route later became a much-used trail (Thwaites, 1905).

The 1830's and early 1840's

Several expeditions that passed through east-central New Mexico during the 1830's and early 1840's are worth mentioning. Even though they produced little strictly geological information, the accounts of these expeditions provided additional descriptions of other aspects of New Mexico's natural history and geography, and added information that would prove useful to the scientific–military expeditions that accompanied and followed the American conquest. Of greatest importance were the trading expeditions of Josiah Gregg. He led four expeditions to Santa Fe in the late 1830's and early 1840's—three along the Santa Fe Trail and one along the Canadian River—and also travelled widely through southern New Mexico and Mexico. His book "Commerce of the Prairies" (Gregg, 1844) was not only the best portrayal of political and social conditions in New Mexico during this time, but also contained much information on the history, geography, fauna, flora and minerals of the territory. Unlike many writers who tended to romanticize their adventures on the frontier, Gregg took pains to be scrupulously accurate, and his book was much relied upon by later explorers. There is little geological information in it, but he did comment on the large petrified logs in the Galisteo area that were weathering out of the sandstone now known as the Eocene Galisteo Formation.

Another expedition that should be mentioned, even though it contributed no information concerning the geology of New Mexico, is the Texan–Santa Fe expedition of 1841. The journal of this expedition, published by George W. Kendall, the editor of the New Orleans Picayune Newspaper (1844), is generally accurate (though terribly anti-Mexican) and is characterized by vividly written observations and a wide-eyed excitement that make it entertaining reading even today. Loomis (1958) provided a sympathetic modern account. The expedition was conceived by Mirabeau E. Lamar, president of Texas, with the intention of diverting trade from the lucrative Santa Fe Trail by opening a new commercial route through Texas to Santa Fe. Equally important goals included asserting the Texan claim to all lands east of the Rio Grande in New Mexico, and, should conditions seem suitable, conquering New Mexico militarily. Accordingly, the expedition was to pose as a commercial trading venture, but take military action if the New Mexican populace could be persuaded to revolt against the regime of Governor Manuel Armijo.

On 18 June 1841, more than 300 men, including a mixture of soldiers, traders, servants and adventurers, left Austin, Texas, for Santa Fe. Initially, Kendall's journal is filled with observations on the geography

and natural history of the route, even describing a bed of fossil oysters a short distance north of Austin, but the attention of the party soon turned to more fundamental concerns. Without a guide who knew the territory ahead of them, and believing the distance to Santa Fe was no more than 500 miles rather than more than a thousand, the expedition proceeded slowly, and by late August was completely lost on the barren Llano Estacado, some 125 miles east of New Mexico. Food and water ran low, Indians killed several men and ran off livestock, and discipline among the civilian members of the party broke down. In desperation, the expedition divided, a hundred of the strongest men under Captain Sutton and William Cooke to push westward at all possible speed to the Mexican villages they believed were not far ahead, and the main part of the expedition to stay behind until the advance party could find a route. The Sutton–Cooke party finally entered New Mexico near Glenrio on 7 September, passed the present site of Logan, and camped on the Conchas River on 10 September, shortly after meeting a surprised group of Mexicans who told them that the nearest town was still 80 miles away. Six men were dispatched ahead to buy provisions and contact the authorities, while four men were sent back to the main party to encourage it to begin moving west again.

By this time, however, news of the expedition had reached Governor Armijo and on 15 September, between Anton Chico and San Miguel, the six-man advance guard was surrounded by New Mexican soldiers, disarmed and thrown into prison. The rest of the Sutton–Cooke party reached Anton Chico on 16 September and the next day were taken into custody as a result of the treachery of one of the Texan officers. This man, who spoke Spanish, assured them that if they would give up their weapons they would be treated with friendship and allowed to trade in New Mexico. Instead, they were stripped, tied and marched under heavy guard into San Miguel.

Meanwhile, the main body of the expedition, under General Hugh McLeod, with its men starving, scurvy-ridden and on foot due to the loss of most of their horses to Kiowas, struggled into New Mexico on 26 September, reached Arroyo Tucumcari (now Plaza Larga Creek) on 3 October, and the next day was intercepted by a large group of New Mexico soldiers who demanded that they surrender. McLeod thought the situation over that evening, while camped opposite the mouth of Bull Canyon, about four miles southeast of present-day Newkirk. Less than half of his remaining 180 men were able to fight, and many of them had thrown their rifles away during the hard march across the Llano. Food supplies were low and, even if they were victorious in battle against the soldiers opposing them, there was no hope of returning to Texas or fighting their way to Santa Fe. The following morning, 5 October, after being assured they would be treated honorably, the McLeod party surrendered.

The men of both the Sutton–Cooke and McLeod parties were marched on foot under conditions of nearly continuous brutality down the Rio Grande to El Paso, and thence to final incarceration in prisons and a leper colony near Mexico City. They were released by Santa Anna in June 1842, and about 140 men eventually made it back to Texas. In retrospect, the Texan–Santa Fe expedition stands as one of the most ill-conceived expeditions in the history of the American West. To proceed without any knowledge of the geography of their route, and with the belief that New Mexicans would welcome their aid in overthrowing Armijo, was careless and naive in the extreme. However, the expedition influenced future Mexican–American relations in several ways. The poor treatment of the captured Texans exacerbated the tensions between Mexicans and Americans and contributed to public support for a final reckoning with the Mexicans, which came in 1846. The hardships suffered by the Texans also increased the strength of the Texan claim to all of New Mexico east of the Rio Grande, including Santa Fe, a claim that Kearny recognized when his army took control of New Mexico, and for which the American government eventually (in 1850) paid Texas $10 million. And finally, the expedition contributed to the enmity felt by New Mexicans toward Texans, which persists to the present time.

James W. Abert, 1845

By 1845 a diplomatic crisis existed between the United States and Mexico, caused in part by Mexico's refusal to acknowledge the independence of Texas and the legality of its subsequent annexation to the U.S. It was recognized by the Polk administration that, although there was a chance of war, the U.S. had little detailed knowledge about the geography of the northern Mexican provinces, including New Mexico. Accordingly, two expeditions involving the Army Corps of Topographical Engineers were dispatched west in the spring of 1845 to acquire scientific and military information. Stephen W. Kearny was to survey the Oregon Trail as far as Wyoming and then proceed southward to Bent's Fort, in southeastern Colorado, while John C. Frémont, assisted by Lieutenant Abert, was directed to survey the Arkansas and Red Rivers and the geography of the region around Bent's Fort. Frémont was further instructed to detach a lieutenant and party to explore the southern Rocky Mountains and region south of the Arkansas when he arrived at the fort (Goetzmann, 1959; unless otherwise indicated information presented here is mainly from Goetzmann, 1959, and Abert, 1846).

Frémont's expedition set out from Ft. Leavenworth, Kansas, on 20 June 1845 and reached Bent's Fort on 2 August. Instead of complying with his orders, however, Frémont and most of the expedition headed west towards California through territory claimed by Mexico, and was eventually caught up in the California rebellion that marked the western theater of the Mexican–American War. Before leaving Bent's Fort, Frémont put Abert in command of a small force that was to make a reconnaissance through Comanche and Kiowa territory in the region of the Canadian River. On 12 August, four days before Frémont departed, Abert's party of 33 set out, lacking even a single barometer for making altitude measurements and likewise without adequate facilities for making collections of the fauna, flora and geology along their route.

James Abert (Fig. 3) was 24 years of age at this time and this was his first command. He had graduated from West Point in 1842, ranked 55th in a class of 56 and was the son of the chief of the Army Corps of Topographical Engineers, Colonel J. J. Abert. Despite his indifferent academic record and lack of specific training in any of the natural-science fields, Abert proved a remarkably keen and inquisitive observer. Seemingly interested in everything he saw, his journals are filled with detailed descriptions of the fauna and flora (their scientific names are scattered liberally through his account), the dress and customs of the Indians he encountered and the sometimes humorous day-to-day happenings as they travelled. Moreover, he was a writer of substantial ability and many of his observations are made in almost poetic terms, reflecting a deep appreciation for the beauty of nature.

Progressing southward from the Arkansas River, Abert's party crossed Raton Pass into New Mexico on 24 August, Abert (p. 18) commenting that:

> We have now reached a great mineral country; but as no specimens fell immediately within our reach we thought it inadvisable to venture into the mountain in a search which might prove unsuccessful, and require



FIGURE 3. James W. Abert.

> our party to be delayed in a country where we were likely to be arrested by the govemment, and deprived of all our notes and papers.

Abert realized that he was entering Mexican territory illegally and was fully aware of the fate that had befallen Pike's expedition. Gold was thought to be found "in almost every portion of New Mexico," but the mines were primitive. Abert expressed the opinion that if the U.S. could take control of the territory, enterprising Americans could reap rich rewards.

The party progressed along the west side of the Canadian River towards its junction with the Vermejo (Fig. 4), exploring on 25 August a region of parallel "trap dikes." They examined these volcanic rocks closely and Abert recorded (p. 20) that they were composed of "a pretty hard and compact green stone, crystallized in somewhat regular hexagonal prisms, with their axes horizontal and perpendicular to the cooling surface." The formation of these dikes was attributed to injection of molten rock into parallel fissures produced by "violent subterranean disturbances," followed by erosion of the surrounding softer rock, leaving the harder dikes exposed as elongate buttes. These dikes are visible today to the west of Eagle Tail Mountain, about 15 miles south of Raton. A little farther south the party saw "slate bluffs of a fine quality, an indubitable proof of the existence of coal" (p. 20); however, these were most likely exposures of the dark-gray Pierre Shale rather than the coal-bearing formations of the Raton area.

By the end of August, Abert's group had progressed laboriously through the gulleys of tributaries of the Canadian, viewed the deep canyons cut by the Canadian in a number of places and was heading southeastward from the mouth of the Mora River across increasingly barren prairies. On 31 August, after descending the Canadian River escarpment east of the present town of Mosquero, they camped on a tributary (probably Mosquero Creek) of the "Arroyo de los Yutas" (Ute Creek). Earlier that day Abert had correctly identified the lower strata exposed in the area as "the new red sandstone" (of Triassic age) and was impressed with its vivid red coloration, commenting (p. 27) that it was "of a color so remarkably bright, that, should a painter, in sketching the landscape, give it the true tone of color, he likely would be censured for exaggeration."

Two more days brought them back to the Canadian River near the present town of Logan, where they inadvertently started a prairie fire that raged for at least a day. Abert described the scene in striking terms (p. 31):

> The sky overhead still shrouded with clouds, which glared with the bright red reflections; the strong black which the night threw around, and the vivid light of the fire, formed a "chiaro oscuro" which would have charmed a lover of Rembrandt. The crackling of consuming vegetation, and the low murmurings of the whirling eddies of wind which skirted the burning edge, deepened the impression of the scene of grand sublimity.

After crossing the Canadian River, the party following the river eastward, feasting on native plums, grapes and prickly-pear fruit and supplementing their diet with wild turkeys, ducks and even a skunk. On 5 September they crossed the present Texas–New Mexico border and near it found, in the "new red sandstone" (p. 33):

> . . . some large petrified logs, in which the ligneous matter had been replaced by some ferruginous composition, which, by long exposure to the wind and rain, had become so completely oxidized, that, had it not been for their peculiar shape, they might have been mistaken for large pieces of iron ore.

Continuing eastward through Texas, the expedition reached Maysville, Arkansas, on 27 October, and St. Louis on 12 November, where the wagons and other equipment were sold. By 27 November Abert was

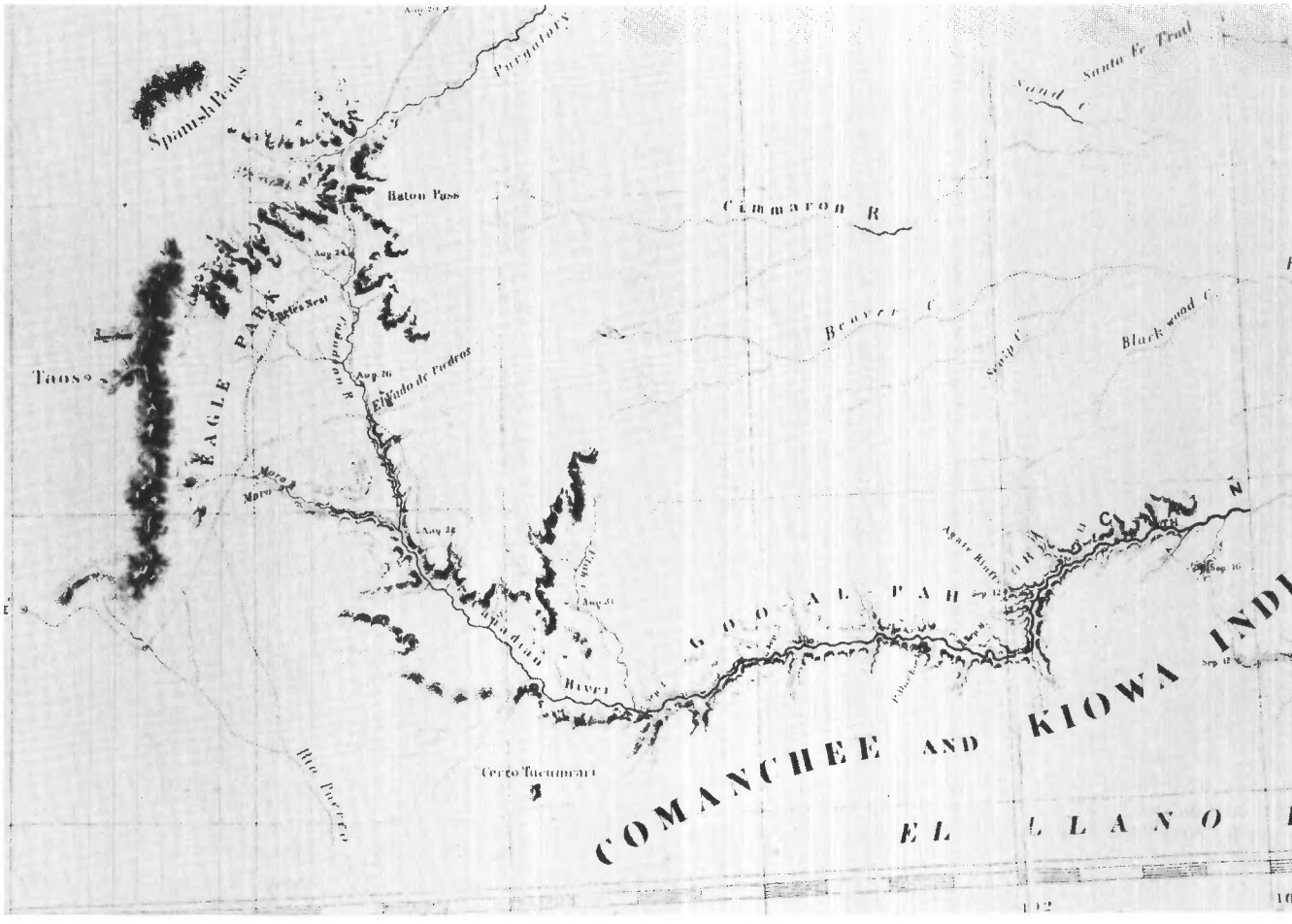


FIGURE 4. Part of James W. Abert's (1846) map of northeastern New Mexico, showing route of his 1845 expedition along the Canadian River and the geography as then known.

reporting the results of his travels to his superiors in Washington, D.C.

Although Abert's geological observations were cursory, the other observational information he provided contributed significantly to American understanding of the geography of east-central New Mexico, and of the fauna, flora and Indians of the area he traversed. And his information was immediately useful, for less than six months after his return to Washington the Mexican–American War broke out.

THÉ AMERICAN INVASION, 1846

The Army of the West

The United States declared war on Mexico on 13 May 1846. Kearny's forces at Ft. Leavenworth were ordered to march to New Mexico and thence to California. Several Corps of Topographical Engineers officers were assigned to the Army of the West, with instructions to collect data on everything of a military, scientific and economic nature that would give the government some idea of the regions traversed. Of particular importance was the accurate determination of latitudes and longitudes, for the U.S. still had no trustworthy record of the geography of most of New Mexico and other areas that might fall under American jurisdiction. It was clearly understood that the scientific mission of the Topographical Engineers officers was to be subordinated to military duties if fighting occurred.

Lieutenant William Hemsley Emory was selected to be Kearny's chief Topographical Engineers officer, supported by lieutenants Warren, Peck and Abert. On 6 June, one day after being ordered to the West, Emory and his assistants left Washington and three weeks later joined Kearny's 1850-man army in Ft. Leavenworth. They began the march down the Santa Fe Trail towards Bent's Fort on 28 June, arriving there in late July, and on 2 August started south towards Raton Pass. Abert, however, had become deliriously ill and was left at Bent's Fort to recuperate. Thus, only Emory's journal (Emory, 1848) directly documents the progress of the Army of the West through New Mexico. Abert followed in September when he was well enough to travel and spent the rest of the year exploring central New Mexico (Abert, 1848), while Kearny and Emory pushed on to California.

Emory possessed all of the best qualities of an officer of the Corps of Topographical Engineers. A man of stern demeanor and picturesque language, he was the perfect image of a frontier soldier (Goetzmann, 1959). Yet, he counted as his friends many of America's most influential natural scientists, and it was in part due to his efforts that the Corps typically paid a great deal of attention to scientific observations on their surveys. His account of the Mexican War expedition is succinct and devoid of the literary embellishments that characterized Abert's journals. It contained, however, a wealth of detailed observations that helped to fill the existing large gaps in knowledge of New Mexico's geography, agriculture, industries and people. Emory collected specimens, measured streams, determined altitudes, evaluated roads, plotted locations and distances, explored Indian ruins, selected and surveyed the site of the first American fort in New Mexico (Fort Marcy in Santa Fe) and speculated on the practical value of the new territory's resources. After the war he served as Boundary Commissioner, helping to establish the southern boundary between the U.S. and Mexico, served with bravery in the Civil War, retired as a general and died at the age of 76 in 1887.

The Army of the West crossed Raton Pass and entered New Mexico on 7 August. Emory noted sandstone deposits eroded into the appearance of castles on top of Raton Pass; these are probably units of the Upper Cretaceous Trinidad Sandstone or possibly sandstones within the Upper Cretaceous–Paleocene Raton Formation. Although coal beds are not uncommon in the Raton Pass area, Emory apparently did not observe coal until he reached the main branch of the Canadian River, several miles farther south. There he found pieces of coal in an anthill and scattered in lumps over the surrounding prairie, the result of erosion from the Vermejo highlands to the west. Two days later, following the western bank of the Canadian southward, he began to see the "trap dykes" that Abert had reported the previous year, but did not have the opportunity to examine them closely. The army turned southwest away from the Canadian River, crossed Cimarron, Rayada and Ocate Creeks, and entered an area of extensive late Tertiary basalt flows, the Ocate volcanic field, now known to extend from Wagon Mound on the southeast nearly to Eagle Nest on the northwest. Emory's observations were remarkably perceptive for their time:

> The hills are composed principally of basalt and a porous volcanic stone, very hard, with metallic fracture and lustre, traversed by dykes of trap. The lava is underlayed by sandstone. From the uniform height of these hills, one would think they originally formed the tableland, and that the valleys had been formed by some denuding process, and their limits determined by the alternate existence or non-existence of the hard crust of volcanic rocks.

This volcanic field is now known to consist of basalts, andesites and dacites erupted from several centers in five pulses during the period from 8.3 to 0.8 million years ago (Nielsen and Dungan, 1985). In recognizing the effects of lithology in influencing the degree of erosion, and in attributing the development of the landscape to a continuous process like erosion (rather than proposing a catastrophic explanation), Emory demonstrated that he was familiar with the latest trends in geological thinking.

Geological matters were largely forgotten, however, as reports began to come in of a Mexican army being assembled against them near Santa Fe. Kearny's army camped near the present site of Watrous on 13 August and marched unopposed into Las Vegas on the morning of 15 August. After establishing control of the town, amid rumors of 600 Mexican soldiers waiting to oppose them "in the gorge of the mountains" two miles from Las Vegas, the Army of the West headed out to give them battle later that same day, but found the Mexican force to be nonexistent. Leaving the gorge (today known as Puerto del Norte, or Kearny's Gap—cut by Agua Zarca Creek into the Crestone), the army marched to Tecolote and from there essentially followed the Santa Fe Trail (now the route of I-25) past the Pecos ruins to Santa Fe, which they entered, still without opposition, on 18 August. Given the perceived ever-present danger of being attacked, and the fast pace at which the army was moving, it is not surprising that Emory had little opportunity to examine the geology along their route. Between Las Vegas and Santa Fe he noted only a "perpendicular wall, 2,000 feet high" with "an immense stratum of red earth" in the Bernal–San Miguel area (the Permian Sangre de Cristo–Yeso sequence exposed on the sides of the large unnamed mesa just south of I-25), and the presence of granite south of Santa Fe. The Army of the West remained in Santa Fe for about two weeks before departing on 2 September to head down the Rio Grande and eventually west through the Santa Rita copper mines to California.

James W. Abert

Meanwhile, Abert was recovering slowly at Bent's Fort. The men of the fort brought him specimens of plants, animals and minerals to examine, and his restless mind turned to studying the Comanche language, resulting in the compilation of an elementary guide to its vocabulary. By 9 September he was well enough to continue to New Mexico. Travelling south to Raton Pass, Abert discovered coal beds and made a collection of fossil plants (from the Raton Formation, on the north side of the Pass), crossing into New Mexico on 19 September. Eager to reach Santa Fe before the Army of the West moved on, Abert and two companions left the party they were travelling with and hastened forward along a route very close to that taken by Kearny and Emory the month before. Abert noted layers of "amygdaloidal trap of a dark purple color and vesicular" and basalt-capped mesas between Rayada and Ocate Creeks, and "hard blue limestone" along the road between Sapello Creek and Las Vegas, but these were hurried observations with no attempt at interpretation. He finally arrived in Santa Fe on 27 September only to learn that Kearny's army had left, but he found orders directing him and Lieutenant Peck, who had become sick in Santa Fe, to carry out a survey of New Mexico and construct an accurate map of the territory.

During the next three months Abert and Peck explored central New Mexico, travelling to the gold mines east of the Sandia Mountains, then south to Abo Pass at the southern end of the Manzano Mountains, and ranging west to the Cretaceous deposits along the Rio Puerco and around the Pueblos of Laguna and Acoma. Then Abert was ordered to Wash-

ington to report firsthand on conditions in New Mexico and complete his maps. He had originally planned to return along his Canadian River route of the previous year, but learning from the trader St. Vrain that the Comanches were determined to kill every white man who passed through their territory, Abert decided to head north to Bent's Fort and then east through Kansas. He left Santa Fe on 28 December in a driving snow storm and progress was slow. Despite almost continuous inclement weather, Abert found time to search again for fossil plants in the Raton Pass area (14 January). Believing that the coal beds and plants were of Carboniferous age, based on the age of coal beds in the eastern U.S., Abert unsuccessfully looked for fossilized ferns, but could only find dicotyledonous leaves. Whether this changed his mind about the age of the plants is not known, but J. W. Bailey, to whom the specimens were given for study, noted correctly (Bailey, 1848, p. 131) that:

> It is thus established beyond a doubt [on the basis of the plant fossils collected by Abert], that the deposit of coal at the Raton is not the equivalent of the great coal formation of the United States, but is of a much more recent origin. . . .

Considering the freezing temperatures and snow and ice on the ground, Abert's paleontological efforts can only be regarded with admiration.

Abert stayed only briefly at Bent's Fort before heading east in late January. This part of the trip turned into a struggle for survival. Travelling in terrible weather, harassed by Indians and bands of starving wolves, and with a loss of draft animals which forced some of the men to pull the wagons, the party very nearly perished. In order to lighten the load, Abert regretfully cached most of his books and papers (they were later recovered), but would not part with his specimens. They finally reached Ft. Leavenworth on 1 March 1847. Abert's journal entry for that day (p. 130) reveals that the hardships he endured had not extinguished his sensitivity to the beauty of nature:

> There was a majesty in the lofty groves which now surrounded us, and a music in the plash of the wild duck as it lit upon the bosom of the river; there was music even in the scream of the parroquette that swept over our heads; there was a charm in everything, for we now really felt that our trials were at an end.

Abert's (1848) report of his survey of New Mexico provided an accurate picture of the newly conquered territory, although it touched only tangentially on east-central New Mexico, which was not included on the map that accompanied the report. The specimens he brought back for Bailey to study were the first New Mexico fossils to be described and illustrated in the published literature. Abert himself never returned to New Mexico and participated in no subsequent exploring expeditions. He served for a time as a professor of art, English and moral philosophy at West Point, fought in the Civil War and then became a professor of mathematics and drawing at the University of Missouri.



FIGURE 5. Adolph Wislizenus.

Adolph Wislizenus

About one month after the reports of Emory and Abert appeared in 1848, the account of another expedition through New Mexico was published. This was written by Adolph Wislizenus (Fig. 5), a St. Louis doctor who was "a German by birth and an American by choice" (Wislizenus, 1848, p. 4). A medical partner of the noted botanist George Engelmann, Wislizenus, on his own initiative, embarked upon a scientific expedition through New Mexico and northern Mexico in 1846, which brought him into eastern and central New Mexico two months before the Army of the West. After exploring part of New Mexico and Chihuahua, he was caught up in the Mexican War and incarcerated near Chihuahua before being rescued by the Doniphan column and returning to the U.S. as the surgeon to that expedition in June 1847. During his travels through New Mexico, Wislizenus made extensive collections of plants, examined the geology and mines of the territory, kept meteorological tables, determined elevations by barometric measurements and "took memoranda in relation to the people—their number, industry, manners, previous history etc" (p. 3). As a natural scientist, his perspectives and purpose in recording information differed somewhat from that of the military men Emory and Abert, and a great portion of his journal is devoted to natural history. Geological observations were made on almost a daily basis and Wislizenus also appended to his journal a primitive geological sketch-map (Fig. 6) along with a summary of the geology encountered along his route (pp. 135–139).

Wislizenus began his journey near Independence, Missouri, by attaching himself to a large trading caravan led by a fellow German, Albert Speyer, headed down the Santa Fe Trail to Santa Fe and then

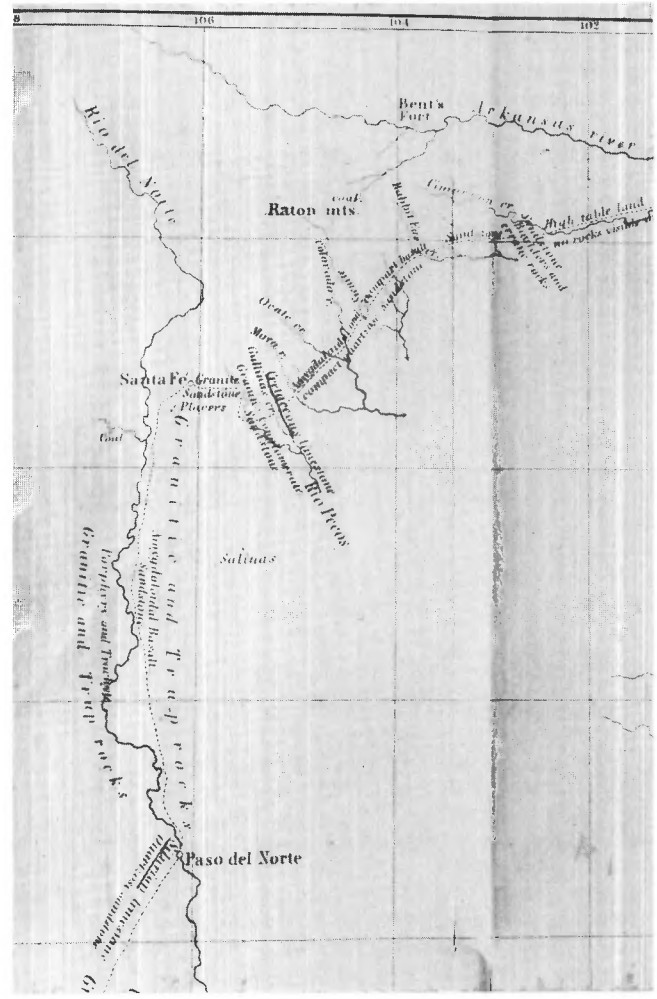


FIGURE 6. Part of Wislizenus' (1848) geological sketch-map of his route through New Mexico in 1846.

to Chihuahua. Unknown to Wislizenus, one purpose of the trading venture was to supply guns to the governor of Chihuahua (Rittenhouse, 1969). Speyer's caravan left the Independence area on 22 May, nine days after war with Mexico had been declared (though the party did not know it at the time), and about a month before the main part of Kearny's forces departed from nearby Ft. Leavenworth. Kearny, in fact, knew what Speyer was up to and sent an advance detachment to intercept him, but was unsuccessful.

The caravan took the Cimarron Cutoff branch of the Santa Fe Trail, thus avoiding Bent's Fort, where embarrassing questions might have been asked about the propriety of selling guns to officials of a country with which the U.S. was at war. It entered New Mexico northeast of the present town of Clayton on 17 June, headed towards "the Rabbit Ears," a mountain and adjacent mesa representing an older eroded volcanic center and a Quaternary shield volcano, respectively (Baldwin and Muehlberger, 1959), which was a prominent landmark on the trail (Simmons, 1984). The evening camp was along "McNee's Creek" (now called Corrumpa Creek or the Northern Branch of the Canadian River), about four miles west of the present New Mexico–Texas boundary. The crossing here was chosen for geological reasons: most of the river bed in this area contains Quaternary alluvial sands, but sandstone of the Dakota Formation is exposed locally, providing a firm crossing for wagons and livestock.

On June 18 Wislizenus reported "yellow sandstone" (Dakota Formation) along the route, as it passed along the northern side of "Rabbit Ear Creek" (now known as Seneca or Cieneguilla Creek). According to Wislizenus (p. 15):

> On the right [south] bank of [Rabbit Ear Creek] rise steep bluffs, formed by that porous, black looking basaltic rock, known as amygdaloidal basalt. . . . It forms perpendicular walls, and is found strewed over the whole river bank. Below is a compact quartzose sandstone, as if common sandstone had been changed by volcanic action. The basalt, as well as the sandstone, lay horizontal.

He further stated (p. 136) that the basalt vesicles were normally empty, but occasionally filled with lime or olivine. The basalt is the Seneca flow of the Quaternary Clayton Basalt, which is widely distributed in Union County (Baldwin and Muehlberger, 1959). The sandstone observed by Wislizenus is the Upper Cretaceous Dakota Formation, which is exposed beneath the Clayton Basalt for nearly 20 miles along Seneca Creek.

The next day, after travelling about eight miles from "Rabbit Ear Creek," Wislizenus ascended a small mountain he called "Round mound" and reported (p. 15) that the "rocks composing it appear to be basaltic, in a state of decomposition; they look brown and are sometimes very compact—sometimes more granular and friable." "Round mound" (now called Mt. Clayton) was another important landmark on the Santa Fe Trail (Pearce, 1965; Simmons, 1984). It is one of three closely spaced volcanic vents that are associated with basalt flows and a large surrounding area of cinders and basalt-derived alluvium (Baldwin and Muehlberger, 1959), for which Wislizenus' description of decomposed basalt is reasonably accurate.

The party camped that evening on "Rock Creek," shown on Wislizenus' map as a stream flowing southeastward into what is now called Ute Creek. There are several small, unnamed tributaries feeding Ute Creek from the north, but these appear to be farther from Mt. Clayton than where Wislizenus indicated the party travelled on 19 June. "Rock Creek" is most likely the modern Carrizo Creek, about 10 miles from Mt. Clayton, which flows southeastward into Texas rather than into Ute Creek. Wislizenus noted both in-situ basalt and underlying sandstone along "Rock Creek"; Baldwin and Muehlberger (1959) showed the Clayton Basalt and Dakota Formation exposed at the crossing of Carrizo Creek by the Santa Fe Trail.

The following morning, after travelling five miles, the party halted at "Whetstone Creek," where Wislizenus reported basalt and a sandstone containing lime that could be used for coarse whetstones. The identity of Whetstone Creek is uncertain, and neither Pearce (1965) nor Simmons (1984) mention it. It is probably one of the small tributaries of Ute Creek that lie east of Palo Blanco Creek, the main northern tributary. The reference to lime in the sandstone is also perplexing, as the Dakota is not known to contain a calcareous facies in this area. The only limestones nearby are in a small exposure of the Graneros and Greenhorn Formations, some two to three miles east of these tributaries, but there is no sandstone associated with these formations, which overlie the Dakota.

Continuing on through exposures of the "yellow sandstone," the caravan made 14 miles in the afternoon and reached "Point of Rocks," another major landmark. Wislizenus (p. 15) perceptively described this area as "a mass of large blocks of sienite [syenite]," recognizing its intrusive rather than volcanic lithology. Wood and others (1953) mapped Point of Rocks Mesa (which they called Pecks Mesa) as part of an exposed Tertiary sill complex consisting of a variety of relatively fine-grained igneous-rock types.

On 21 June the party reached the banks of the "Rio Colorado" or Canadian River, a short distance south of the former settlement of Taylor Springs, and about seven miles southeast of the present town of Springer. Wislizenus (p. 15) referred to another isolated hill "of very compact black basalt, underlaid by sandstone" along this day's route about 12 miles to the west of "Point of Rocks" (p. 136). No modern geologic map shows any basalt in this area, although a small outlier of Clayton Basalt is present near the trail about 4 miles west of Point of Rocks Mesa. A low hill in the location indicated by Wislizenus is capped by the Upper Cretaceous Greenhorn Limestone (Wood and others, 1953), a greenish ledge-forming sedimentary unit that might have appeared from a distance to be volcanic. Although Wislizenus does not mention it, the point where the Cimarron Cutoff branch crossed the Canadian River was almost certainly the "famed Rock Crossing of the Canadian" (Simmons, 1984), another familiar point on the Santa Fe Trail. Here the river has eroded through the surrounding Graneros and Carlile shale sequence down to the underlying Dakota Formation, allowing travellers to ford the river on a firm sandstone bottom rather than in mud.

After crossing the Canadian, the caravan progressed towards the southwest, reaching Wagon Mound on 23 June. Wislizenus ascended this eroded volcanic neck "as far as the rocks would allow," and correctly recognized its volcanic nature, stating (p. 16) that it consisted of "a compact black and spotted basalt, that rises on the top to steep, perpendicular, indented columns of about 100 feet." Wagon Mound is now known to have been emplaced during the early stages (5.5 to 8.1 million years ago) of the eruption of the Ocate volcanic field (Neilsen and Dungan, 1985). The next day, in the vicinity of Wolf Creek, basalt and underlying quartzose sandstones were encountered again; the basalts being part of the large Quaternary basalt field (dated at 0.8 to 1.4 million years: Neilsen and Dungan, 1985) associated with Maxon Crater between Wagon Mound and Watrous. On 25 June they arrived at Gallinas Creek, just north of Las Vegas, where Wislizenus (p. 17) commented, ". . . the bluffs here consist of a dark-bluish shistose [sic] limestone with fossils belonging to the cretaceous [sic] formation." These fossils were casts of the bivalve *Inoceramus* (p. 136), and they were almost certainly derived from the Greenhorn Limestone which, with the overlying Carlile Shale and underlying Dakota and Graneros Formations, is exposed along the Crestone ridge north and west of Las Vegas.

From Las Vegas the party followed the Santa Fe Trail through Tecolote, San Miguel and Pecos to Santa Fe, arriving on the morning of 30 June. Wislizenus described the sandstones that are so prominent in the Glorieta Pass area (p. 19):

> . . . all the rocks around us consisted of sandstone in the most varied forms—of common, siliceous, and calcareous sandstone, white, red, grayish, striped and spotted—sometimes looser and coarse-grained; sometimes finer and very compact.

Wislizenus was viewing the late Paleozoic sequence here, which includes the thick red sandstones of the Sangre de Cristo and Yeso Formations, the white Glorieta Sandstone and the gray San Andres Formation. He also encountered *in situ* granite for the first time a few miles south of Santa Fe. Observing geology and collecting specimens in New Mexico at this time was not without its dangers. While examining the rocks along a creekbed one early morning near Pecos, Wislizenus was ac-

costed by a party of Comanches with unfriendly intentions, but he managed to mount his horse and escape before they could attack.

While in Santa Fe, Wislizenus learned for the first time that the U.S. and Mexico were at war, and he was questioned closely by Governor Armijo as to when American troops could be expected. The war had no effect on Speyer's caravan; apparently it was "business as usual" and Armijo collected taxes ($625 per wagon) and issued passports for travel to the interior. The caravan and Wislizenus headed south after 10 days in Santa Fe, reached El Paso on 9 August, and Chihuahua on 24 August. While in Chihuahua, the news arrived of the capture of Santa Fe by Kearny's army, and Wislizenus, after escaping from an angry mob of Mexicans, was forced into exile in a small town nearby. He was released in March 1847 by Colonel Alexander Doniphan's forces, which had travelled southward from Santa Fe to invade Chihuahua as part of the American action against Mexico during the war. Unfortunately, no topographical engineer was assigned to Doniphan, and thus there are no scientific observations of his route through Santa Fe (Goetzmann, 1959).

The geological information recorded by Emory, Abert and Wislizenus was generally sketchy and restricted to isolated observations of the lithology of areas passed during their travels. Little time was available for detailed studies relating the stratigraphy of one area to another, or for searching for the fossils that would have provided definite information about the ages of the strata encountered. Wislizenus' geological sketch-map (Fig. 6), for example, provided only brief comments about the geology of his route, although he was able to identify the rocks in the Las Vegas area as being Cretaceous based on the inoceramids found along Gallinas Creek. The observations of these early explorers, however, marked a beginning in the study of New Mexico's geological record and alerted the geologists who would come later, such as Marcou and Newberry, to the rock types they could expect to find in specific areas of the territory.

MARCY AND SIMPSON, 1849

Having assumed control of New Mexico during the Mexican–American War, the U.S. also assumed the responsibility for administering the new territory fairly, increasing if possible the prosperity of the inhabitants and protecting them from the long-standing problem of Indian attacks. In addition, since the American domain now extended across the continent, measures had to be taken to maintain and enhance communications from the Mississippi River to the Pacific, in order to more securely link the eastern and western parts of the country, and, after 1848, to accommodate the flood of travellers who were heading to the gold fields of California. New Mexico at this time (1850–1863) encompassed not only the area of the present state, but also all of Arizona and parts of Colorado and Nevada. This large territory lay across one potentially important east–west overland route. With a relatively mild climate and no serious mountain barriers, the Southwest could become a major artery for cross-continent travel, with accompanying economic benefits to communities in the region. In New Mexico, much more detailed information was needed concerning the topography, supplies of water, food and timber, location of suitable camping sites, potential danger from Indians and availability of road-building materials along possible routes. As the geology of an area strongly influences some of these geographic features, it became obvious that geological observations would be an important component of future explorations in New Mexico.

Even before the discovery of gold in California, some western states like Missouri had been pressing for reconnaissances to aid in developing overland roads and perhaps eventually a railroad across the Southwest. As a consequence, in early April 1849 Colonel Randolph B. Marcy (Fig. 7) was ordered to lead a military party and large group of emigrants from Fort Smith, Arkansas, to California. In addition to establishing the best route through the Southwest, protecting the gold-seekers, and conciliating the Indians of the area, Marcy was also ordered to:

> . . . cause an accurate examination of the country, survey, and measurement of the road travelled to be made, keeping a correct journal of each day's march; noting the distances between good camping places; whether wood and water are to be met with in abundance; and, in short, embracing all subjects worthy of observation, or that may be of interest or service to the future traveller (Marcy, 1850, p. 170).



FIGURE 7. Randolph B. Marcy (Photo courtesy of the Museum of New Mexico, Neg. No. 10311).

Marcy was assigned one of the brightest members of the Army Topographical Engineers, Lieutenant James H. Simpson, to act as topographer and assistant during the expedition. Marcy's party left Fort Smith with about 80 soldiers and a long wagon train of emigrants on 4 April 1849; Simpson joined the party several days later.

Marcy was an infantryman 37 years of age and a veteran of the Mexican–American War. He was to serve long and ably on the frontier in the 1850's, attain the rank of general in the Civil War and retire as Inspector-General of the Army in 1881. Simpson, one year younger than Marcy, was embarking on his first expedition to the West. He was almost continuously in the field until the outbreak of the Civil War, establishing a brilliant record as an Army explorer. After the war he served as Chief Engineer of the Department of the Interior, and in other positions as an engineer until his death in 1881. Marcy's report (1850) is the main record of the expedition; Simpson (1850) contributed a shorter report that summed up his observations and recommendations. Both men also produced maps of the geographic features observed along their route.

The expedition followed the Canadian River through Oklahoma and Texas, entering New Mexico on about 15 June, after traversing a spur of the Llano Estacado. Marcy's description of the Llano gave faint prospect that civilization would ever exist there (p. 185):

> When we were upon the [Llano Estacado], a view presented itself as boundless as the ocean. Not a tree, shrub, or any other object, either animate or inanimate, relieved the dreary monotony of the prospect; it was a vast, illimitable expanse of desert prairie—the dreaded "Llano Estacado" of New Mexico; or, in other words, the great Zahara [sic] of North America. It is a region almost as vast and trackless as the ocean—a land where no man, either savage or civilized, permanently abides; it spreads forth into a treeless, desolate waste of uninhabited solitude, which always has been, and must continue, uninhabited forever. . . .

By 17 June the party had reached the vicinity of the north end of Mesa Redonda and during the next two days travelled along the Plaza Larga, accompanied by a large group of Comanches. Both Marcy and Simpson made some general observations of the geology, and Simpson reported Cretaceous fossils from the sequence exposed here (see Kues,

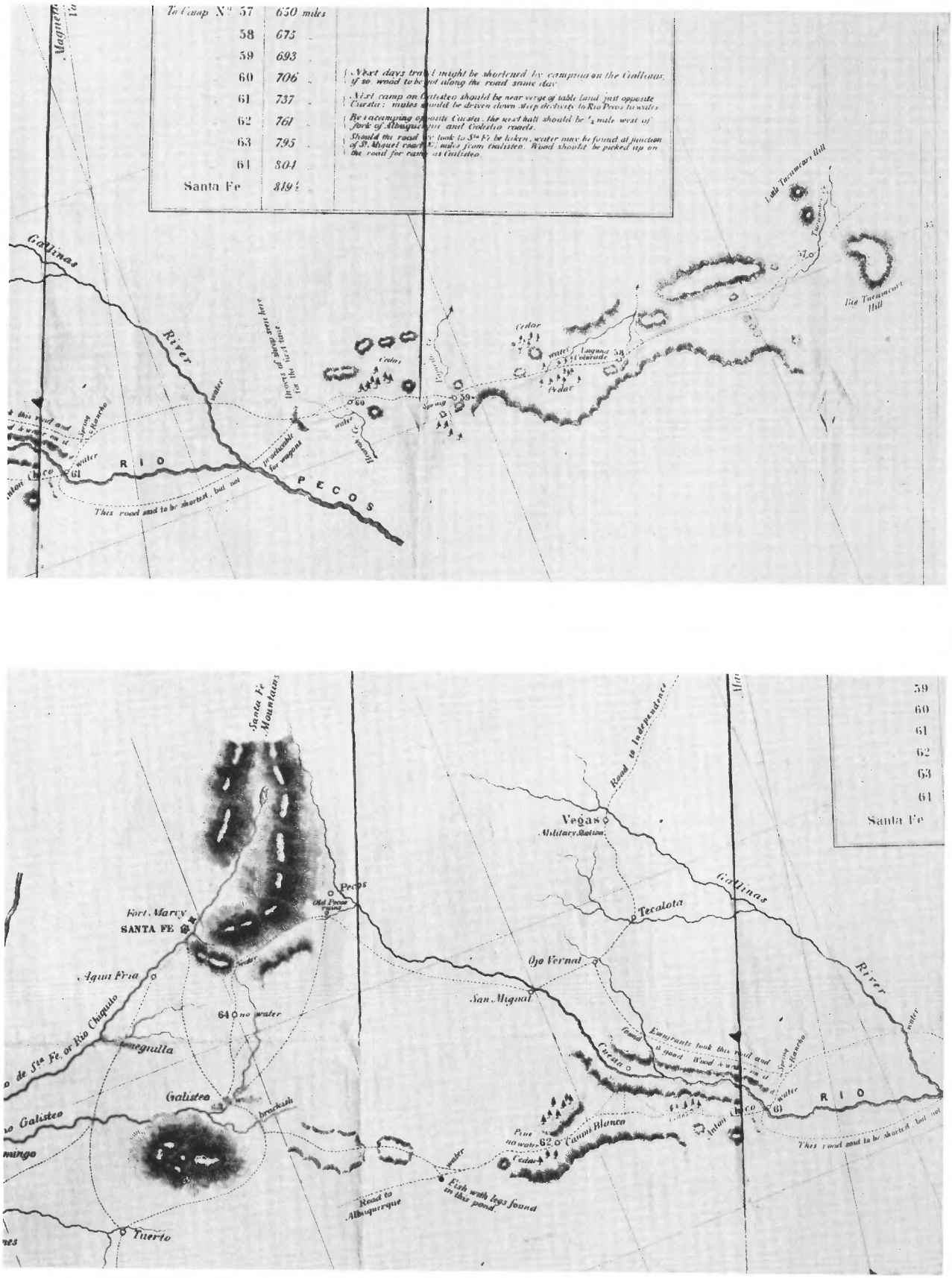


FIGURE 8. Part of Simpson's (1850) map of east-central New Mexico, showing geographic features and the route of the Marcy expedition in 1849. Upper portion, area from Tucumcari Mountain to Anton Chico; lower portion, area from Anton Chico to Santa Fe and Galisteo.

1985, for further description of their geological observations concerning the Tucumcari area). Marcy attempted to establish peaceful relations with the Comanches, but considered some of their customs, particularly regarding the treatment of their women, revolting. Simpson had an enlightened view of how the Indians should be treated (Simpson, 1850, p. 16–17):

> I feel confident that the proper way to subdue the wild Indians into a generous return of good feeling and favor, is to act generously toward them ourselves, and not, as I have heard some—I trust they are but few—inculcate—that in order to self-preservation, we should not wait for an attack, or a demonstration of an attack, but shoot them down to prevent it.

Moving westward, the party camped at "Laguna Colorado" (near the present town of Montoya) on 20 June, then at "Pajarito Creek" (which actually was Cuervo Creek rather than the stream presently called Pajarito Creek) and "Hurrah Creek" (Esteros Wash), before crossing the Gallinas River and reaching Anton Chico on 23 June. At this point, instead of taking the usual route to Santa Fe by heading north to Bernal and thence to San Miguel, Pecos and Santa Fe along the Santa Fe Trail, Marcy chose to take a route to the south. Passing along the western side of the Pecos River, they came opposite "a beautiful little town on the Pecos, called 'Questa' [the modern Villanueva]." Marcy rode to the bluffs overlooking the town:

> . . . until I suddenly and unexpectedly came upon the crest of a bluff terminating the high plain. Here, a most magnificent view presented itself, as I stood upon the top of the almost perpendicular cliff bordering the valley of the Pecos, and one thousand feet above it [an overestimation]: I could see the valley up and down the river for several miles. It is here about one mile wide, and shut in with immense walls of lime and sandstone. Casting my eyes down from this giddy height, a magnificent carpet of cultivated fields of wheat, corn, and other grains was spread out direct beneath me, with the beautiful little river winding quietly and gracefully through the centre; this, together with the Mexicans in their broad-brimmed sombreros and strangely shaped costume, plodding quietly along behind their ploughs and "carretas," and the "Sierra Blancos" [Santa Fe Mountains], covered with perpetual snow, and glistening in the distance like burnished silver as the sun shone upon them, formed one of the most beautiful landscapes that it is possible to conceive of (Marcy, 1850, p. 190).

From the Pecos River the party moved westward through Cañon Blanco, past a pond reported by Simpson (p. 18) to contain "fish with legs" (larval amphibians?), to Galisteo, entering Santa Fe on 28 June. Marcy (p. 191) noted the first appearance of "primitive" rocks in the canyons south of Santa Fe, which were composed of "huge masses of granite." Summing up his observations on the suitability of the Fort Smith to Santa Fe route for a railroad, Marcy stated (p. 192):

> . . . few localities could be found upon the continent which (for so great a distance) would present as few obstacles to the construction of a railway as upon this route. It is true that, upon its western extremity, there is but little timber except cottonwood; but, in many places destitute of timber, there are large quantities of lime and sandstone, whose divisional structures are so perfectly smooth and uniform that the masses could easily be wrought into shape, and in many cases made use of as substitutes for timber. The surface of the ground is so perfectly even and level that little labor would be required to grade the road. . . .

Simpson (p. 22) agreed that the route had many advantages if a railroad were to be considered, but declared, ". . . to my mind the time has not come when this or any other railroad can be built over this continent." Simpson believed that the cross-continent routes should be first fostered as military roads, then settled and railroads planned only after the resources and population had developed sufficiently. In this opinion Simpson ran contrary to the prevailing sentiment in the U.S., and it would be only a few more years before several routes for a railroad across the West would be surveyed in earnest. Interestingly, Simpson predicted that a railroad to the Pacific could not be completed within 20 years, an estimate that proved to be correct.

Marcy and Simpson remained in Santa Fe several weeks. Marcy eventually travelled south along the Rio Grande to Doña Ana, and then explored eastward to evaluate a southern route through southeastern New Mexico and west Texas. Simpson had originally expected to continue to California, but instead received orders to complete his report and map as quickly as possible in Santa Fe. These were sent to Washington on 15 August 1849, just one day before, in accordance with another change in orders, he departed on a military reconnaissance expedition to the Navajo country of northwestern New Mexico. During this trip he visited, and provided the first accurate description of, the Chaco Canyon ruins.

The Marcy expedition provided some additional information about the geology of east-central New Mexico, such as establishing the existence of Cretaceous strata in the Tucumcari area, but its main value was geographical. Because neither Marcy nor Simpson were trained as geologists, their observations were limited and descriptive rather than synthetic, but they did realize the importance of geological information (e.g., Marcy's statement quoted above). Their maps, especially Simpson's (Fig. 8), added considerably more accurate information about landforms, rivers and distances than were previously available, and established the Canadian River route as a strong contender for future consideration as a railroad route.

WHIPPLE AND MARCOU, 1853

By 1853 interest in a transcontinental railroad had increased to the extent that at least eight routes were advanced as possibilities. Each of these routes was vociferously advocated by local groups in the Mississippi River region, from Chicago to Vicksburg, which would stand to benefit from increased land values and control of western commerce if their city or town were chosen as the eastern terminus of the railroad. This situation represented an almost unsolvable political dilemma and Congress, in an attempt to at least narrow the field of potential routes, passed the Pacific Railroad Survey bill in March 1853. This bill appropriated $150,000 for surveys of three of the most politically expedient routes by the Corps of Topographical Engineers. One of these routes, along the 35th parallel of latitude through the Tucumcari area, passed through New Mexico, and later in the year funds were diverted to provide for additional exploration of another route—along the 32nd parallel through Texas and southern New Mexico—that was favored by some members of the Corps as well as by many Southern interests. All surveys and final reports were to be completed in the impossibly short time of ten months.

Lieutenant Amiel Weeks Whipple (Fig. 9) was chosen to lead the 35th-parallel expedition and directed to concentrate on the area between Zuni and the Colorado River, as the eastern New Mexico segment of the route was considered to be fairly well known because of the information provided by Gregg, Abert, Marcy and Simpson. Whipple's party, well staffed with scientific personnel but short on instruments such as transits and barometers, departed from Fort Smith on 14 July 1853. Jules Marcou (Fig. 10), who had recently published a geologic map of the United States and who was a protege of Louis Agassiz, was the "geologist and mining engineer" of the expedition.



FIGURE 9. Amiel W. Whipple.



FIGURE 10. Jules Marcou.

Whipple's party proceeded westward along the southern side of the Canadian River and entered New Mexico on 19 September. The next day they began encountering Cretaceous fossils in creek beds that had eroded from the Llano Estacado, a short distance to the south, and on 21 September reached the vicinity of Mesa Redonda and Tucumcari Mountain. Marcou made numerous geological observations along this part of the route. However, because of a disagreement between him and Secretary of War Jefferson Davis after the expedition was finished, William P. Blake wrote the geological report for the Whipple expedition (Blake, 1856a) and published a translation of Marcou's field notes which were written in French (Blake, 1856b). Marcou contributed a brief discussion to the preliminary version of Whipple's report (Marcou, 1855a), together with summaries of the geology that were published in Europe (Marcou, 1855b, 1858). Additional information on the geology along the route, no doubt provided to Whipple by Marcou as they travelled, appears in Whipple's report (Whipple, 1856). Both Marcou (1858) and Blake (1856a) produced geologic maps of the route (Figs. 11, 12), Marcou's being the more detailed and accurate because he had actually examined the geology, whereas Blake had never visited New Mexico. Marcou's geological studies in the Tucumcari area, particularly his identification of the Llano Estacado sequence as consisting of Triassic and Jurassic strata, touched off a controversy that lasted more than 40 years (fully documented elsewhere in this guidebook: Kues, 1985).

Whipple's expedition passed leisurely through the Plaza Larga valley west of Tucumcari Mountain on 23 September and progressed through the gap between Palomas Mesa and Luciana Mesa, camping that night on a tributary of Pajarito Creek, near the present town of Newkirk. Whipple (1856, p. 39) noted red sandstone along the bluffs which might be easily quarried and used as building material, and Marcou (Blake, 1856b, pp. 138–139) observed that the white and yellow Jurassic sandstones, that had overlain the Triassic redbeds earlier, disappeared as the Llano Estacado (Luciana Mesa in this area) turned towards the south. The following day the party was "constantly on the upper Trias" (Blake, 1856b, p. 139), an accurate enough observation in view of the wide expanse of Chinle and Redonda exposures west of Newkirk. Marcou (Blake, 1856b) also reported a conical mound near the route that was capped by Jurassic strata (probably Cuervo Hill, which has the Jurassic Exeter and Morrison Formations near its summit). Marcou's map (Fig. 11) shows several other isolated areas of Jurassic to the north of the route, presumably mesas such as those known today as Mesas Cherisco and Pino. These structures are capped by the light-brown Cuervo Sandstone Member of the Chinle, which could easily have been mistaken for the similarly colored Jurassic formations by a traveller seeing it from a distance. The party camped on the night of 24 September on "Hurrah Creek" (Marcou's map), or "l'Assisteros" as it was called by Whipple (the modern Esteros Creek), a few miles east of the junction of the Pecos and Gallinas Rivers, and stayed there to rest on the 25th. The botanist Bigelow explored southwestward to a "cañon cut almost perpendicularly through the plain to a depth of 500 feet" (Whipple, 1856, p. 41), somewhat of an exaggeration for the 200- to 300-foot cliffs above the Pecos north of Colonias.

The following day, 26 September, the party crossed the Gallinas River and an advance detachment entered Anton Chico that evening, with the main group arriving the following morning. Marcou (Blake, 1856b, p. 139) observed "greyish-white limestone with the nodular structure of the Llano, which must be Jurassic" near camp, but stated that most of the day was spent traversing the red sandstone and clays of the upper Triassic (=Chinle Formation). These limestones may have been calichified pediment deposits overlying the Triassic units, because the party appears to have been too far east of the Pecos River during the morning to have encountered the Upper Permian limestones exposed along its side. Blake (1856a, p. 27) stated, however, that from the Gallinas River to Anton Chico the route was on "the gypsum formation," indicating that the party did traverse exposures of the San Andres Formation as they neared Anton Chico from the east. Marcou also noted granitic and basaltic diluvium in the valley of the Gallinas River, and to the northeast "high hills, forming table-lands, the summit of which

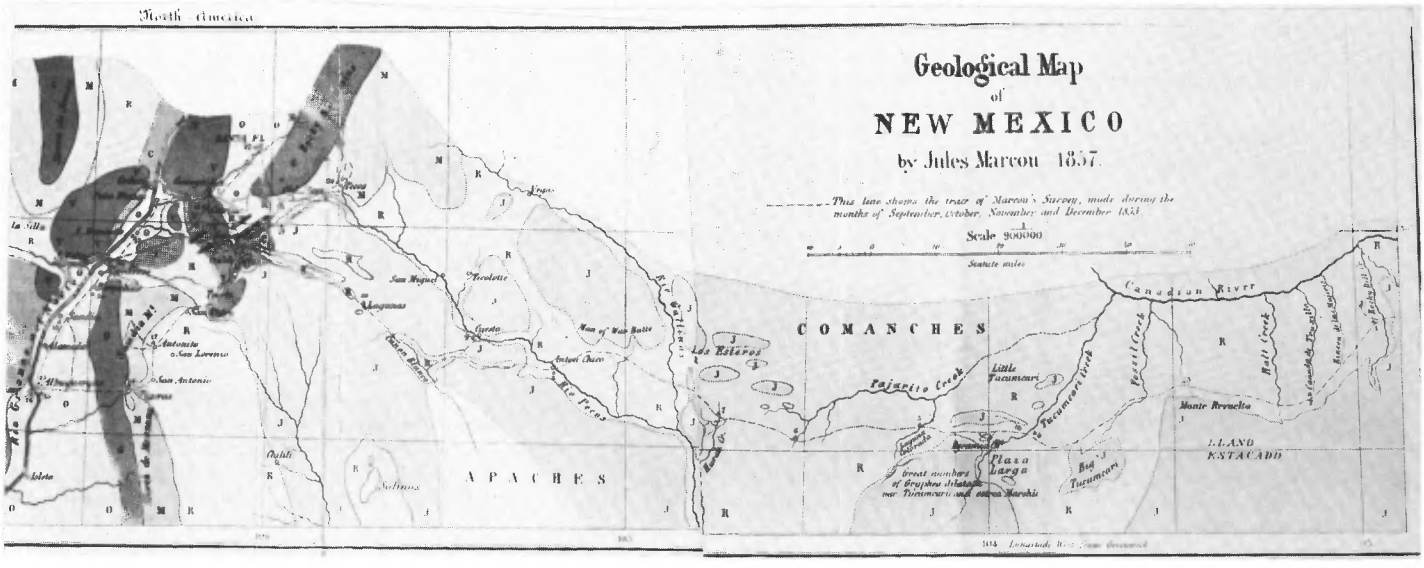


FIGURE 11. Part of Marcou's geologic map of New Mexico along the 35th parallel. V, volcanic rocks; G, granite; M, Carboniferous; R, New Red Sandstone (Triassic); J, Jurassic; C, Cretaceous; O, Quaternary.

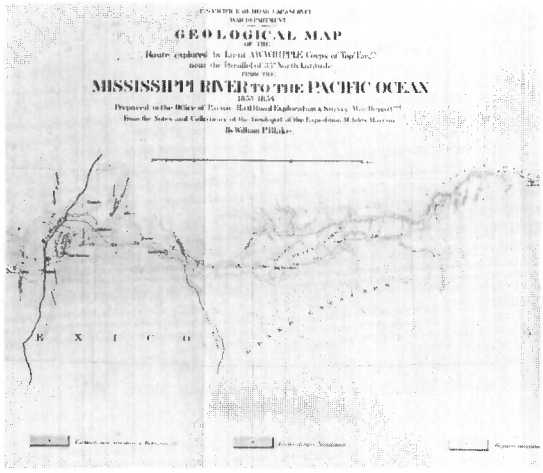


FIGURE 12. Part of Blake's (1856a) map of the geology of New Mexico along the 35th parallel. 1, granitic and metamorphic rocks; 4, Carboniferous limestones and Devonian(?); 5, Carboniferous sandstone; 6, Gypsum formation; 7, Cretaceous.

must be Jurassic, judging from the color of the rocks (Blake, 1856b, p. 139). Marcou's map shows a large area of Jurassic ("Man of War Butte") surrounded by Triassic exposures that stretched from near Anton Chico northward and west of the Gallinas River nearly to Las Vegas. This is Apache Mesa, which is primarily composed of the Jurassic Exeter and Morrison Formations, capped by the Cretaceous Dakota Sandstone.

Marcou's identification of Jurassic strata above the Triassic redbeds in the area from Tucumcari to Anton Chico was based on his identification of fossils he believed to be Jurassic near the top of the sequence at Pyramid Mountain, southwest of Tucumcari Mountain. These fossils were later determined to be Early Cretaceous in age (see Kues, 1985), but the thick, unfossiliferous units between the Triassic and the fossil horizon are indeed Jurassic, as Marcou maintained against the nearly unanimous criticism of most American geologists of the day. These geologists, including Blake, did not accept Marcou's determination of either the Triassic or the Jurassic in this region. They believed the fossil horizon was Upper Cretaceous and considered the entire sequence likewise to be Cretaceous. Thus, Blake's geologic map (Fig. 12) published with the Whipple report shows only Cretaceous exposures from Tucumcari westward past Anton Chico and northward to Pecos and Las Vegas. Although he did not recognize the Cretaceous in this area, Marcou's concept of the regional stratigraphy, with its extensive exposures of Triassic and Jurassic units, stands today as a more perceptive and accurate portrayal of the stratigraphic sequence here than was Blake's. This should not be surprising, as Blake and Marcou's other critics had never been in New Mexico.

Remaining near Anton Chico on 27 and 28 September to rest and wait for the swollen Pecos River waters to subside, the party divided into two groups on the 29th. The main party headed west towards Albuquerque, while Whipple, Marcou, Bigelow and an adventurous German explorer named Baldwin Mollhausen rode northward to the town of La Cuesta (Marcy's Questa, now Villanueva), essentially retracing Marcy's route of four years before. Marcou (Blake, 1856b, p. 139) described the cliffs above this town on the Pecos as consisting of "a beautiful section of the upper Trias and lower Jurassic," the upper two-thirds of which were said to be Jurassic. Here Marcou was in error, for this part of the Pecos cuts deeply into the Permian section. The white Glorieta Sandstone and the gray-to-white San Andres Formation are extensively exposed for many miles along the Pecos north of Anton Chico, and these units overlie the redbeds of the Yeso Formation near Villanueva. Marcou's "sandy and marly dolomite" and intercalations of "greyish-white marly beds" in the "white Jurassic sandstone" probably refer to calcareous and gypsiferous San Andres lithologies and suggest that he mistook the Glorieta and San Andres Formations for the sandstone-dominated Jurassic interval he had identified to the east. The Yeso must have appeared to be a continuation of the Triassic redbeds so prevalent along Marcou's route of the previous few days.

The following day, realizing that the steep cliffs along the Pecos precluded any possibility of a railroad crossing, Whipple's party continued westward through Cañon Blanco, overtaking the main body of the expedition at Lagunas. Marcou (Blake, 1856b, p. 140) stated that the bottom of the canyon was Triassic, overlain by "white and yellow Jurassic sandstone, with some interposed beds of grey marls, and a greyish-white nodular limestone." Again Marcou failed to recognize that this sequence was Permian. The same Yeso–Glorieta–San Andres succession that is exposed along the Pecos is also present in Cañon Blanco and for a distance of 8 to 10 miles to the north and south of the canyon. The absence of fossils along this part of the route undoubtedly hindered the age determination of these rocks, but Marcou also failed to perceive the correct stratigraphic relationships of the true Triassic strata above the Permian sequence as he was moving west from Anton Chico. This relationship should have been visible, for the lower part of the Chinle Formation is exposed on the summit of structures such as Ciruela Mesa, which was within sight of Marcou's route through the area. Closer attention to the details of the stratigraphy would have revealed that the Triassic units lay above another red unit (the Permian Bernal Formation, which Marcou, if he had observed it, would have probably considered Triassic). The Bernal, in turn, overlies the gray and white Glorieta–San Andres part of the sequence to the north and west.

On 1 October the party again divided, one group, including Marcou, moving northwest towards Galisteo and the other west towards Albuquerque. The first group proceeded up several arroyos and creeks to the "Arroyo de la Xara" (now called Arroyo de la Jara), was treated to a view of the Santa Fe and Jemez Mountains far to the north and the "Gold Mountains" (Ortiz Mountains) to the west, and camped near the Galisteo village plaza that evening. Marcou (Blake, 1856b, p. 140) described the day's route as mainly upon the upper Triassic, but near Galisteo it crossed a belt of white to yellow, concretionary Jurassic sandstones that formed a line of north–south-trending hills. The strata in these hills dipped "east and west" at angles of 15 to 60 degrees. Such a line of hills, called the "White Bluffs" on recent topographic maps, is present about 7 miles southeast of Galisteo, where the Arroyo de la Jara has cut through them. These hills consist of Triassic redbeds at their base, overlain by the Jurassic Entrada and Morrison Formations, and fit the description given by Marcou. The Entrada especially is a conspicuous white to light-yellow, cliff-forming sandstone that would hardly have failed to be noticed by Marcou.

The following day, 400 yards north of Galisteo, Marcou (Blake, 1856b, p. 140) noted a "trap dyke" ten feet wide that he believed cut through yellowish-white Jurassic sandstones, and stated that the "beds of the Trias beyond are upheaved." Later, Marcou (1858, p. 56) stated that the dike cut through the New Red Sandstone (Triassic). This dike, a microdiorite of Oligocene(?) age (Johnson, 1975), is a prominent structure about 0.9 miles north of the present town of Galisteo and trends nearly east–west, cutting through the Eocene Galisteo Formation rather than through Triassic or Jurassic rocks. The Galisteo is predominantly a thick, dark-red to white sandstone unit (Gorham and Ingersoll, 1979) and would have appeared to Marcou to be lithologically similar to the Triassic or Jurassic strata to the east.

From Galisteo the Whipple expedition proceeded to the Rio Grande via Cerrillos and La Cienega and moved southward to Albuquerque, arriving on 5 October. The party was forced to wait there for several weeks until supplies could be procured. Marcou took advantage of the delay to survey Tijeras Canyon and the Sandia Mountains, the gold mines east of the Sandias and as far north as Pecos and Santa Fe before returning to Albuquerque to rejoin the expedition. These explorations in central New Mexico yielded considerable geological and paleontological data, but, as they are generally outside the northeast quadrant of New Mexico, will not be discussed in their entirety here. However, Marcou's return to Galisteo and visits to Pecos and Santa Fe on 12–15 October are summarized, as they do fall within the scope of this paper.

12 October found Marcou and Bigelow travelling north from Tuerto (north of the present village of Golden: Pearce, 1965) around the east side of "Gold mountain" (Ortiz Mountains), through deposits of yellow sandstone and gray sandy clays, which Marcou called Jurassic, that were situated "horizontal against a mountain of quartzose granite" (Blake, 1856b, p. 144). These beds Marcou traced with little interruption to northeast of Galisteo, and Blake's translation of Marcou's field notes (Blake, 1856b), punctuated by missing phrases, indicates that Marcou found "a tooth and vertebra of a Saurian," a Jurassic *Ostrea,* a species of *Inoceramus* and broken bones of fish or reptiles about three miles north of Galisteo, and specimens of the bivalve *Lucina* farther to the south.

Marcou, who disavowed Blake's publication of his field notes, considered some of the yellow sandstone in this area Jurassic, based on lithological similarity to units identified as Jurassic farther east, but he also identified Cretaceous strata in the Galisteo area. Marcou's Jurassic sandstones in the area between the Ortiz Mountains and Galisteo are actually the Upper Cretaceous Mesaverde Formation and Eocene Galisteo Formation. His map (Marcou, 1858) shows a small area of Cretaceous immediately to the east of Galisteo and more extensive Cretaceous exposures overlying the Triassic from Galisteo west to within a few miles of Algodones. Marcou's map, of course, is very general, but a sizeable part of these western Cretaceous areas are recognized today as the fossiliferous Upper Cretaceous units of the Juana Lopez Grant and Hagan basin. In his preliminary geological resume for Whipple's report, Marcou (1855a) described the Cretaceous rocks east of Galisteo as follows:

> a greyish schistose clay, containing nodules of iron and numerous plaquettes, composed of the scales and fragments of bones of fishes, belonging to the genus *Ptychodus*. In this sandstone and clay, which rest horizontally on the upheaved beds of the Trias, the Jurassic, and the Carboniferous, are found the remains of *Ammonites, Scaphite* [sic], *Inoceramus,* and the *Ptychodus,* which indicates, for the relative age of this formation, the cretaceous [sic] group, and, further, the white chalk of Europe.

Marcou was exactly correct in his assignment of a Late Cretaceous age to these fossils, and in pointing out the fact that these beds were younger than the fossiliferous Mesozoic strata he had observed in the Tucumcari area.

Later, Marcou (1858, p. 33) described a large and distinctive ray tooth from this locality as *Ptychodus whipplei,* new species, and dedicated "this beautiful species of cretaceous fish to my friend Capt. A. W. Whipple, the able and learned chief of our Explorations in the Rocky Mountains." In addition to the fossils mentioned above, Marcou also reported the small oyster *Ostrea congesta* from this locality. The locality was stated to be three miles north of Galisteo, on the road to Pecos, but this is somewhat misleading since he made his collections from the Upper Cretaceous Graneros, Greenhorn and Carlile sequence more to the east than to the north of Galisteo. The Cretaceous outcrops shown by Marcou (1858) along Galisteo Creek just to the west of the town actually represent the Tertiary Galisteo and Espinaso Formations. Fossils described from Cretaceous exposures farther to the west of Galisteo include *Inoceramus lerouxi,* new species, from the Mancos Shale exposed in "ravines along the Rio Galisteo, New Mexico, precisely at the point where the road from Santa Fe to Algodones crosses the Rio" (on the Juana Lopez grant), and the bivalves *Cytherea missouriana* Morton and *Tellina occidentalis* Morton from "a yellowish-gray limestone [possibly the Greenhorn Limestone Member of the Mancos] placed between the gray marls that occupy the country between Gold Mount and the villages of Galisteo and Algodones" (Marcou, 1858, pp. 36–37, 42). None of these three species has subsequently been reported from New Mexico.

Marcou's notes (Blake, 1856b, pp. 144–145) for the approximately 20 miles from Galisteo to Pecos are brief: ". . . we leave the Jurassic Formation, and follow canons in the Trias as far as old Pecos [the Pecos ruins], the top of the canons being of Jurassic sandstone." From his map it appears that Marcou followed the east side of Galisteo Creek for most of the distance to old Pecos, a route that would have joined the Santa Fe Trail near Glorieta, and skirted the north side of Glorieta Mesa. Marcou's map shows the Jurassic along the east side of his route all the way to Pecos. These "Jurassic" exposures, however, are actually large areas of the light-brown Triassic Santa Rosa Sandstone, which along Glorieta Mesa are underlain by a succession of Permian units, the Bernal, San Andres, Glorieta and Yeso Formations, in descending order (Budding, 1972; Johnson, 1972, 1973, 1975). South of Cañoncito, the brownish-red, Upper Pennsylvanian to Lower Permian Sangre de Cristo Formation is exposed along Galisteo Creek and occupies the entire area between Glorieta and Pecos villages. Again, as he did near Anton Chico, Marcou mistook Pennsylvanian–Permian redbeds for the Triassic, and overlying lighter-colored Permian (and in this area Triassic) units for the Jurassic.

Near the village of Pecos, Marcou examined Carboniferous limestones and collected numerous brachiopods and other invertebrates. He considered these exposures to be the "Mountain limestone" of early Carboniferous age, but other workers who examined part of his collections from the Pecos area (e.g., Hall, 1856) correctly indicated that these strata were of "Coal Measures" or Pennsylvanian age. Marcou's field notes (Blake, 1856b, p. 145) mentioned the "superior carboniferous" (Pennsylvanian) between old Pecos and Pecos, which must refer to the Sangre de Cristo Formation that overlies the fossiliferous limestones in this area, but his map shows the Triassic overlying the "Mountain limestone" here. Hall (1856) and Marcou (1858) described the taxa collected near Pecos, which included three new species. For a detailed account of Marcou's activities and fossil localities in the Pecos area the interested reader may consult Sutherland and Harlow (1973). Northrop (1961) and Kelley and Northrop (1975) reproduced illustrations of Marcou's Pecos fossils and provided additional discussion of them. According to Sutherland and Harlow (1973), Marcou's collections came from Virgilian (Upper Pennsylvanian) horizons of the Alamitos Formation.

On 14 October Marcou headed southwest from Pecos, past the southern end of the Sangre de Cristo Mountains and then north to Santa Fe, arriving there on 15 October. The route for most of 14 October was "on the Trias" (actually the Sangre de Cristo Formation), and near Santa Fe he remarked upon the rose-colored, feldspar-rich granites and "other eruptive rocks" (Blake, 1856b, p. 145). Then he travelled down the Rio Grande to rejoin Whipple's party in Albuquerque.

The Whipple expedition reached Los Angeles and disbanded in late March 1854. Whipple was enthusiastic about the suitability of the 35th-parallel route for a railroad, but he estimated its cost at a much higher figure ($169 million, an astronomical figure in those days) than was estimated for the other routes under consideration. The cost estimate was eventually revised downward, but after all of the surveys had been completed it became apparent that both Jefferson Davis and Captain A. A. Humphreys, the Topographical Engineers officer responsible for evaluating the data from the Pacific Railroad expeditions, favored the 32nd-parallel route despite the fact that Whipple's route was clearly superior and supported by a broad spectrum of political interests. The resulting impasse helped to make action on a transcontinental railroad impossible in the 1850's, and the country had more pressing concerns—the Civil War—in the early 1860's. Ironically, when the railroad was finally completed, in 1869, it was primarily along a different route than any that had been surveyed in the 1850's. And it was not until the first years of the twentieth century that a railroad was constructed along Whipple's route in east-central New Mexico.

Whipple eventually became the chief topographical engineer and a brigadier general in the Union army during the Civil War and was killed at the Battle of Chancellorsville in 1863. Marcou never returned to New Mexico after the 35th-parallel expedition, enjoying a long and controversy-filled career as a gentleman geologist in Boston before dying in 1898. Marcou's geologic studies in New Mexico were of great significance, for they provided a relatively detailed and regionally cohesive picture of the stratigraphy and geologic structures along his route, in contrast to the isolated brief observations made by earlier explorers. Moreover, Marcou correctly identified the ages of many of the formations he encountered in east-central New Mexico, and assembled and described the first moderately large collections of fossils from the state. His 1858 map (Fig. 11), and the less accurate one by Blake

(1856a) based on his observations (Fig. 12), represent the first true geological maps constructed for any part of New Mexico. Later studies would show, however, that Marcou had misinterpreted some stratigraphic sequences, and his conclusions sometimes extended far beyond his actual observations. In some areas, around Anton Chico, Galisteo and Santa Fe for example, his observations of the geology were superficial and lacked the sophistication in interpretation that Newberry would supply a few years later. Nonetheless, Marcou amassed a fair amount of generally accurate information under conditions that prohibited anything more than a brief examination of the geological features of the areas he traversed, and his work helped to lay the foundation for the more detailed studies that would follow.

NEWBERRY, 1858, 1859

Although the Whipple–Marcou reconnaissance marks the last series of geological studies of New Mexico during its first decade as an American territory, brief mention must be made of the work of John Strong Newberry (Fig. 13), who spent several months studying the geology of New Mexico in 1858 and 1859. To adequately summarize Newberry's contributions to knowledge of New Mexico geology would require far more space than is available here. His observations in central and northeastern New Mexico were characterized by a closer attention to detail and more penetrating and knowledgeable interpretations of the stratigraphy, structure and geologic history of the areas he examined than Marcou was able to produce. In areas where both men worked, like the Galisteo–Santa Fe–Pecos region, the contrast is striking. Marcou's account of the geology of this area was relatively brief, barely enough to establish some of the major stratigraphic relationships, whereas Newberry (1876) provided 17 pages of detailed discussion, stratigraphic sections, considerable paleontological information and an interpretation of the regional geology that was remarkably modern in its approach.

Newberry's explorations in New Mexico developed almost incidentally from two expeditions whose main purposes were to survey areas to the west of the territory. In 1857 he was selected to be the surgeon–naturalist on an expedition led by Lieutenant Joseph Christmas Ives to explore the Colorado River. This expedition assembled in San Francisco in October 1857, divided into three groups and reassembled at Fort Yuma in January 1858. From there the party rode a specially constructed steamboat up the Colorado River to Black Canyon, near the present site of Boulder Dam, and then travelled overland across northern Arizona to arrive in Fort Defiance, the end point of the expedition, on 23 May. Ives returned to Fort Yuma, while the rest of the expedition travelled through New Mexico to Fort Leavenworth, Kansas, allowing Newberry the opportunity to examine the geology of central and northeastern New Mexico. Newberry's route eastward to Albuquerque was essentially that taken by the Whipple expedition travelling in the opposite direction five years earlier. From Albuquerque Newberry proceeded up the Rio Grande to Galisteo Creek, followed it eastward and northward to Santa Fe, and then travelled on the Santa Fe Trail past Pecos, Bernal, Las Vegas, Point of Rocks and McNee's Crossing—about the same route Wislizenus had taken when he entered New Mexico in 1846. Newberry's geological observations were published in the report of the Ives expedition (Newberry, 1861).

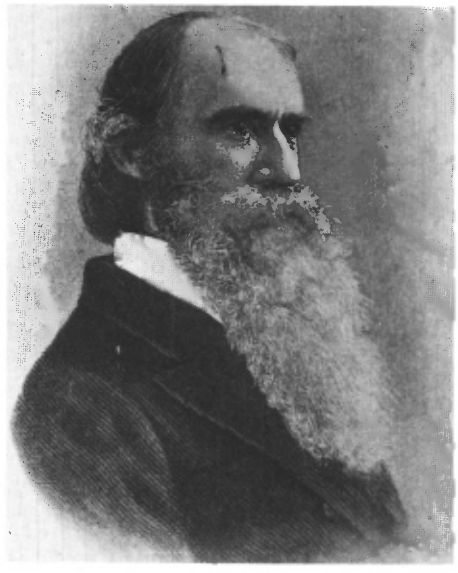


FIGURE 13. John S. Newberry.

The following year Newberry returned to New Mexico from the east along the Santa Fe Trail to join Captain John N. Macomb's expedition in Santa Fe in July 1859. This expedition travelled north along the Old Spanish Trail into Colorado and then turned westward to explore the Colorado Plateau, especially the drainages of the San Juan, Green and Grand Rivers, and eventually returned to Santa Fe in late September. Newberry had his geological report ready by May 1860, but, because of the Civil War, bureaucratic inertia and other reasons, it was not published until 1876. In this report Newberry added to and refined some of his conclusions concerning the geology of the Santa Fe area that he had covered in his report for the Ives expedition. Newberry's participation on the Ives and Macomb expeditions allowed him to generalize about the geologic history of the Colorado Plateau and central New Mexico, and the quality of his work established his place among the first rank of American geologists.

AFTERWORD

With the coming of the Civil War in 1861, geological exploration of New Mexico and the West ceased. Nearly all of the Corps of Topographical Engineers and other military officers who had led expeditions through New Mexico in the 1840's and 1850's served in the war, most with the Union Army, but a few, like Ives, in the Confederate forces. The Corps itself, which had played so important a part in these explorations and in their emphasis on scientific as well as military objectives, was one casualty of the war (Goetzmann, 1959). Gradually, however, as the country recovered, its attention once again turned to the West, and four great geographical/geological surveys were established, which continued the pre-war effort, but on a much grander scale. These surveys (the Hayden, King, Wheeler and Powell surveys) operated from 1867 to 1879 before being consolidated into a single organization charged with the study of the geology of the United States—the U.S. Geological Survey (Bartlett, 1962). During this time only Hayden, in 1869, and the Wheeler Survey in the 1870's entered New Mexico, and their explorations were primarily concentrated in the Sangre de Cristo Mountains and areas to the west. East-central New Mexico was essentially ignored by geologists until the late 1880's and 1890's, when Hill, Cummins and Hyatt re-examined the Tucumcari area, primarily to check Marcou's stratigraphic determinations from the Whipple survey (Kues, 1985).

The expeditions that traversed northeastern New Mexico through the middle 1850's were entering a territory in which the geology was virtually unknown. Because many of their observations were superficial or naive, and subsequent work has modified, corrected, or added a wealth of detail to their conclusions, it may seem that their contributions were slight. Looking back from a modern vantage point, aware of the edifice of geological knowledge that has been constructed since their time, it is easy to forget that the accounts of these military men, naturalists and geologists of more than a century ago provided the first glimpse of the remarkable geological record that is preserved in New Mexico. Their efforts stimulated the interest of those who would follow, giving them a foundation on which to build their own observations and interpretations. The journals and reports of these early explorers eloquently testify to the difficulties inherent in studying the geology of a vast, often dangerous, largely uninhabited area under conditions hardly conducive to the kind of comprehensive, detailed studies that modern geologist pursue. The best of them shared the same keen interest in geology and a desire to accurately describe and interpret their observations that animates modern geologists, and they accomplished much within the constraints imposed upon them by the time in which they lived and the nature of the country they were exploring.

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REFERENCES

Abert, J. W., 1846, Journal of Lieutenant J. W. Abert from Bent's Fort to St. Louis, in 1845: U.S. 29th Congress, First Session, Senate Document 438, pp. 1–75.

Abert, J. W., 1848, Report of Lieutenant J. W. Abert, of his examination of New Mexico, in the years 1846–1847: U.S. 30th Congress, First Session, Senate Executive Document 23, 130 pp., and House Executive Document 41, pp. 417–546.

Baldwin, B. and Muehlberger, W. R., 1959, Geologic studies of Union County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 63, 171 pp.

Bartlett, R. A., 1962, Great surveys of the American West: Norman, University of Oklahoma Press, 410 pp.

Blake, W. P., 1856a, Report of the geology of the route, No. 1—General report upon the geological collections; *in* Reports of explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, vol. 3, part IV: U.S. 33rd Congress, Second Session, Senate Executive Document 78 and House Executive Document 91, pp. 1–98, 106–119.

Blake, W. P., 1856b, Report on the geology of the route, No. 2—Resume and field notes by Jules Marcou, a translation; *in* Reports of explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, vol. 3, part IV: U.S. 33rd Congress, Second Session, Senate Executive Document 78 and House Executive Document 91, pp. 121–164.

Budding, A. J., 1972, Geologic map of the Glorieta quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 24.

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

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

Gorham, T. W. and Ingersoll, R. V., 1979, Evolution of the Eocene Galisteo basin, north-central New Mexico: New Mexico Geological Society, Guidebook 30, pp. 219–224.

Gregg, J., 1844, Commerce of the prairies: Norman, University of Oklahoma Press [1954 edition, edited by M. L. Moorhead], 469 pp.

Hall, J., 1856, Descriptions and notices of the fossils collected along the route; *in* Reports of explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, vol. 3, part IV: U.S. 33rd Congress, Second Session, Senate Executive Document 78 and House Executive Document 91, pp. 99–105.

James, E., 1823, Account of an expedition from Pittsburgh to the Rocky Mountains; *in* Thwaites, R. G., ed., [1905], Early western travels, 1748–1846, v. 14–17: Cleveland, Arthur H. Clarke Co., pp. 27–321 (v. 14), 356 pp. (v. 15), 291 pp. (v. 16), pp. 1–93 (v. 17).

Jessup, A. E., 1823, Observations on the mineralogy and geology of a part of the United States west of the Mississippi; *in* Thwaites, R. G., ed., [1905], Early western travels, 1748–1846, v. 17: Cleveland, Arthur H. Clarke Co., pp. 183–255.

Johnson, R. B., 1972, Geologic map of the Bull Canyon quadrangle, Santa Fe County, New Mexico: U.S. Geological Survey, Geologic Quadrangle Map GQ-1077.

Johnson, R. B., 1973, Geologic map of the Pecos quadrangle, San Miguel and Santa Fe Counties, New Mexico: U.S. Geological Survey, Geologic Quadrangle Map GQ-1110.

Johnson, R. B., 1975, Geologic map of the Galisteo quadrangle, Santa Fe County, New Mexico: U.S. Geological Survey, Geologic Quadrangle Map GQ-1234.

Kelley, V. C. and Northrop, S. A., 1975, Geology of Sandia Mountains and vicinity, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 29, 136 pp.

Kendall, G. W., 1844, Narrative of the Texan–Santa Fe expedition: London, Wiley and Putnam, 2 volumes, 405 pp. (v. 1), 406 pp. (v. 2).

Kues, B. S., 1985, Stratigraphy of the Tucumcari area: a historical account: New Mexico Geological Society, Guidebook 36.

Loomis, N. M., 1958, The Texan–Santa Fe pioneers: Norman, University of Oklahoma Press, 329 pp.

Marcou, J., 1855a, Resume of a geological reconnaissance extending from Napoleon, at the junction of the Arkansas with the Mississippi, to the Pueblo de Los Angeles; in California, *in* Whipple, A. W., Report of explorations for a railway route near the thirty-fifth parallel of latitude from the Mississippi River to the Pacific Ocean: U.S. 33rd Congress, First Session, House Executive Document 129, pp. 40–48 [reprinted in Whipple, 1856].

Marcou, J., 1855b, Résume explicatif d'une carte géologique des Etâts-Unis et des provinces anglaises de l'Amérique du Nord, avec un profil géologique allant de la vallée du Mississippi aux côtes du Pacifique, et une planche des fossiles: Bulletin de la Société Géologique de France, 2nd series, v. 12, pp. 813–936.

Marcou, J., 1858, Geology of North America, with two reports on the prairies of Arkansas and Texas, the Rocky Mountains of New Mexico, and the Sierra Nevada of California, originally made for the United States Government: Zurich, Zurcher and Furrer, 144 pp.

Marcy, R. B., 1850, Report of Captain R. B. Marcy: U.S. 31st Congress, First Session, Senate Executive Document 64, pp. 169–227.

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

Neilsen, R. L. and Dungan, M. A., 1985, The petrology and geochemistry of the Ocate volcanic field, north-central New Mexico: Geological Society of America, Bulletin, v. 96, pp. 296–312.

Newberry, J. S., 1861, Geological report; *in* Ives, J. C., Report upon the Colorado River of the West: U.S. 36th Congress, First Session, Senate Executive Document 77 and House Executive Document 90, 154 pp.

Newberry, J. S., 1876, Geological report; *in* Macomb, J. N., Report of the exploring expedition from Santa Fe, New Mexico, to the junction of the Grand and Green Rivers of the great Colorado of the West: Washington, Government Printing Office, pp. 9–118.

Northrop, S. A., 1961, Mississippian and Pennsylvanian fossils of the Albuquerque country: New Mexico Geological Society, Guidebook 12, pp. 105–112.

Pearce, T. M., 1965, New Mexico place names: Albuquerque, University of New Mexico Press, 187 pp.

Rittenhouse, J. D., 1969, Introduction; *in* Wislizenus, A., Memoir of a tour to northern Mexico: Albuquerque, Calvin Horn Publisher, Inc., pp. v–x.

Simmons, M., 1984, Following the Santa Fe trail: Santa Fe, Ancient City Press, 215 pp.

Simpson, J. H., 1850, Report from the Secretary of War, in compliance with a resolution of the Senate, the report and map of the route from Fort Smith, Arkansas, to Santa Fe, New Mexico, made by Lieutenant Simpson: U.S. 31st Congress, First Session, Senate Executive Document 12, 25 pp.

Sutherland, P. K. and Harlow, F. H., 1973, Pennsylvanian brachiopods and biostratigraphy in southern Sangre de Cristo Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 27, 173 pp.

Thwaites, R. G., 1905, Preface; *in* Thwaites, R. G., ed., Early western travels, 1748–1846, vol. 14: Cleveland, Arthur H. Clarke Co., pp. 9–26.

Whipple, A. W., 1856, Report of explorations for a railway route near the thirty-fifth parallel of north latitude, from the Mississippi River to the Pacific Ocean, Part I; *in* Reports of explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, vol. 3: U.S. 33rd Congress, Second Session, Senate Executive Document 78 and House Executive Document 91, pp. 1–136.

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

Wood, G. H., Jr., Northrop, S. A. and Griggs, R. L., 1953, Geology and stratigraphy of Koehler and Mount Loughlin quadrangles and parts of Abbott and Springer quadrangles, eastern Colfax County, New Mexico: U.S. Geological Survey, Oil and Gas Investigations Map OM-141.