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STRATIGRAPHY OF THE TUCUMCARI AREA: A HISTORICAL ACCOUNT

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INTRODUCTION

Tucumcari Mountain (elevation 4956 ft or 1511 m) rises about 750 ft (229 m) above the surrounding valley surface some 2 mi (3.2 km) south of the town of Tucumcari (Fig. 1). It was one of the first geographic features to become known to Americans south of the Canadian River in New Mexico and has long been a landmark for travellers entering New Mexico across the Llano Estacado. Together with other isolated remnants of the Llano in the area, it was involved in one of the most bitter controversies in the history of American geology, and even its exact location was disputed nearly 50 years after it first appeared on a map. The history of the Tucumcari Mountain area and the development of our understanding of the stratigraphy of east-central New Mexico are intertwined, and both are summarized here. This paper complements a summary of early geological explorations in east-central New Mexico found elsewhere in this guidebook (Kues, 1985). Figure 2 shows the location of places mentioned in the text.

A major focus of this paper is the controversy over the age of the formations exposed in the Tucumcari area that resulted from Jules Marcou's geological studies while a member of the Whipple expedition in 1853. This controversy pitted Marcou against most of the leading American geologists of the mid-nineteenth century and attained a level of rancor and antagonism that few other geological disputes have matched. Normally such stratigraphic disagreements are settled easily and amicably between geologists as data and observations accumulate, but in this case the antagonism escalated far beyond consideration of the immediate questions in the Tucumcari area and was vented in literally dozens of publications in the 1850's and 1860's. In this atmosphere, rational assessment of the evidence often was submerged beneath personal invective, and the ill-feeling thus generated between the main disputants hung like a dark cloud over early studies of western Mesozoic stratigraphy far beyond the boundaries of New Mexico. All of this indicates that much more was involved than a mere difference of opinion on the stratigraphy of east-central New Mexico. In this paper, the original dispute and its revival in the late 1880's and 1890's are described in considerable detail, in order to document and elucidate this fascinating intrusion of personality and emotion into nineteenth-century geological studies.

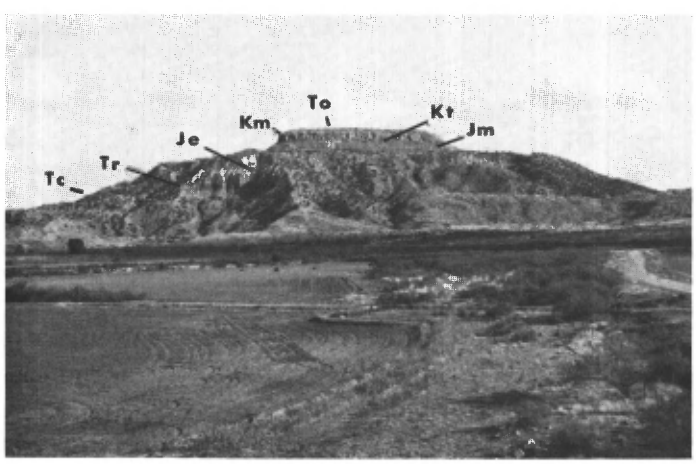


FIGURE 1. Tucumcari Mountain, looking southeast from Interstate 40. Tc, Chinle Formation; Tr, Redonda Formation; Je, Exeter Sandstone; Jm, Morrison Formation; Kt, Tucumcari Shale; Km, Mesa Rica Sandstone; To, Ogallala Formation.

EARLIEST VISITORS

Tucumcari Mountain lay along the route taken by Francisco Coronado and his party of Spanish conquistadors in their futile search for the legendary golden cities that seemed to hover like mirages, always beckoning but always just beyond their reach. Moving eastward from Bernalillo, Coronado's caravan crossed the Pecos River near Puerto de Luna, travelled along the southern drainage of the Canadian River, skirted Mesa Cuervo, entered the area of Pajarito Creek near the present town of Newkirk and passed within view of Tucumcari Mountain in April 1541 (Bolton, 1949). The area was within the range of the Comanche Indians, and it is likely that the name Tucumcari is a corruption of a word or phrase in the Comanche language. Two of the most likely possibilities for the origin of the name are that it is derived from *cuchtonaro,* meaning "to make a fire," referring to the peak's use in sending smoke signals, or, alternatively, from the term *tukamukaru,* "to lie in wait for someone or something to approach" (Pearce, 1965). During the eighteenth and first half of the nineteenth centuries the area around Tucumcari Mountain was a meeting place for Spanish traders and Comanches, and the Plaza Larga valley was linked to the Rio Grande settlements by good roads (Marcou, 1893c).

The first Americans to enter the area came with Josiah Gregg, a trader on the Santa Fe Trail. On his fourth and last expedition to Santa Fe in 1839, Gregg blazed a new trail along the Canadian River that allowed his party to enter the city before his competitors. Returning east in the Spring of 1840, he retraced the route but diverted southward along Pajarito and Tucumcari Creeks and camped four or five miles southeast of what he called Cerro de Tucumcari (Moorhead, 1954). Cerro de Tucumcari was accurately located on Gregg's map (1844), although the mountain was not described. Cerro Tucumcari also appears on the map accompanying Lieutenant J. W. Abert's report (Abert, 1846) of his 1845 exploring expedition from Bent's Fort, Colorado, south and east to Arkansas (see Kues, 1985). However, Abert's party did not travel south of the Canadian River and thus did not actually see Tucumcari Mountain.

MARCY AND SIMPSON, 1849

The earliest detailed accounts of the Tucumcari area were made by Captain R. B. Marcy (1850) and Lieutenant J. H. Simpson (1850). Marcy's party, of which Simpson was a member, camped a few miles east of Cerro Tucumcari on 17 June 1849 while en route from Fort Smith, Arkansas, to Santa Fe (Kues, 1985). The mountain had been visible for the preceding 30 mi (48 km) and was described by Marcy (1850, p. 186) as "apparently round and symmetrical, and [it] is a most conspicuous landmark. It presents, when seen at a long distance, very much the appearance of the dome of the Capitol at Washington." Marcy also noted the discovery on 17 June of petrified vertebrae and ribs of a buffalo, and "several petrifactions of pieces of wood and muscles." The party continued westward on 18 June and camped on a small creek:

> directly between two mountains, called by the Comanches the Big and Little Tucumcari. The larger one is about three miles to the south of our road and some eight miles in diameter at the base. The small one is about eight miles north of the road, two miles in diameter, and 750 feet high (Marcy, 1850, p. 187).

During 18 June Lt. Simpson, accompanied by three soldiers, broke off from the main party and rode to examine and ascend the northern

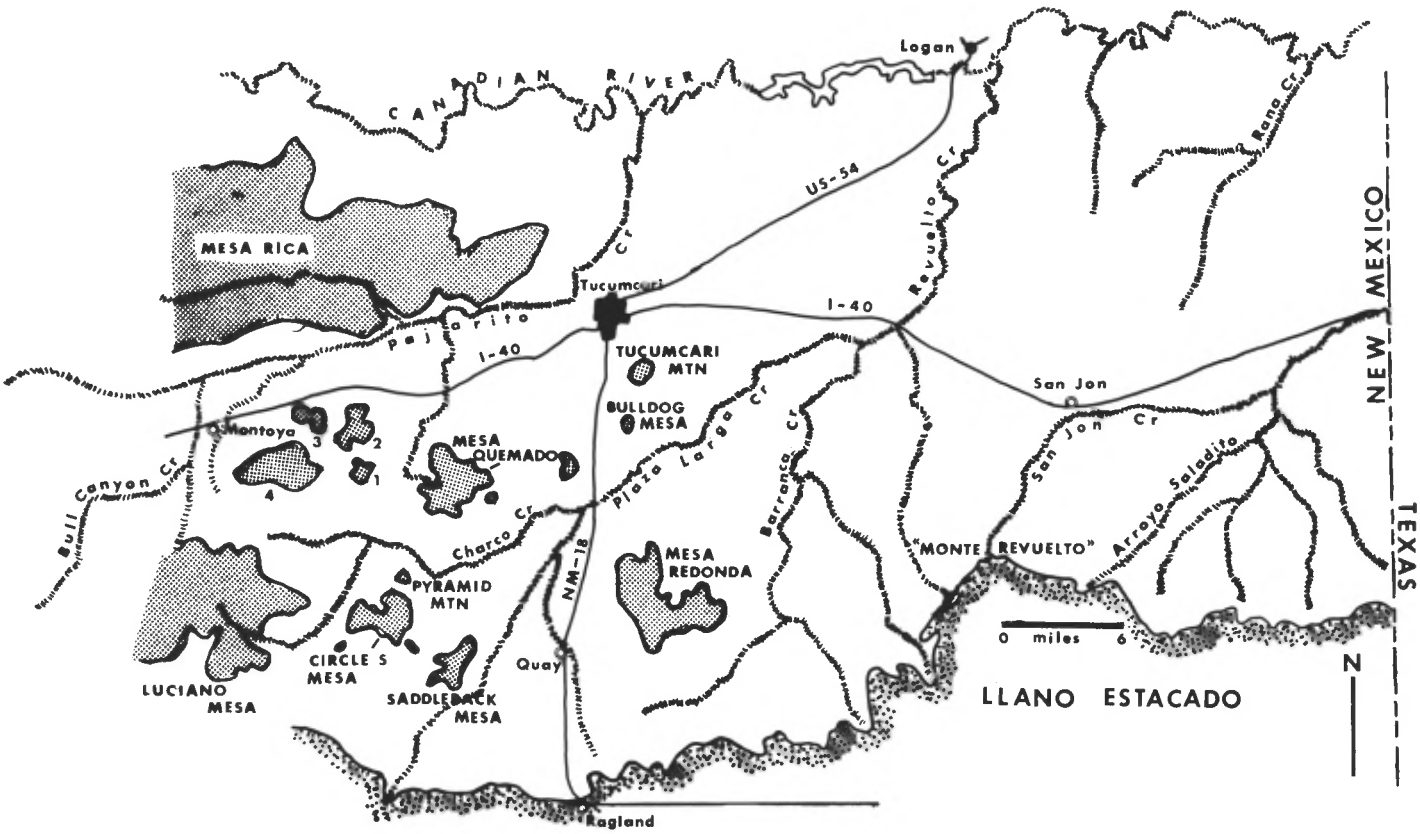


FIGURE 2. Map of Tucumcari area, showing main geographic features mentioned in text. 1, Quemado Hills; 2, Mesa del Puerta; 3, Palomas Hills; 4, Palomas Mesa.

mountain, which they were assured was the Cerro de Tucumcari of Gregg. Simpson (1850, p. 14) recorded his observations:

> After a most laborious ascent, of which some 50 feet were nearly vertical, we reached at last its summit. On every side was an unobstructed view. To the west and south lay a confused mass of irregular hills, with here and there a well defined and conical one, to characterize the scene. . . . To the south, some 8 miles distant, I could see with my reconnoitring [sic] glass the serrated tents of our little command, quietly reposing on a timbered affluent of the Canadian, to which they had resorted since I had left them. To the southeast and east lay the famous "Llano Estacado" of the Mexicans. To the northeast and north lay a limitless extent of broken undulating prairie, no signs of the Canadian being present. Pacing the top of the mound, I found it to be 230 yards by 370 in area; and by a measurement of the slope of the hill, and roughly reducing it to an angle of 45 degrees, I made its height over 700 feet. The circumference of its base, to our surprise, I found to be nearly 6 miles, it having taken a horse two hours, less eight minutes, to walk around it. It was most refreshing to both the dragoon and myself in our descent, when we were almost ready to die with thirst, to find a couple of small springs, where we drank copiously.

Although Simpson only mentioned Cerro de Tucumcari in his journal, his map shows three peaks (Fig. 3): "Little Tucumcari Hill" and an unnamed small hill northeast of Tucumcari Creek (Plaza Larga and Revuelto Creeks of today), and the much larger "Big Tucumcari Hill" southeast of the creek. Cerro de Tucumcari is not mentioned on the map. This created confusion as to which of the three hills was *the* Cerro de Tucumcari (e.g., Parke's 1851 map of New Mexico Territory, which shows "Little Tucumcari Hill" but applies the name "Cerro Tucumcari" to what Simpson labeled as "Big Tucumcari Hill"). From Simpson's and Marcy's accounts of the location and size of the peaks in the vicinity it is clear that Cerro Tucumcari is the peak called "Little Tucumcari Hill" by the Comanches and on Simpson's map. Marcy's (1850) map shows Cerro Tucumcari north of the route, where Simpson located "Little Tucumcari," but does not show "Big Tucumcari." Comparison of Simpson's map with recent topographic maps indicates that "Little Tucumcari Hill" is the present Tucumcari Mountain, "Big Tucumcari Hill" (called Soldier's Mesa for a time in the 1870's) is presently named Mesa Redonda, and the small unnamed hill between them is now called Bulldog Mesa (Fig. 2).

After resting on 19 June, and entertaining a large group of Comanches, Marcy's party continued westward along the headwaters of Tucumcari Creek on the 20th. Simpson, who was not trained in geology

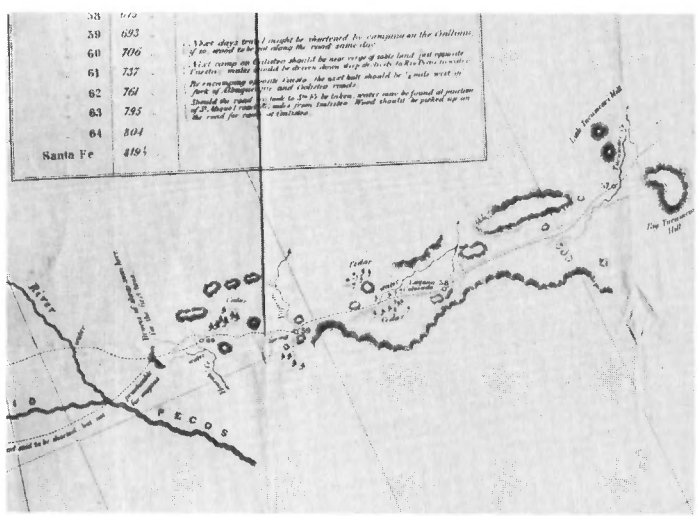


FIGURE 3. Part of Simpson's (1850) map, showing relationships between his "Big" and "Little" Tucumcari Hills and the route of the Marcy expedition through the area. "Little Tucumcari Hill" is Tucumcari Mountain; "Big Tucumcari Hill" is Mesa Redonda; Laguna Colorado is near Pajarito Creek, near the present town of Montoya; "Pajarito Creek" is the present Cuervo Creek; and "Hoorah Creek" is now called Esteros Wash or Creek.

but who was an accurate observer of topographic features, was impressed with the landscape as they rode up Tucumcari Creek (along what is now called Charco Creek, a major tributary of Plaza Larga Creek) between the present Mesa Quemado and Circle S Mesa. Simpson (1850, p. 17) noted that the:

> regular stratification of these hills, their party white and red color in horizontal zones, and the whole surface, besprinkled as they are with stunted cedar of a dark green color, will not fail to be noticed by the traveller as giving them a very beautiful and unique character. The formation of these hills, which are from one hundred to three and four hundred feet high, is at the base a red, argillaceous rock, easily frangible; next, proceeding upwards, a zone of sandstone rock, very friable, and of greenish-white color; last and uppermost, a sandstone rock of a brownish hue, and rather coarse character. . . . On all these hills, and in the silt of the streams at their base, are found fossil shells of a species which point to the cretaceous period [a footnote identifies it as *Inoceramus*].

The stratigraphic units described by Simpson are readily identifiable as the basal Chinle and Redonda Formations, overlain by the Exeter–Morrison interval, and surmounted by the Mesa Rica Sandstone.

Simpson's report of an inoceramid here is of interest because inoceramids are not recorded in the faunal lists of Hill (1895), Dobrovolny and Summerson (1946) or Brand and Mattox (1972) for Cretaceous formations (Tucumcari Shale, Mesa Rica Sandstone, Pajarito Shale) that are exposed in the Tucumcari Mountain area. However, Scott (1970) identified *Inoceramus comancheanus* from the Tucumcari Shale farther east, near San Jon (Brand and Mattox, 1972, also noted *Inoceramus*? from this locality), and reported that *I. bellvuensis* co-occurs with *Texigryphaea tucumcarii* through much of the southern Western Interior. One or both of these inoceramids will probably be "rediscovered" eventually in the Tucumcari area.

WHIPPLE AND MARCOU, 1853

Introduction

About four years after Marcy and Simpson passed through the area, an Army Corps of Topographical Engineers expedition surveying along the 35th parallel for a railroad route to the Pacific Ocean reconnoitered the Tucumcari Mountain area. Led by Lieutenant A. W. Whipple, this expedition was also accompanied by Jules Marcou (Fig. 4), a trained geologist, whose main responsibility was to study and map the geology along the route and write the geological report when the expedition was completed. Due to events in part beyond his control, the presentation of Marcou's geological observations became far more complicated and controversial than he could ever have imagined. Some aspects of the sequence of events were recounted by Northrop (1962) and DeFord (1972); a brief summary is given here in order to provide background relating to Marcou's work in the Tucumcari area and the way in which his results were received by the American geological establishment.

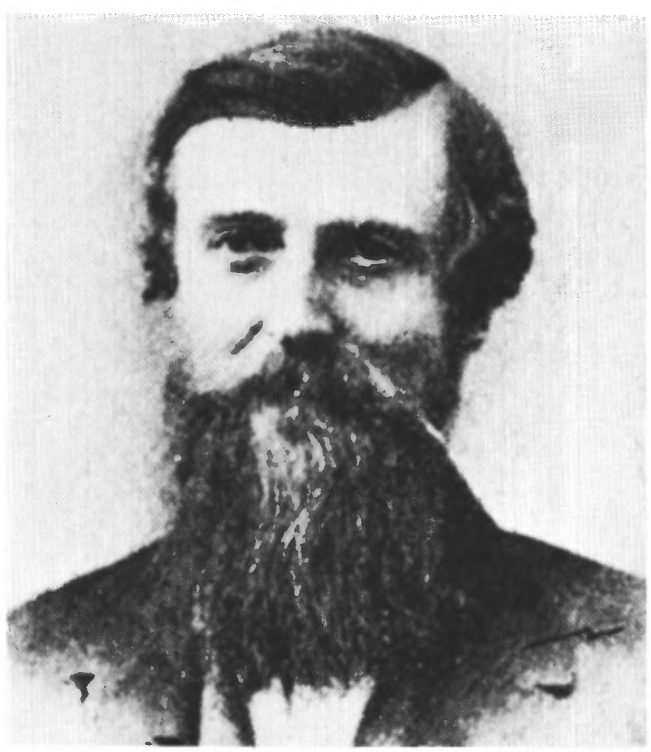


FIGURE 4. Jules Marcou (from Merrill, 1924).

Marcou accompanied the Whipple expedition to its destination in Los Angeles, arriving on 26 March 1854, and returned to Washington, D.C., via the Isthmus of Panama route on 1 June. Because of a serious illness contracted in Panama, Marcou planned to spend the winter in Europe (Marcou had been born and trained in France), and made arrangements to depart from Boston on 27 September. While recovering in Boston, at the request of Whipple he wrote a brief resume of the geology of the route (Marcou, 1855a) that was published in Whipple's preliminary report (Whipple, 1855) and reprinted in the final report (Whipple, 1856). Two days before his scheduled departure, Marcou received notes from Whipple and Captain Pope (leader of a railroad-route expedition along the 32nd parallel, for whom Marcou had also written a short geological report) conveying orders from Jefferson Davis, then Secretary of War, that he must stay in the United States to do his geological report. If he chose to leave the U.S., he was ordered to turn over his notes and collections to American authorities. As 20 boxes of notes and specimens were already on the ship, Marcou resigned his position as geologist and departed for Europe. When he arrived in France, however, he:

> found a letter from Washington which threatened, in case I did not at once relinquish the specimens and notebooks belonging to the Government, to prosecute me in conformity with a treaty of extradition lately concluded between the United States and France. I might have taken my chance in a lawsuit with the American Government, but I preferred to give up everything, indignant at such treatment, and I replied that I would place in one box all the specimens and notes that the Secretary of War demanded, and would give them up to any responsible person who could give me a receipt in due form, which would release me from all subsequent claim on the part of Mr. Jefferson Davis (Marcou, 1858a, p. 3).

According to Marcou, this was accomplished in February 1855.

Marcou, however, did not return *all* of the specimens. He retained several suites of fossil specimens, including all of the types, and particularly the critical type specimens of *Gryphaea tucumcarii*, the main support for his assignment of a Jurassic age to the upper strata of the Tucumcari area. The specimens he kept were distributed to various museums in Europe. In addition, according to Blake (Merrill, 1924, pp. 675–676), when the fossils returned by Marcou were inspected by himself and James Hall it became apparent that some of them were European specimens from the Jurassic of the Jura Mountains, which Marcou had substituted for those collected along the route of the Whipple expedition. Marcou's explanation, that some European shells had gotten mixed up with the American collections during packing, is not very convincing. Hall (1856) eventually described in Whipple's final report what remained of Marcou's specimens when the European forms had been weeded out.

In May 1855 Marcou published in Europe a new geologic map of North America (following one published in 1853) along with a discussion of the geology (Marcou, 1855b) that was based in part on his Whipple expedition notes. Later he wrote a book on the geology of the continent, in which he presented in more detail his conclusions regarding the geology along the route taken by the Whipple expedition in New Mexico (Marcou, 1858a). The specimens Marcou had turned over to American authorities were eventually given to William P. Blake, who informed him by letter in January 1856 that he, Blake, would be writing the geological report for the Whipple expedition and also was going to publish, with an English translation, Marcou's field notes (which were written in French). Both appeared in Whipple's final report (Blake, 1856a, b). In addition to the impropriety of publishing, without permission, another geologist's field notes, Blake had no direct knowl-

edge of New Mexico geology, as he had never been in the Territory. Marcou (1858a, p. 144) later disavowed Blake's reports, stating:

> . . . I decline all responsibility as to the use that has been made by W. P. Blake, J. Hall, and A. A. Humphreys of my official note-books and specimens, which for me have no existence whatever. . . . Mr. Blake has done his best to nullify and deny all my discoveries on this Survey.

The acrimonious atmosphere that this sequence of events engendered helps to explain the antagonistic criticism that Marcou's work, especially in the Tucumcari area, received from American geologists. That Marcou was even allowed to return to the United States in 1860 may have been due to the reaction against Jefferson Davis that developed in the months preceding the beginning of the Civil War (Goetzmann, 1959).

Observations along the route

Whipple's party entered New Mexico from Texas on 19 September 1853, and on 20 September approached to within sight of the "Tucumcari Hills." Whipple (1856, p. 38) noted that "[f]ossils of the cretaceous or jurassic formation were found in the creeks crossed today." Marcou (Blake, 1856b) mentioned in his field notes for 19 September and 20 September the presence of Triassic red beds and Cretaceous limestones. On 20 September he reported near Camp 48 (a few miles northeast of Mesa Redonda) "some rolled specimens of *Ostrea aquila* and a *Trigonia*, which proves that this Neocomien [Lower Cretaceous] bed is situated on the top of the Llano. . . ."

The party progressed about 16 mi westward on 21 September, crossing several tributaries of Tucumcari Creek (now Plaza Larga and Revuelto Creeks), skirting the north edge of Mesa Redonda and camping in the Plaza Larga valley about midway between the north end of Mesa Redonda and the east edge of Mesa Quemado. Neither Marcou nor Whipple viewed Tucumcari Mountain at close range, as their route passed about six or seven miles (10–11 km) south of it. Whipple (1856, p. 39) was impressed with this area, noting that Plaza Larga:

> is famous in New Mexico for beautiful scenery, fertile soil, and charming climate. It extends from among the Tucumcari hills apparently to the Canadian [River]; and should this route be selected for a railway, offers every facility for a large settlement. Indeed, in a few years it may become the centre of a flourishing state.

The geology of the day's route was described by Whipple as "200 feet lias [Jurassic], overlaid by the same thickness of cretaceous formation, with sandstone and limestone containing fossil shells." Marcou's field notes for 21 September (Blake, 1856b) state that "New Red [Triassic] is found all the way . . . , with cretaceous on the top of Mount Revulto and Tucumcari."

Blake's report on the geology of the area, compiled while Marcou was in Europe, added little more to knowledge of the stratigraphy of the Tucumcari area:

> I do not find any description of the strata of this mound in the notes of Mr. Marcou, but I do not doubt, from the statements of Lieutenant Whipple, that they agree exactly with those of the Llano. This is also indicated by the fact that the slopes of the mound are covered with cedars, exactly as on the northern slopes of the Llano. We have also the section of Pyramid Mountain, by Mr. Marcou, which is not far distant, and may be regarded as an exhibition of the mineral character of the Tucumcari and of the Llano (Blake, 1856a, p. 25).

Marcou's observations of the Tucumcari area reveal that he shared Whipple's enthusiasm but was also eager to move on:

> Our camp no. 49 [21 September] on Tucumcari Creek, in a beautiful valley called by the Mexicans Plaza Larga, was environed by high hills called Big Tucumcari, Little Tucumcari, Monte Revuelto and the bluffs of the northern side of the Llano Estacado. A better locality for geological explorations is seldom met with; but unhappily the situation is very inaccessible, in the middle of the country over which the Comanche Indians range; exploration without a strong escort is very dangerous; and at that time the expedition was progressing rapidly towards the West. Hurried by the fatigue of men and animals, we were looking for the valley of the Rio Grande del Norte to recruit our strength and forget the privations and hardships of the prairies (Marcou, 1858a, pp. 17–18).

Whipple's party continued up the head of Tucumcari Creek (along the tributary now called Charco Creek) on 22 September. Marcou and several others left the main party to examine an isolated hill to the south of the road about 6 mi from the previous night's camp (Fig. 5). They called this peak Pyramid Mountain (=Lovers Peak or Crazy Woman Butte on recent U.S. Geological Survey maps; see Kues and Kietzke, 1985). Marcou (1858a, p. 18) described it thusly:

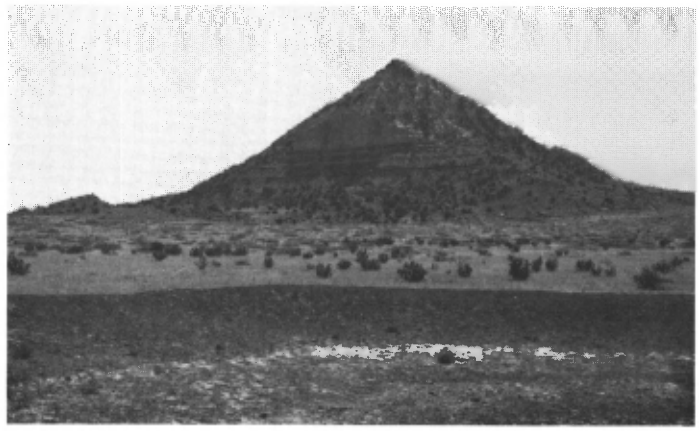


FIGURE 5. Pyramid Mountain as it appears today, viewed from the northwest. Except for the cattle pond in the foreground, this is probably nearly identical to Marcou's view as he approached it in 1853.

> The north side . . . is entirely precipitous, perpendicular as a wall, without any particle of vegetation and showing all the strata; it is impossible to desire a clearer or better geological section. The height of the bluff, where the beds outcrop, is five hundred feet.

Marcou spent four hours there, drafted a stratigraphic section (Fig. 6) and provided the following information about the stratigraphy (Marcou, 1858a, pp. 18–19):

> From the base half way up, the first two hundred feet are composed of strata of variegated marls, red, green and white, having the same appearance as the upper part of the Keuper [Upper Triassic] in the quarries of the Boisset, near Salins, France. A bed of grayish blue clay (A) one foot thick, forms the last strata of new red sandstone, and is in contact with a white very fine grained sandstone (B), which is eight feet thick and belongs to the Jurassic formation. Above there is an enormous mass, eighty feet in thickness, of very hard fine grained sandstone (C) of a light yellow color, and cut by cleavage perfectly perpendicular like a wall. Beds of white sandstone (D) are superposed; they are very fine, soft and easily disintegrated by the action of the atmosphere; at the foot of each bed little heaps of sand are seen which result from this decomposition; the thickness of the beds is twenty-five feet. Then comes clay (E) of a slight grayish blue color and subschistose structure, thirty feet thick.
>
> In this blue clay, six inches distant from the white sandstone, I found a zone of *Gryphaea* not more than three inches thick, but the specimens are so abundant that they are in contact with each other. The *Gryphaea* that I had collected at the foot of the bluff and on the ascent, though rolled and worn, had struck me as resembling in shape the *Gryphaea dilatata* of Oxford and the Vaches Noires in Normandy. When I had them in the strata itself, and had collected a hundred in perfect preservation, I no longer doubted their identity with *Gryphaea dilatata* of the Oxfordian group of England and France. Soon after, in the same zone with the *Gryphaea* I found two specimens of the *Ostrea marshii*, a very characteristic fossil of the lower oolite of England, France and Germany. This discovery of Jurassic fossils proved to me that I had at last met with the true Jurassic rocks in North America.
>
> To return to Pyramid Mount. Above the fossiliferous blue clays are beds of sandy limestone (F) of a deep yellow color and very hard; when broken it shines and shows brilliant points, like the yellow limestone of the inferior oolite of the Jura. These beds are five or six feet thick and rise to the top of the pyramid where the upperr strata is a white siliceous and very compact limestone (G) resembling lithologically the Forest Marble (Calcaries de la Citadelle) of the environs of Salins and Besancon.

This section and abbreviated description, with minor differences, are also recorded in Marcou's field notes (Blake, 1856b) and Blake's (1856a)

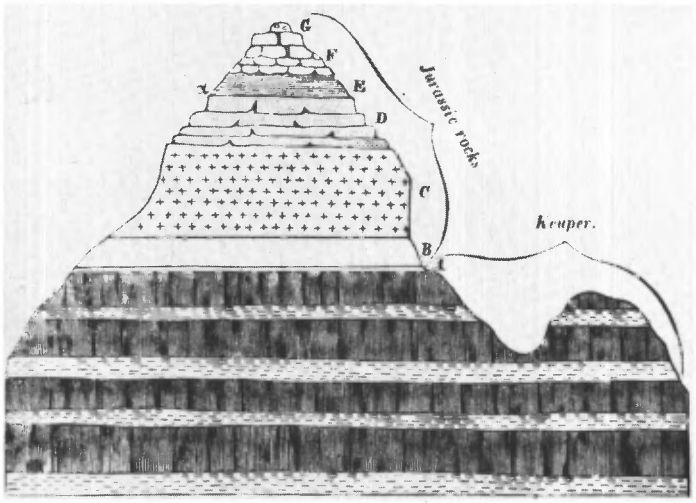


FIGURE 6. Marcou's (1858a) illustration of Pyramid Mountain and its stratigraphic sequence.



FIGURE 7. Marcou's (1858a) map of the geology of the Tucumcari area. R = New Red Sandstone (Triassic); J = Jurassic.

summary of the geology of the area. Marcou vascillated on his assignment of the large *Gryphaea* from Bed E, calling it in various publications *Ostrea dilatata,* provisionally *Gryphaea tucumcarii* new species, *G. dilatata* variety *tucumcarii* and finally *G. tucumcarii* (see Kues et al., 1985). As this species is now recognized as distinct (*Texigryphaea tucumcarii*), it will be referred to consistently in the following discussion as *G. tucumcarii*.

Marcou's assignment of a Triassic age to the lower half, and a Jurassic age to the upper part of the Pyramid Mountain section was first presented in 1855 (Marcou, 1855a, b). It is clear that his discovery of fossils he thought to be closely related to European Jurassic forms at Pyramid Mountain caused him to change his mind regarding the age of the upper beds. Marcou's field notes (Blake, 1856b) for the previous few days show that he had been leaning towards a Neocomian (Early Cretaceous) age, based on eroded fossils he had been seeing in creek and arroyo sediment. However, in Marcou's (1858a, pp. 54–55) later version of his daily geological observations in the Tucumcari area, the only fossil mentioned is *Gryphaea dilatata* var. *tucumcarii,* which is referred to the Jurassic, and the possibility that these beds are Cretaceous is never mentioned. He adhered to his determination of their Jurassic age for the rest of his life. As a result of his conviction, the upper strata of Big and Little Tucumcari Mountains and the entire Llano Estacado were designated as Jurassic on Marcou's geologic maps (1855b, 1858a) of the area (Fig. 7).

Marcou's side-trip to Pyramid Mountain was also recorded by Baldwin Mollhausen, a German with a love for exploring the American frontier. After a previous expedition through the prairies of the U.S., Mollhausen returned to Berlin, became restless and came back to the U.S., arriving in Washington just in time to be attached to the Whipple expedition as topographer and draftsman, with instructions to keep a journal. His account of his travels along the 35th parallel was eventually published in German as a two-volume book and almost immediately translated into English (Mollhausen, 1858). It provides an entertaining mixture of observations and anecdotes, emphasizing the day-to-day life and human side of the expedition, and thus augments the more succinct military and scientific accounts of Whipple and Marcou. Mollhausen accompanied Marcou, the botanist Bigelow and several other men in the ascent of Pyramid Mountain, and his description of the trip shows that the activities of field geologists haven't changed much in 130 years. The progress of the party was continually slowed by being enticed away from the best path by particularly well-preserved fossils, and when it was time to leave they could still hear Marcou hammering away at the outcrop, trying to collect a last few specimens. For the most part the non-collectors in the party had amused themselves at the summit by rolling boulders down the steep slopes of the peak. Mollhausen produced a somewhat fanciful drawing of Pyramid Mountain (Fig. 8) which was reproduced as a colored lithograph in Whipple's (1856) final report.

CONTROVERSY, PHASE I

Publication of Marcou's views on various aspects of North American geology, including the age of the Tucumcari area sequence (Marcou, 1855a, b) led to an immediate and negative reaction by American geologists. Such a reaction was almost certain, as Marcou's objectivity and knowledge of North American geology had been brought into question two years earlier, when he had published (Marcou, 1853) a geological map of North America and an accompanying summary prior to becoming a member of the Whipple expedition. An anonymous reviewer, said later by Marcou to have been "without doubt" James Hall (Fig. 9), published a scathing review (Anonymous, 1854) in the pages of the "American Journal of Science," the most influential American scientific journal of the time. The reviewer detailed a long list of errors on Marcou's map and in his geological summary, and made it clear that Marcou neglected a number of important studies in his synthesis of North American geology.

Slighting references to Marcou's work also appeared in papers otherwise devoted to very different subjects. Whitney (1855, p. 379), an associate of Hall's, added a footnote to a long review of Murchison's "Siluria" in the "American Journal of Science," stating that "Murchison has been, in several instances, led into great errors by adopting M. Jules Marcou as one of his American authorities." Referring to Anonymous (1854), the footnote went on to say ". . . we have little doubt that, after examining that article, he will prefer to consult more reliable authors." In the same issue Hall, writing anonymously again (Anonymous, 1855, p. 397), began a long and negative review of Ebenezer Emmons' work with a gratuitous, out-of-context attack on Marcou:

> It is but a few months since another pen than ours called attention to Mr. Marcou's poor caricature of a geological map of North America, and showed that both the map and the accompanying text are full of errors and mis-statements, calculated to give foreign readers most erroneous ideas, not only of the state of American science, but of the true geological structure of the country. We recall this with more regret, because we observe that Sir R. I. Murchison was deceived by Mr. Marcou's pretensions, and lent to the map a certain sanction in the pages of Siluria, before he was apprized of its worthlessness. The fact that Mr. Marcou is a comparative stranger in our country may explain his ignorance though not his presumption.

The attacks intensified after publication of some of Marcou's Whipple expedition results (Marcou, 1855a, b). Blake (Fig. 10) and Hall were first to object to Marcou's determination of a Jurassic age for the upper part of the Pyramid Mountain section. Blake (1856a), in his discussion of the geology of Whipple's route, argued that, although *G. tucumcarii*



FIGURE 8. Mollhausen's sketch of Pyramid Mountain, from Whipple's final report (Blake, 1856a, facing page 25).



FIGURE 9. James Hall.

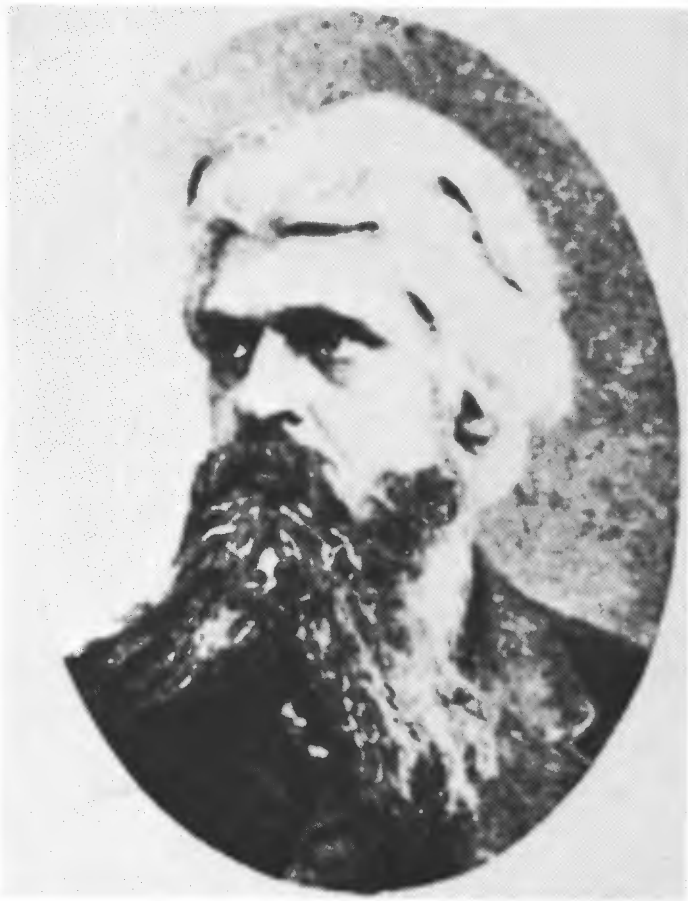


FIGURE 10. William Phipps Blake (from Merrill, 1924).

closely resembled the Jurassic *G. dilatata,* similar forms of this highly variable genus were known from deposits of undoubted Cretaceous age, and that it was far more likely that Marcou's Jurassic beds were Cretaceous. Blake also challenged Marcou's assignment of a Keuper (Late Triassic) age to the underlying red beds, stating that such correlations made entirely on lithological similarity were suspect, and that all that could be said is "the strata lie between the known cretaceous beds above [=Marcou's Jurassic] and the carboniferous below" (Blake, 1856a, p. 78). Blake's caution was reasonable, but Marcou was correct in his age assignment—these beds are Upper Triassic Keuper equivalents, the Chinle and Redonda Formations of present usage. Blake's map of Whipple's route (Whipple, 1856) shows Big Tucumcari Mountain and the surrounding area as Cretaceous, underlain by a "gypsum formation" of indeterminate age (Fig. 11).

The portion of Marcou's fossil collections returned to the U.S. was described by James Hall (1856), who assigned *G. tucumcarii* to *G. pitcheri,* a species known from several localities of Cretaceous age. Blake (1856c) followed with a review of Marcou's 1855 map, based on a talk presented in August to the American Association for the Advancement of Science, repeating his earlier criticisms and adding some others. He cited several earlier reports of Cretaceous fossils from central New Mexico and Texas and indicated that the Tucumcari beds were of the same age, a weak argument given the dearth of detailed information that was available about the areas in question. With more validity, Blake challenged Marcou's assignment of tremendous areas of the central U.S., from Texas to the Missouri River, to the Triassic, based only on observations made along Whipple's route. As no fossils from this gypsiferous red-bed interval were known, the age could be, according to Blake, Permian to Jurassic. Although Blake admitted the possibility that Marcou was correct, he thought that it "would be most in accordance with the indications to refer them to the Cretaceous and Carboniferous, the two adjacent formations above and below" (Blake, 1856c, p. 388). Although Blake could provide no better information to supplant Marcou's age determination, he did point out one of Marcou's major shortcomings—a pronounced tendency to generalize far beyond the limits of his data and observations.

Criticism continued in 1857. Enough work had been done on Cretaceous stratigraphy and paleontology of the eastern and midwestern U.S. and Texas so that efforts at correlation could begin. The Cretaceous rocks of central New Mexico, as well as the section at Tucumcari, where Cretaceous strata were thought by many to be, had to be fitted into the larger picture. Hall (1857a), in a paper included in the report of the Mexican Boundary Survey (later reprinted with minor changes in the "American Journal of Science"; Hall, 1857b), attempted such a

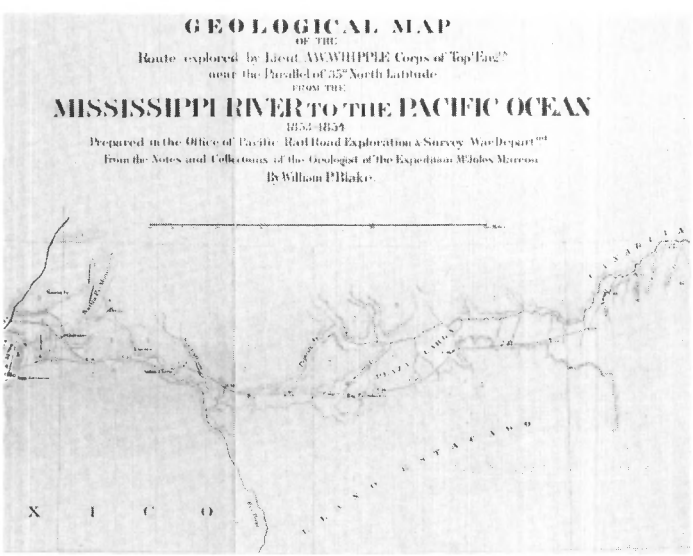


FIGURE 11. Blake's (1856a) map of the geology of the Tucumcari area. 6=Gypsum formation; 7=Cretaceous.

synthesis. Hall presented a stratigraphic section of the Cretaceous in Nebraska, based on earlier work by Meek, Hayden and himself, which divided the Cretaceous "formation" into five subdivisions. Bed 1, the lowest, lay above Carboniferous rocks; Beds 2 and 3 contained fossils such as *Inoceramus problematicus,* identified in many places including Galisteo and the Rio Puerco of New Mexico. Hall considered Beds 2 and 3 to be "middle Cretaceous" (this interval is now known to the Upper Cretaceous), and Bed 1 to be "lower Cretaceous." Bed 1 later was named the Dakota Formation and was for a time the earliest Cretaceous unit recognized in North America. As defined by Hall and others, it included not only the presently recognized Upper Cretaceous Dakota Formation, but also Lower Cretaceous units later (1912) separated from it as the Purgatoire Formation (Waage, written comm. 1985).

In discussing Marcou's Pyramid Mountain section, Hall stated emphatically that "I have no hesitation in saying that the specimens labeled by [Marcou] *Gryphaea Tucumcarii* . . . are the *Gryphaea Pitcheri* of Morton, and present no features either in form, character, condition of preservation, or otherwise, which can serve to distinguish them from *Gryphaea Pitcheri* in the Boundary Survey collections, from strata forming a continuation of the Llano Estacado" (Hall, 1857b, pp. 84–85). The other species found by Marcou at Pyramid Mountain, *Ostrea marshii,* was called by Hall *Ostrea subovata,* a Cretaceous species recently described by Shumard from Texas. On that basis Hall assigned Marcou's beds E through G to Nebraska units 2 and 3, in other words to equivalency with the lower part of what is now the Upper Cretaceous. The rest of Marcou's Pyramid Mountain section, including Beds A through D and the underlying 200 ft of red beds (Marcou's Keuper, or Upper Triassic) Hall assigned to his Nebraska Bed 1. On Hall's geologic map of the western U.S. (Hall, 1857a), published with the Boundary Survey report, "Big Tucumcari" is "middle and upper Cretaceous," with most of the extensive red-bed areas of Oklahoma, northern Texas and northeastern New Mexico shown as equivalent to Nebraska Bed 1, or "lower Cretaceous." It is interesting to note that Blake's criticism of Marcou's map, with its vast areas of Triassic, could equally well apply to Hall's map, in which "middle" and "upper" Cretaceous exposures are shown extending over more than two-thirds of New Mexico and much of western Texas. It was inconceivable of course that the work of Hall, the dominant American paleontologist of his time, would have received criticism remotely resembling the antagonistic reception Marcou's map received.

Meek and Hayden (1857) covered somewhat the same ground with a summary of their work on the Cretaceous of Nebraska, Kansas and Montana. They presented a chart (p. 132) correlating the Pyramid Mountain section with Cretaceous units in Nebraska, New Jersey and Alabama. As in Hall's paper, Nebraska Unit 1 ("lower Cretaceous") included all of Marcou's section up to Bed E. Bed E, which produced the fossils Marcou called Jurassic, was correlated with Nebraska Unit 2, and Beds F and G with Nebraska Unit 3. Meek and Hayden could not account for the absence of *Inoceramus problematicus,* a characteristic fossil of Nebraska Units 2 and 3, in Marcou's section. Further, they erroneously correlated beds identified as Cretaceous by Marcou near Galisteo, more than 100 miles (160 km) to the west of the Tucumcari area, with the fossiliferous Beds E and F of the Pyramid Mountain section, even though there were no fossils in common, and Marcou had been certain enough of the differences in ages of these two intervals to assign the former to the Upper Cretaceous and the latter to the Jurassic. Meek and Hayden, like Blake and Hall, had never actually been to the Tucumcari area to check Marcou's observations or to make their own collections of fossils.

Early in 1858 Marcou published his book on North American geology (Marcou, 1858a), with a chapter on New Mexico that represented the information that would have been included in Whipple's final report if he had been allowed to publish it there. Marcou's book is a curious mixture of his geological observations along the 35th parallel, a geologic map of the United States, an account of his tribulations following his return from the Whipple expedition, fulminations against his critics and comments on the history of geological studies in North America. Stung for four years by harsh criticism of his efforts, Marcou placed on record

some of his feelings about the situation. With respect to his geological maps he recognized that they were not perfect (p. 87): "I see in my maps many faults, and many more imperfections and wants, and am *very far* from being satisfied with [them] . . ." but asserted that as "rough sketches" they had some value and did not deserve the acrimonious criticism they had received. He claimed that he was justified in publishing his 1855 map because ". . . I think, I may say truly, that at the time of its publication in 1855, I had seen more of North America than any living geologist either of America or Europe" (p. 86).

Marcou then turned to the strain of anti-European feeling that ran through the remarks of some of his critics, which implied that because he was "recently arrived" from Europe he should not have attempted to produce something as ambitious as a geological map of North America:

> I have reproached with being a *stranger,* and consequently not as well acquainted with American geology as a native. To introduce in this way the *know-nothing* doctrine [a political doctrine current at the time emphasizing America's need for isolation from European influence] into a judgement of a scientific work, is to say the least extraordinary, and not much in favor of the liberality of its authors (p. 87).

James Hall, the dominant American paleontologist of the time, was regarded by Marcou as being responsible for generating the ill will towards his work on the part of American geologists. Marcou (p. 88) remarked that

> . . . there is a sort of association in America composed of half a dozen geologists who try to impose their opinions . . . upon all who attempt to look at the rocks of the New World. The recognized leader of this association is Mr. James Hall, of Albany. . . .

Marcou was not far off in his assessment. In the 1850's Hall was approaching the height of his influence and power, and his personality was such that he wielded his influence at every opportunity. He was the teacher, mentor, employer and/or friend of many of the younger geologists and paleontologists of the day, including Blake, Newberry, Meek, Hayden and Dana—all of whom had been or were soon to be critics of Marcou's work. Moreover, Hall had been working desultorily on his own geologic map of North America since 1843 and was undoubtedly angered by the publication of Marcou's maps. Always short of funds, and with an appetite for new fossil collections that knew no bounds, Hall had asked to be considered for a federal exploring expedition in the late 1840's, and had sent Meek and Hayden into the White River badlands area in 1853 to collect fossils after a government party the previous year had brought back accounts of the paleontological treasures to be found in the West. Hall and other American geologists probably believed that the study of the geology and paleontology of the vast, largely unknown area along the 35th parallel should be accomplished by American geologists, not Europeans. There is no direct evidence, but it is possible that this attitude was made known to Jefferson Davis and influenced his order to Marcou that the Whipple expedition collections must stay in the United States. A comprehensive account of Hall's life by his biographer, Clarke (1923), is an excellent source of information not only about Hall but also about the state of American geology through the last seven decades of the nineteenth century.

Having gained the enmity of an important component of the American geological establishment for reasons partly beyond his control, Marcou exacerbated the situation in his "Geology of North America." In Chapter 9 he assessed again the history of geological study in North America. Europeans who had made relatively short excursions to North America mainly during the 1840's were allotted more credit for their discoveries than they really deserved. More damaging, however, was Marcou's opinion of Hall's monumental "Paleontology of New York," one of the most important works on American geology ever written, which had achieved as much acclaim in Europe as it had in America. Marcou wrote (p. 121):

> The *Paleontology of the State of New York,* by James Hall, of which two volumes have already appeared, is a very useful work, but the determination and description of species are not very satisfactory; compared with publications of the same nature, such as the beautiful memoirs of Barrande, de Koninck, M'Coy, Milne Edwards and Jules Haime, de Verneuil, Sandberger, Angevin, etc., the "Paleontology of New York" appears quite inferior,—the best part of it being the plates drawn by Mrs. Hall, and also the geological order.

Such a manifestly unfair and inaccurate portrayal of Hall's work, especially the insulting statement that the best part of it was Mrs. Hall's illustrations, could only work against Marcou, although he may have taken pleasure in writing it as a response to Hall's attacks on his work. Hall, needless to say, was enraged, but the affront extended to all American geologists. Marcou's representation of the best of American geological research as being decidedly inferior to that done by numerous Europeans only fueled the feeling against him. Hall remembered Marcou with displeasure almost 40 years later, commenting to Clarke in 1895 (Clarke, 1923, p. 219):

> Marcou came to this country as a representative of the Geological Society of France commissioned to make for them collections of American fossils. He came to me and I entertained him at my home and sent him into the Helderbergs but he was too lazy to get fossils; he was very tall and it hurt him to stoop over.

There is some evidence that Marcou hoped that the fuller discussion of the geology of the Tucumcari area contained in his book would help to mute criticism of his results. With the strong feelings the book had generated, however, the attacks on its author only increased in ferocity. Before the storm of criticism broke around him near the end of 1858 and into 1859, Marcou wrote a letter to Meek and Hayden, which he privately published (Marcou, 1858b), that responded to several letters and publications by these geologists expressing their objections to Marcou's age determinations of the strata in the Tucumcari area. Much of the discussion focussed on the identity of *Gryphaea tucumcarii* and *Ostrea marshii*. Marcou vigorously maintained that, contrary to the belief of American paleontologists, these two species were not identical to *G. pitcheri* and *O. subovata,* respectively, which had been found in Cretaceous strata to the east. Marcou believed he was the only person really qualified to judge this issue, as he was the only one of the disputants who had surveyed and collected fossils not only from the Tucumcari area but also from several Lower and Upper Cretaceous localities both east and west of Tucumcari. Before entering New Mexico in 1853, the Whipple expedition had traversed southern Oklahoma and northern Texas. At Comet Creek (near the Washita River in western Oklahoma) Marcou had collected a suite of fossils, including a form he called *G. pitcheri,* that he recognized as "Neocomien" or Lower Cretaceous, a conclusion that stands to this day. Moreover, Marcou had seen numerous other collections of Cretaceous fossils from Texas and central New Mexico and was certain that neither of the two species collected at Pyramid Mountain were present in any of the Cretaceous collections (Marcou, 1858b, p. 7). The identity of the two disputed species is discussed later in this paper; suffice it to say here that Marcou eventually was proven correct in his assertion of the distinctiveness of *G. tucumcarii,* but his *O. marshii* is now recognized as *Lopha subovata*.

Marcou also responded to assertions that his Jurassic and Triassic were equivalent to Nebraska Unit 1, regarded as Cretaceous by American geologists. However, the methods he used only served to fuel the disagreement without clarifying their true relationships. Hayden had collected numerous angiosperm-plant leaves from Unit 1 along the Missouri River, near the mouth of the "Big Sioux River" (near the intersection of Nebraska, South Dakota and Iowa) and had sent "rough sketches" of these to Oswald Heer, one of Europe's foremost paleobotanists. Heer pronounced the leaves as being of lower Miocene (= Oligocene) age. Marcou used Heer's opinion to suggest that Unit 1 was "partly Jurassic and partly Miocene," despite the fact that the leaves had been collected immediately below Unit 2, which contained undoubted marine Cretaceous fossils. A Cretaceous *Baculites* found with the leaves in Unit 1 was discounted by Marcou as a reworked specimen.

Marcou closed his letter with an expression of annoyance at the criticism he had been receiving:

> . . . you will permit me to suggest, that it would be better for Science if my adversaries would go themselves on the field and follow my route near the 35th parallel, instead of making a show of their powers of argument in [the "American Journal of Science"], or at the meeting of scientific associations.

Meek and Hayden may have smiled (or grimaced) at this, in view of Marcou's pontifications on the age and stratigraphy of Nebraska Unit 1, which he had never seen in the field, a few pages earlier in his letter.

Marcou's spirited defenses of his opinions often provided additional ammunition for his critics. An example occurs in this letter, where (pp. 9–10) Marcou mentioned that he included the Permian with the Triassic "in the New Red Sandstone Formation" and went on to say:

> I know that good reasons, based exclusively on paleontological grounds, have been advanced by geologists desirous to place the Permian in the Paleozoic, but I think the old classification a better one, and more, I think the term Permian, at least as given by Murchison . . . a very improper one.

He was immediately called to account for this offhand statement by Roderick Murchison (1859) himself, the founder of the Permian System and one of the most renowned geologists of the nineteenth century. The faunas of the Permian and Triassic are, of course, about as different as the faunas of any two successive geologic periods can be, and Murchison's dignified criticism of Marcou's opinion in the pages of the "American Journal of Science" added to the evolving portrayal of Marcou as a geologist whose observations were not to be trusted and who was sadly out of touch with the mainstream of geological thinking. It is of interest to note that *lithologically* Permian and Triassic strata in the Southwest, especially red beds, may be quite similar. Marcou was then and remained a geologist for whom lithologic similarity was often a more persuasive indicator of time equivalency than any information the fossil record could give.

A month after Marcou's letter to Meek and Hayden was published, Marcou's "Geology of North America" was reviewed by J. D. Dana (Fig. 12), editor of the "American Journal of Science." The tenor of the review is indicated immediately in a footnote to the title, which criticized Marcou for listing the title "United States Geologist" after his name on the title page of his book (Dana, 1858, p. 323):

> . . . there is no such office under the Government, and no national Geological Corps. When an expedition for exploration and survey is organizing some person is usually associated with the party for scientific research, by appointment from the Department in charge of the survey. Those selected are sometimes good geologists and sometimes otherwise.



FIGURE 12. James Dwight Dana.

There would have been little doubt in anyone's mind after reading Dana's review that Marcou was to be included in the "otherwise" category.

Dana reiterated the by now familiar criticisms of Marcou inaccurately assessing previous work on North American geology, utilizing strictly lithological criteria in correlating large areas of the central U.S. with the Triassic of Europe and in assigning parts of the American sequence to the three European subdivisions of the Triassic, the Keuper, Muschelkalk and Buntsandstein. According to Dana (p. 329), "this offhand settling of a problem that requires care even among the fossiliferous beds of Europe, was a bold exploit in geological gymnastics."

The Jurassic age of the upper strata at Pyramid Mountain was also challenged, on the basis of the opinions of Hall and Blake that *G. tucumcarii* and *O. marshii* were incorrectly identified and actually were Cretaceous species. To augment these opinions, Dana tried something new; he brought forth an anonymous "surprise witness," identified only as "another able paleontologist, highly commended by Mr. Marcou" (Dana, 1858, p. 330), who dutifully stated that *G. tucumcarii* was actually *G. pitcheri* Morton and *O. marshii* was actually *O. subovata* Shumard. The anonymous paleontologist also pointed out (correctly), as Hall had done in 1856, that the species identified as *G. pitcheri* by Marcou from the Lower Cretaceous of Oklahoma was not *G. pitcheri* Morton but a separate variety (later raised to species), *G. navia*. These differences of opinion as to the correct nomenclature for various gryphaeid species are considered in more detail below; the effect of this avenue of criticism, however, was to suggest that Marcou could not identify fossils correctly and thus his age determinations made on the basis of fossils were not to be trusted.

Dana's review covered many other points of alleged error, some decidedly trivial, in Marcou's (1858a) book and map. The review concluded with an extraordinarily severe assessment of Marcou's work (Dana, 1858, p. 333):

> In conclusion we would say that our reconsideration of the labors of Mr. Marcou in America has not raised our estimate of their value. We know well that if any American geologist had mapped out strata and synchronized those of America and Europe on such data as have satisfied the author of the "Geology of North America," he would have been deemed young in the science, with much yet to learn before he could have a sober hearing. We cannot, therefore, think that his former reviewers and opponents deserve, because they differ from him, either to have their names expunged from American geological history, or thrown into discredit; nor do we believe that their reputations will seriously suffer from the judgment of our ambitious Rocky Mountain explorer. Finally, our readers must be fully persuaded, that "Marcou's Geology of North America," is not "good authority,"—except with regard to the author and his style of work.

The anonymous paleontologist cited by Dana was F. B. Meek. After Dana had published his review, he wrote to Meek (Letter, 14 December 1858; Fielding B. Meek papers, 1846–1877, Smithsonian Institution Archives) saying, "I have told no one out of our editorial circle that you are the Paleontologist of my article, and think it best still to keep it a secret." In the same letter Dana referred to Louis Agassiz's determination to defend Marcou in the "American Journal of Science," and stated that he would review Agassiz as he had Marcou if Agassiz went ahead with his plan. Dana's feelings about Marcou went deeper even than was expressed in his review, for his letter to Meek ended with "Marcou's ignorance and presumption and his falsehoods deserve more rebuke than they have had."

Louis Agassiz, who had encouraged the young Marcou in his earliest geological studies in the 1840's and sponsored him for the position of geologist on the Whipple expedition, did come to Marcou's defense in the "American Journal of Science" (Agassiz, 1859). The defense, however, was a weak one because, as Agassiz noted, he had not yet seen Marcou's "Geology of North America." Agassiz's comments, based on Marcou's earlier map (Marcou, 1855b), were directed mainly towards excusing Marcou's great area of Triassic exposures on the basis

that so little of the area had yet been studied that generalization was impossible to avoid. Agassiz also noted that *G. tucumcarii* seemed to him more closely allied with European Jurassic species than with Cretaceous forms. Agassiz's statements were relatively mild in tone, and he appears to have been going through the motions of defending his student rather than supporting Marcou's ideas with real conviction.

Dana (1859) responded immediately to Agassiz, noting that Agassiz had failed to comment upon most of the criticisms Dana had made and remarking upon the impossibility of a reviewer (Agassiz) adequately assessing a book that he hadn't read. Dana added one piece of support to his case against the Jurassic age of the upper Tucumcari strata—a quote from a letter by J. S. Newberry (see below) that had been published by Meek and Hayden (1859a) in the same issue of the "American Journal of Science" as Dana's note. Dana re-emphasized that Marcou's claims for discovering the Permian, Triassic and Jurassic in the West were dubious, stating that "in the Rocky Mountain region, his Permian is not proved to be Permian, his Triassic not Triassic, and his Jurassic not Jurassic. Where are then his discoveries?" (Dana, 1859, p. 139).

Marcou could not let Dana's criticisms pass and published in Europe another privately printed, 40-page letter, "Reply to the criticisms of James D. Dana" (Marcou, 1859). The letter was published because, as Marcou put it (p. 3), ". . . there are cases in which silence may do harm; for if the attack rests without reply, many persons may believe the charges advanced to be true, and so the progress of science will be checked, and unjust blame and discredit be thrown where they are not due." Marcou reprinted in this letter both of Dana's critical articles (Dana, 1858, 1859) as well as Agassiz's (1859) note in his defense and attempted to rebut Dana point by point. The term "United States Geologist," which Dana had objected to, was shown by Marcou to be used routinely by geologists attached to federal exploring expeditions. As for dealing unfairly with the contributions of some American geologists, Marcou pointed out that Dana's writings on American geological history also omitted numerous workers. Dana's anonymous paleontological authority had not remained a secret for long, for Marcou (p. 20) referred to "Mr. J. B. Meek" (actually F. B. Meek) as the paleontologist, and characterized him slightingly as a man "whose personal acquaintance with [the western U.S.] is not very extensive." Although it is true that Meek only made one trip to the upper Missouri region (Hayden did the bulk of fossil collecting for the Meek–Hayden team), no one knew the stratigraphy and paleontology of the region better than Meek.

Marcou (p. 21) also stated his philosophy on correlation, to answer Dana's (and earlier Blake's) charges that he relied too much on lithological features in establishing the age of strata:

> I consider stratigraphy [meaning the sequence and physical relationships of strata] as the first of all the characters, and I spare no pains to ascertain it by direct and numerous observations; then come fossil remains, and lastly the lithological characters. I always try as far as possible to use these three different series of characters together, and when one or even two of them fail completely, I apply myself with more care to examine the one or two that remain.

Although today paleontological evidence would be the chief means of determining the time-equivalency of strata in widely separated locations, Blake's and Dana's criticisms of Marcou's work left Marcou in what he felt was a no-win situation. He was criticized for using non-paleontological criteria in determining the Triassic, in which there were no diagnostic fossils, but when he did use fossils, as in his identification of the upper Pyramid Mountain units as Jurassic, his paleontological evidence was rejected. Marcou (p. 21) remarked that, ". . . if they [his critics] admit the characters of fossil remains, it is with a curious and immodest condition, that nobody else but themselves can rightly interpret them."

Marcou's letter also dealt with conflicting opinions on numerous specific points, which need not concern us here. With respect to Agassiz's paper defending him, Marcou added the following bit of information (p. 30):

> Mr. Dana's love of the truth and duty to science obliged him to decline publishing [Agassiz's] article in my favor without alterations, which the author refused to make, not wishing to pass under Mr. Dana's editorial scissors, and Mr. Agassiz was obliged to threaten the withdrawal of his name from the ["American Journal of Science"] to induce Mr. Dana to modify his views of duty sufficient to publish the article as it was written.

This statement shamefully stretched the truth, if it was not an outright lie. What actually happened, as was explained by the editors of the "American Journal of Science" (Anonymous, 1859a), was that Dana, upon receiving Agassiz's article, had simply asked Agassiz to read Marcou's book before submitting a review of it. Agassiz indignantly refused, and Dana acquiesced (Lurie, 1960, p. 272). There was no threat of censorship on Dana's part, and Marcou, by making public this episode, contributed to a deterioration of the close friendship between Dana and Agassiz.

Finally, Marcou (p. 35) alluded to Dana's criticism of his condescending attitude toward the accomplishments of American geologists:

> Mr. Dana speaks repeatedly of my ill treatment of the American Geologists, and as this may create a prejudice against me I will say, that I honor and respect the labors of American Geologists . . . I have never considered the accident of birth as having any relation to geology. . . .

Marcou's letter was written in a tone of righteous indignation, laced with sarcasm, and was far less cordial than his previous published letter (Marcou, 1858b) to Meek and Hayden had been. The level of personal antagonism between Marcou and several American geologists was now so high that an angry Marcou would use any means, including distortion of facts, to strike at his critics.

At the same time Meek and Hayden (1859a) were responding to points made in Marcou's (1858b) letter to them. They somewhat grudgingly acknowledged that they had erroneously included the lower 200 ft of Marcou's Pyramid Mountain section (Marcou's Triassic) in their Nebraska Unit 1. They were quick to assert, however, that "we yet regard all, or nearly all, of Mr. Marcou's Pyramid Mountain section, referred by him to the Jurassic System, as equivalent to the Cretaceous formations No. 1, 2, and 3 of Nebraska" (Meek and Hayden, 1859a, p. 32). Regarding the lower part of the section, referred by Marcou to the Triassic, they said "we think [it] equivalent to the Kansas deposits between the base of No. 1, as we now understand it, and the beds containing . . . Permian fossils"; in other words somewhere between the Upper Permian and Cretaceous. Meek and Hayden took pains to explain precisely this correlation because a preliminary announcement of their work had been misunderstood (possibly intentionally) by Marcou, who stated (Marcou, 1858c):

> . . . the series of Messrs. Meek and Hayden agrees perfectly with mine, and it is with great pleasure I see that these learned geologists admit not only the existence of the New Red Sandstone (Permian and Trias) and Jurassic, but that they are led to regard as Jurassic, formation No. 1 of their Nebraska Cretaceous Series, a formation . . . I have no hesitation in regarding as Jurassic.

Actually, Meek and Hayden had neither recognized the Triassic in the West nor admitted that Unit No. 1 was Jurassic (see footnote, p. 34, Meek and Hayden, 1859a).

In a pair of papers published a short time later, Meek and Hayden (1859b, c) clarified the circumstances leading to Heer's identification of their Unit 1 plants as lower Miocene. They had sent Heer sketches of some of these plants in August 1858 because J. S. Newberry, the American paleobotanical authority, was in New Mexico at the time. Heer's opinion of the age of the plants did not reach Meek and Hayden until December. Along with Heer's letter came Marcou's published letter (Marcou, 1858b), in which he quoted Heer's opinion. Apparently Marcou—in Zurich at the time, as was Heer—had followed Heer's studies of the plants closely and learned before Meek and Hayden did that Heer believed them to be of Tertiary age. In the meantime, Newberry had returned from his travels, examined the actual specimens and unhesitatingly pronounced them to be Cretaceous in age. Newberry's opinion was quoted by Meek and Hayden (1859a) in the January 1859 issue of the "American Journal of Science."

As Marcou (1858b) had already published Heer's opinion, however, Meek and Hayden (1859b, c) had to address the issue of the age of Unit 1. They excused Heer on the basis that "had the whole collection been submitted to him, instead of mere sketches of a few of the species, his opinion would have been very different" (p. 221), and went on to

say, "we can assert, with the fullest confidence, that it is *absolutely impossible* that this formation, or any part of it, can be Tertiary, for we know that it passes . . . beneath at least eight hundred feet of Cretaceous strata." The stratigraphic and paleontological evidence presented by Meek and Hayden left no doubt as to the Cretaceous age of Unit 1. Marcou's assertion (1858b, p. 12) that Unit 1 was partly Jurassic and partly Miocene was stratigraphically ridiculous, and publishing Heer's opinion before it reached Meek and Hayden bordered on the unethical. Marcou was grasping at straws here, hoping that by destroying the credibility of a Cretaceous age for Unit 1 his critics' argument for the Cretaceous age of his Jurassic Tucumcari section would be invalidated. Marcou was, unfortunately, doing exactly what he claimed his critics were doing to him—criticizing stratigraphic conclusions without having seen the area in question.

As a result of his travels and geological studies in New Mexico, Newberry was inevitably brought into the controversy. In his comments regarding the Cretaceous age of the Unit 1 plants from Nebraska (*in* Meek and Hayden, 1859a, p. 33), Newberry added:

> I may say in confirmation of the assertion that your fossil plants are Cretaceous, that I found, near the base of the yellow sandstone series in New Mexico, considered Jurassic by Mr. Marcou—a very similar flora to that represented by your specimens, one species at least being identical with yours, associated with *Gryphaea, Inoceramus* and *Ammonites* of lower Cretaceous species.

Newberry did not state where in New Mexico these fossils had been found, but he had spent most of 1858 exploring the Southwest as the geologist with a U.S. Corps of Topographical Engineers expedition led by Lieutenant Joseph C. Ives (Kues, 1985). In the geological report for that expedition, Newberry (1861, pp. 84–85) reported the fossils referred to above in a section near the "Moqui [=Hopi] villages" in what is now northeastern Arizona. Newberry correctly correlated these strata with Nebraska Units 1 and 2, but erred in considering them to be the same units that Marcou had called Jurassic in the Tucumcari area. One reason for this error was that Newberry believed he had found *G. pitcheri* in the Upper Cretaceous of New Mexico and Arizona, and, since *G. pitcheri* was supposed to be the species Marcou called *G. tucumcarii* at Pyramid Mountain, it followed that Marcou's Jurassic must be equivalent to Newberry's Cretaceous strata. However, much later Newberry's *G. pitcheri* was found to have no relationship to the "*G. pitcheri* group" (see Hill and Vaughan, 1898, for discussion), and is today known as *Pycnodonte newberryi,* a common Upper Cretaceous species in New Mexico.

Newberry (1861, p. 101) did admit, on the basis of his observations in northern New Mexico, that there was "little doubt that strata many hundreds of feet in thickness, intervening between the Carboniferous and Cretaceous formations, are the equivalents of Triassic rocks in Europe, and that at some future day the evidence of identity, which up to the present has not been discovered will be supplied."

Later on in 1859, after Newberry had embarked on the Macomb expedition from Santa Fe to the Green and San Juan Rivers in southern Utah, he communicated by letter to Meek some of his observations, which were reported in the September 1859 issue of the "American Journal of Science" (Anonymous, 1859b). Although the note is anonymous, it was probably written by Dana, judging from the title: "Dr. Newberry's late explorations in New Mexico—he shows Marcou's so-called Jurassic to be Cretaceous." Newberry had found more Cretaceous leaves in sandstones underlying marine beds containing *Inoceramus* associated with ammonoids and *G. pitcheri* (which was equated with *G. tucumcarii* in the note). The author of the note went on to say excitedly (Anonymous, 1859b, p. 299):

> Thus we have the same stone which Mr. Marcou and Prof. Heer would make *Miocene, overlaid* by beds containing not only well known and admitted Cretaceous fossils, but along with these the very *Gryphaea* relied upon by Mr. Marcou for the establishment of the existence of the Jurassic. So if Mr. Marcou and Prof. Heer are right, the Miocene proves to be older than the Cretaceous and the Jurassic! and the unfortunate American geologists find to their confusion that the roof of their geological ediface was constructed before the foundation was laid.

This statement reflects two misconceptions that were a central part of criticisms of Marcou's work: that *G. tucumcarii* was identical to *G. pitcheri* (it is actually, as Marcou believed, a separate species), and that the units elsewhere in New Mexico containing Cretaceous leaves and an Upper Cretaceous marine fauna were the same as Marcou's Jurassic sequence at Pyramid Mountain. Anonymous (1859b, p. 299) was forced to concede that the "facts elicited by Dr. N. [Newberry] seem however to sustain the Trias in New Mexico." Newberry had found Upper Triassic plant fossils near Abiquiu. Marcou (1860) published a short rebuttal to Meek and Hayden (1859a, b), referring again to Heer's identification of plants from Unit 1 as Miocene and attempting, unconvincingly, to show that the plants identified by Newberry also were Tertiary rather than Cretaceous in age.

During the time since the middle 1850's another geologist, B. F. Shumard, had been studying the Cretaceous sequence in Texas and Oklahoma, and publication of a paper summarizing his observations (Shumard, 1860) brought him into the controversy. Shumard worked mainly in what was later recognized as the Lower Cretaceous, and he first applied names to important stratigraphic units (Washita, Austin, Comanche) in the Texas Cretaceous sequence. Shumard presented his concept of the Texas Cretaceous in a stratigraphic section in his 1860 paper, along with lists of the characteristic fossils found in each unit and his correlation of the Texas sequence with that at Pyramid Mountain. Shumard found both *G. tucumcarii* and *O. subovata* (Marcou's *O. marshii*) in his Washita Limestone, which he assigned to the Upper Cretaceous and correlated with Nebraska Unit 3 and with Marcou's units E, F and G at Pyramid Mountain. A unit beneath the Washita Limestone, called "blue marl," was said to contain *Inoceramus problematicus,* a common constituent of Nebraska Unit 2, and near the bottom of his section Shumard reported an "Arenaceous Group" which he correlated with Nebraska Unit 1 and with Marcou's units B, C and D. This seemed to show that Marcou's Jurassic units at Pyramid Mountain were securely within the Cretaceous and supported the correlations made by Hall, Meek, Hayden and Newberry. Shumard's paper was reviewed approvingly in the "American Journal of Science" (Anonymous, 1861).

Marcou responded with a polite paper (Marcou, 1861a) that praised Shumard's accomplishments but disagreed with his concept of the stratigraphic sequence in Texas and his correlations with the Tucumcari section. Marcou pointed out several errors in Shumard's sequence: the Austin Limestone, with its Late Cretaceous fossils, should have been positioned above rather than below the "Comanche Peak Group"; the "Blue Marl," with *Inoceramus problematicus,* should be near the top of the section rather than below the Washita Limestone; and the Washita itself, reported as Upper Cretaceous by Shumard, was actually Lower Cretaceous. The lower two formations in Shumard's section (the only ones identified as being Lower Cretaceous) Marcou referred to near the top of the section, above the Comanche Peak and Washita units. One of these "lower" units, the "Arenaceous Group," was reported by Shumard to contain *Ostrea congesta,* which Marcou had identified near Galisteo, New Mexico, from strata he assigned (correctly) to the Upper Cretaceous.

The revised sequence of Texas Cretaceous units given by Marcou (p. 93) was ignored at the time, but ultimately proved to be considerably more accurate than Shumard's sequence. Nearly 30 years later Hill (1887a, p. 75) noted that Shumard's sequence:

> . . . most assuredly places the bottom of the Texas strata on top, the top in the middle, and all the other subdivisions equally out of place. Mr. Jules Marcou, in 1861, called attention to this discrepancy, and published an approximately correct ideal section, but his then recently published erroneous opinion concerning the alleged Jurassic age of certain Texas strata prevented this criticism from carrying the weight it deserved.

Despite the disorder in Shumard's section, however, he did correctly correlate his Washita Limestone with the horizon containing *G. tucumcarii* in the Tucumcari area. Confirmation of this correlation did not come until the 1890's.

Much of Marcou's (1861a) paper dealt with the intricacies of gryphaeid taxonomy, especially the confusion between *G. tucumcarii* and *G. pitcheri* that was augmented by some mislabeled figures of these and related species in papers by Hall and Conrad. Marcou realized that

three species were actually involved: *G. tucumcarii, G. pitcheri* and a "false" *G. pitcheri* which he had identified as *G. pitcheri* from the Lower Cretaceous of Oklahoma but now believed to be a new species. Hall (1856) had earlier described this taxon as *G. pitcheri* var. *navia*. One circumstance that contributed to the confusion was the fact that Marcou had kept nearly all of the specimens of *G. tucumcarii* he had collected from Pyramid Mountain, instead of returning them to the United States so that they could be studied by other paleontologists. While he was in Europe (1854–1860), Marcou distributed specimens to museums in Moscow, Berlin, Munich, Stuttgart, Basel, Zurich, Geneva, Paris and London (where the type specimens were deposited). Only upon his return to the U.S. did he also place specimens in an American museum, the Museum of Comparative Zoology at Harvard (Marcou, 1861a, p. 97). Marcou had stoutly maintained the validity and Jurassic affinities of *G. tucumcarii* for several years, but was obviously not eager to allow typical specimens from Pyramid Mountain to come under the scrutiny of his critics.

Despite this reluctance to make his specimens of *G. tucumcarii* available to other investigators, Marcou never missed an opportunity to assert their Jurassic age. For example, a reference to the species as being Cretaceous in a long list of Cretaceous fossils published by Gabb (1860) brought a critical letter from Marcou (1861b) to the Philadelphia Academy of Natural Sciences. Gabb (1861, 1862) responded by reporting that he had compared Marcou's illustrations of *G. tucumcarii* to the type specimens and other collections of *G. pitcheri* and had found "an unbroken series of gradation from one form to the other." Given the information available at the time, this was not an unreasonable conclusion.

Meek (1861) contributed a short paper to the "American Journal of Science," outlining his role in the mislabeled figures referred to by Marcou (he had drawn the figures but had nothing further to do with them) and commenting on the *G. tucumcarii–G. pitcheri* controversy (p. 280):

> Mr. Marcou lays great stress upon the differences between the so called *G. Tucumcarii* [sic] and the narrow form formerly referred by him to *G. Pitcheri* [sic], as if this has some bearing on the question at issue in regard to his Pyramid Mountain Jurassic. Whether we regard these forms, however, as distinct, or only as varieties of one species, has no bearing whatever on the main question at issue, since it is well known, as has been shown by Dr. B. F. Shumard, that they are both Cretaceous, and occur together in the same bed in Texas along with the so-called *Ostrea Marshii* [sic], and numerous well marked Cretaceous fossils.

This was a reasonable assessment and should have ideally been followed by an effort to obtain additional collections from the Tucumcari area in order to better compare faunas from Marcou's "Jurassic" with Cretaceous faunas from Texas and the Midwest. However, because the Tucumcari area was extremely remote, nearly three decades were to pass before new collections from the disputed horizon were made.

The next year Meek and Hayden (1862) presented an extended summary of the Cretaceous of Nebraska and applied names to the units previously designated 1 through 5. Unit 1 was named the Dakota Group; Unit 2, Fort Benton Group; Unit 3, Niobrara Division; Unit 4, Ft. Pierre Group; and Unit 5, Fox Hills beds. Units 1 through 3 were assigned to a "Lower Series" and units 4 and 5 to an "Upper Series." The "Lower Series" was correlated with the Turonian and Cenomanian of Europe, and the entire sequence is recognized today as Upper Cretaceous, with the exception of the basal beds of Unit 1, which were recognized as the Lower Cretaceous Purgatoire Formation in 1912 (Waage, written comm. 1985).

During the fall of 1863, Marcou, realizing that he needed to see for himself the Nebraska Cretaceous sections that Meek, Hayden and others believed to be correlative with his Pyramid Mountain "Jurassic," made a steamboat excursion up the Missouri River to examine them. His observations, however, were restricted to examination of a few isolated points along the shore of the Missouri River from St. Joseph, Missouri, to Sioux City, Iowa, and most of these were late Paleozoic strata. He published his geological summary of the area in the "Bulletin of the Geological Society of France" (Marcou, 1864). Meek (1865), who knew the area better than anyone, responded with a paper criticizing Marcou's conclusions. Along that part of his route where late Paleozoic rocks were exposed, Marcou assigned a few units to the Pennsylvanian but most to the Dyas (= Lower Permian) and Subcarboniferous (= Mississippian). In addition to misidentifying numerous fossils, Marcou also correlated mainly on lithological similarities to rocks in Europe with which he was most familiar. Virtually all of the Paleozoic sections examined by Marcou, Meek pointed out, are characterized by typical "Coal Measures" faunas and are Pennsylvanian in age, not Mississippian or Permian. While these observations are not directly related to the stratigraphy of the Tucumcari area, they do illustrate that Marcou continued, after 11 years, to confuse Pennsylvanian strata and fossils with those of Mississippian age, as he had done in the Sangre de Cristo and Sandia–Manzano Mountains of New Mexico in 1853. This episode also shows clearly some of Marcou's weaknesses as a geologist and scientist: a reluctance to thoroughly familiarize himself with the existing literature on a subject, carelessness in identifying fossils, a tendency to correlate based on lithology rather than paleontology (Meek stated that Marcou correlated entirely on lithology and then identified fossils so that they supported his lithological correlations), an inability to acknowledge the possible validity of opinions different from his own and an arrogance in presuming that his conclusions, based on superficial examination of the geology of an area, should supplant those of workers who were much more familiar with a subject than he was.

Marcou eventually reached the exposures of Nebraska Unit 1 that had yielded the plants identified as lower Miocene by Heer and as Cretaceous by Newberry. Meek (1865, p. 172) remarked that:

> . . . it must have been with no ordinary degree of interest that Mr. Marcou caught the first glimpse of those sandstone escarpments as he ascended the Missouri, especially as he had with him a skilful [sic] botanical paleontologist [the Italian, Capellini] to assist him in unraveling the knotty problem.

Marcou (1864) was forced to admit that Nebraska Unit 1 (Dakota Formation) was Cretaceous, but he also found fossils in this formation that were identical to some he had reported from the Upper Cretaceous near Galisteo, New Mexico. Marcou emphasized that Nebraska Unit 1 was not Lower Cretaceous, as it had earlier been called by Hall, Meek, Hayden and Shumard, but rather lay near the base of the Upper Cretaceous, an interpretation that Meek (1865, p. 173) had later on been leaning towards as well. Marcou also presented a slightly revised version of the relationships of New Mexico Upper Cretaceous units, in which the strata of the Albuquerque and Rio Puerco areas were shown to overlie the sequence at Galisteo, an essentially correct view. He denied in the strongest terms the correlation of Unit 1 with his Pyramid Mountain Jurassic.

With his characteristic penchant for playing up new discoveries made by himself, Marcou also established a new species based on a few shells he collected from Unit 1, naming the species *Cyrena nova–mexicana* on the supposition that it was identical to some fossils he had found in New Mexico. Meek noted that the "new species" had long ago been described under a different name from the same locality and position in Nebraska that Marcou had examined.

By 1865, however, the controversy over the Jurassic or Cretaceous age of the upper strata of the Tucumcari area had been decided to the satisfaction of American geologists, in favor of the Cretaceous. Marcou's views were now held in so little regard that Meek (1865, p. 173) was able to dismiss them by stating:

> Mr. Marcou also has some remarks on the question of the parallelism of this sandstone [Nebraska Unit 1] and the overlying *Inoceramus* beds, with the upper part of his Pyramid Mountain section in New Mexico. We have not the space to enter upon the discussion of this question here, nor is it necessary. The able review of this whole subject in Dr. Newberry's report as Geologist of Ives's Colorado Expedition [Newberry, 1861], and Dr. Shumard's several papers on the geology of Texas, place this question in so clear a light that probably no one but Mr. Marcou has any doubts on the subject.

In actuality, Marcou's concept of the Cretaceous sequence in Texas and New Mexico (Marcou, 1861a, 1864) was considerably more accurate than that of his contemporaries. Although Marcou was later shown to be wrong about the Jurassic age of the *G. tucumcarii* horizon at Pyramid

Mountain, his critics were incorrect in correlating it with Upper Cretaceous strata. Shumard (1860) was correct in correlating the horizon with the Washita of Texas, but erred in believing the Washita was Upper Cretaceous rather than Lower Cretaceous.

INTERLUDE

After Marcou's visit to the Tucumcari Mountain area in 1853, no geologist viewed the region until the late 1880's. Marcou, from his residence in Boston, turned his attention to other areas of geology, particularly the "Taconic problem" in New England, in which he again crossed swords with Hall. His return to the United States in 1860 was primarily to assist Agassiz in the organization and teaching activities of the newly established Museum of Comparative Zoology at Harvard where he held a position as geologist from 1862 to 1864. There were some who felt that he had been poorly treated by his opponents, and eventually Marcou worked again for the U.S. Government, notably with the Wheeler Survey in California (1875) and in compiling an annotated list of geologic maps of the Americas for the new U.S. Geological Survey (Marcou and Marcou, 1884). He also applied himself to pursuits outside of geology, producing a highly original piece of scholarship on the derivation of the name America and a two-volume study of the life of Louis Agassiz. Apparently relishing controversy, he also attacked John Wesley Powell and the research orientation of the U.S. Geological Survey (Lurie, 1974).

The misconception that Cerro Tucumcari was the mesa referred to by Marcy and Simpson as "Big Tucumcari" (Mesa Redonda) persisted for a time (e.g., Carleton's map of the New Mexico Territory, 1864), but by the 1870's maps of New Mexico consistently placed Sierra Tucumcari or Tucumcari Mount at the location where "Little Tucumcari" had appeared on earlier maps. The name Tucumcari apparently posed some problems for mapmakers, for on the 1876 Department of Interior General Land Office map of New Mexico the mountain appears as "Sierra Tucumcada," and on the Land Office's 1882 map this had mutated to "Sierra Vicumcari," before being corrected on later editions.

HILL, CUMMINS, AND MARCOU AGAIN—CONTROVERSY, PHASE 2

Interest in the stratigraphy of the Tucumcari area revived in the late 1880's as a result of renewed studies conducted on the Cretaceous sequence in Texas. It was recognized that the long-dormant disagreement on the age of the upper strata of the Tucumcari region, and by implication the age of the Llano Estacado as well, had to be resolved, for Tucumcari represented one of the westernmost exposures of the Texas Mesozoic sequence. In August 1888, R. T. Hill, of the U.S. Geological Survey, visited Tucumcari Mountain to check Marcou's determination of a Jurassic age of the strata overlying the Triassic red beds. Hill (1887b) had already worked out in some detail the Cretaceous sequence in Texas and, among other things, had determined that Shumard (1860) had constructed his composite section of units from widely separated localities and had scrambled the sequence of units completely, mixing rather indiscriminately Lower and Upper Cretaceous formations. Thus, one of the main pieces of evidence against Marcou's correlations was thrown into doubt.

Hill (1887c) originally believed that he had found Marcou's *Gryphaea tucumcarii* in Cretaceous strata in Texas, but upon visiting the Tucumcari Mountain area found that *G. tucumcarii* (called *G. dilatata* by Hill) "occupies a definite horizon, occurring by the thousands, far below what had hitherto been supposed to be the base of the American Cretaceous, where the small and entirely different typical variety of *G. pitcheri* Morton usually abounds" (Hill, 1888, pp. 172–173). He went on to say that for "thirty years the observations of Mr. Marcou have suffered the disapproval of American geologists on this point, but I am inclined to believe the correctness of his position." This apparent affirmation of Marcou's views led him to begin publishing again on Tucumcari area stratigraphy. It is clear from the tone and subject of these papers, published in the late 1880's and early 1890's, that Marcou wished to re-establish his claims of priority in various discoveries made in New Mexico and to present his ideas in a climate where they might be more readily accepted than in the 1850's and 1860's. Unfortunately for Marcou, Hill's agreement concerning the probable Jurassic age of the upper Tucumcari strata was premature, and the geologists who studied the stratigraphy of the Tucumcari area in the 1890's, including Hill, quickly became convinced that these beds were Lower Cretaceous rather than Jurassic.

Marcou (1889a) began with a summary of the errors made by previous workers, especially Newberry (1861, 1876), in reporting *G. pitcheri* from Cretaceous units in central New Mexico and Arizona, and in equating *G. pitcheri* with *G. tucumcarii* to establish the equivalency of Cretaceous formations with the upper part of Marcou's Pyramid Mountain section. As discussed previously, Marcou was correct on both points. He followed (Marcou, 1889b) with a long paper that outlined the history of study and various disagreements on the age of the Tucumcari strata, and reiterated in great detail the injustices done to his work—the pent-up frustration and bitterness of three decades coloring his final paragraphs:

> Instead of improving my classification of the American Mesozoic . . . of 1853 and contributing to the progress of American geology all the efforts of my critics during the last thirty-six years have been devoted to prevent its acceptance. They have failed to give a single new fact, only mixing the series of Mesozoic strata in a hopeless mass of confusion and errors; and by their obstruction preventing acceptance of truth and misleading the geologists who have trusted them.
>
> I am glad to say that a new generation of young observers has at last come to the front; and that already the Neocomian [Lower Cretaceous] has been signalized on vast surfaces of Texas and in southern Kansas; the Jurassic is recognized in the Tucumcari area and western New Mexico; the Trias is extended south and north of my line of travels by the 35th parallel . . . (Marcou, 1889b, p. 227).

Marcou (1889c) also reviewed Hill (1888) very favorably, protesting only against Hill's tentative inclusion of the "Trinity Series" in the lowermost Cretaceous rather than the Jurassic. Hill's correlation of the Trinity to the Tucumcari Mountain sequence is vague (see Hill, 1888, p. 125), but he seems to have considered the Trinity to occupy a position directly above Marcou's Jurassic units. Marcou was not so approving regarding Hill's work the next year (Marcou, 1890), accusing him of trying to pre-empt credit for discovery of the Lower Cretaceous in North America. Although it is true that Marcou first identified Lower Cretaceous strata near Comet Creek, Oklahoma, Hill's efforts in working out the Lower Cretaceous sequence in Texas and establishing it as a series equal in status to the Upper Cretaceous stands as a far more significant contribution.

Hill returned to the Tucumcari area in April 1891, and in the same year W. F. Cummins, of the Geological Survey of Texas, also explored the area. Cummins (1892) summarized equitably previous studies and presented a simple stratigraphic section measured up the north side of Tucumcari Mountain (Fig. 13). This section included a lower sequence of Triassic red, purple and blue clay and sandstone (236 ft), overlain by "massive yellow sandstone" (235 ft), "shale" (50 ft) and "massive sandstone" (60 ft) units—all three assigned to a unit he named the "Tucumcari beds"—and capped by 20 ft of "white, clayey limestone" of Tertiary age. Cummins' "Tucumcari beds" were exactly equivalent to the entire Jurassic sequence of Marcou at Pyramid Mountain, except that Marcou included the Tertiary limestone in his Jurassic. It is worth noting, because modern workers usually credit Cummins, that Marcou (1889c, p. 365) used the term "Tucumcari beds" for this interval three years before the term was suggested by Cummins.

Cummins (1892, p. 203) also "made a large collection of the invertebrate fossils" from the "Tucumcari beds." Twelve mollusc species were identified, including the two species Marcou found in 1853—*Gryphaea tucumcarii* and *Ostrea subovata* (Marcou's *O. marshii*). Curiously, *G. pitcheri,* which Cummins acknowledged was very different from *G. tucumcarii,* also appeared in the faunal list. Because the faunas of the Texas Lower Cretaceous were adequately known by that time, Cummins was able to convincingly correlate the "Tucumcari beds" with the Washita "division" (uppermost Lower Cretaceous) of Texas, in effect placing the "Tucumcari beds" much higher in the Lower Cretaceous sequence than did Hill. A poorly preserved angiosperm-

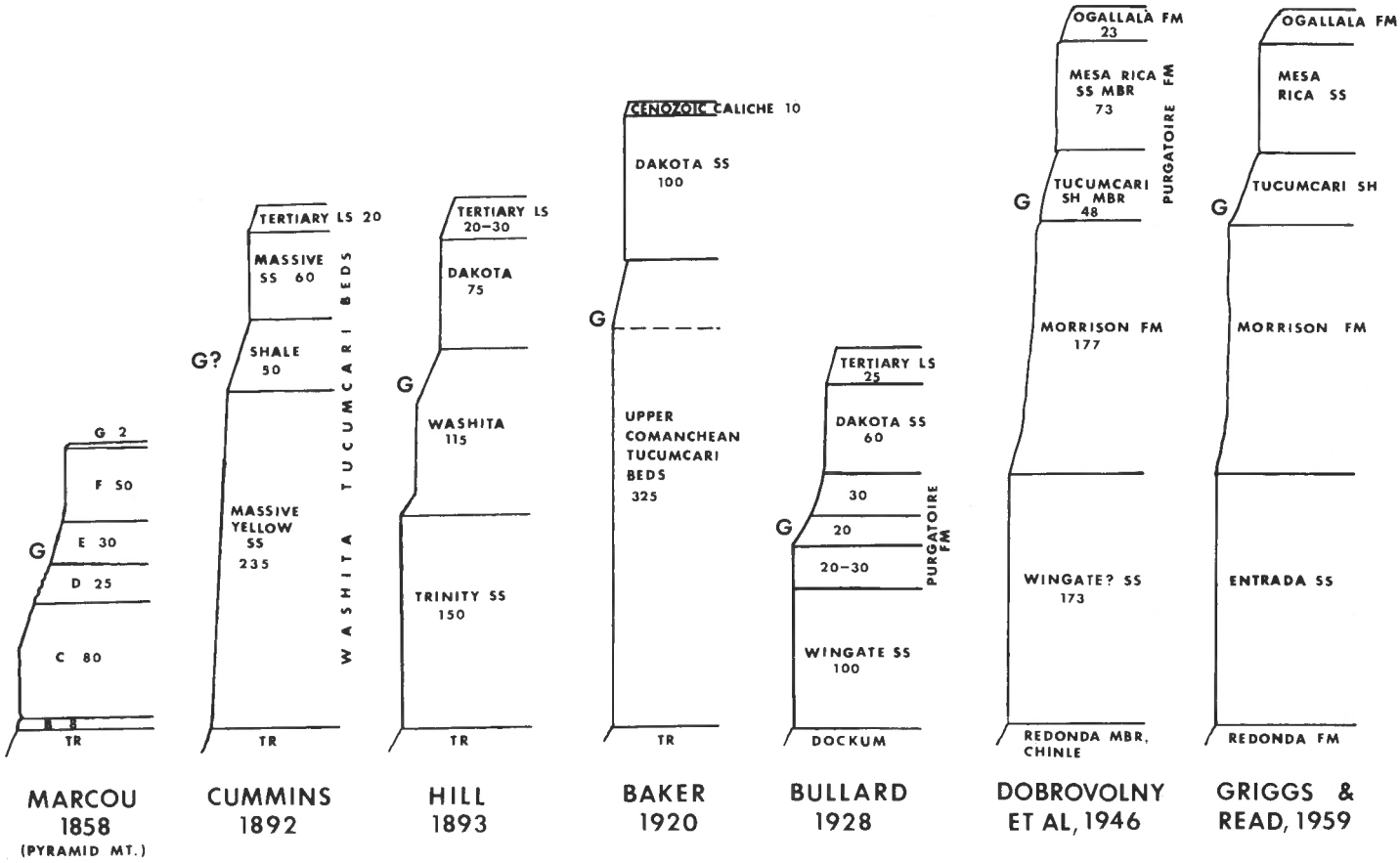


FIGURE 13. Stratigraphic sections and nomenclature of Tucumcari Mountain by various workers, with Marcou's Pyramid Mountain section for comparison. Numbers are thicknesses, in feet, assigned to each unit; G indicates level of *Gryphaea tucumcarii* horizon.

plant leaf from the upper sandstone of the "Tucumcari beds" (Mesa Rica Sandstone of present usage), four miles west of "Big Tucumcari Mountain," was described by Cummins as *Sterculia drakei,* new species, and used as additional evidence for the Cretaceous age of the interval. Hill (1895, p. 232) later reported that this species was not new and came from the sandstone below the *G. tucumcarii* interval rather than above it (see Kues et al., 1985, for discussion).

One can only imagine the effect that Cummins' paper had on Marcou. Expecting vindication for his view of the Jurassic age of the "Tucumcari beds" from "the new generation of observers," he was confronted instead with virtually unassailable evidence that they were indeed Cretaceous. That they were Early rather than Late Cretaceous in age, as his earlier opponents had maintained, was small consolation. Marcou (1892) responded by questioning Cummins' identifications of the fossils, especially with regard to the co-occurrence of *G. tucumcarii* and *G. pitcheri,* repeating that the two species he found at Pyramid Mountain were Oxfordian (Jurassic) in age and citing some very dubious reports of angiosperm leaves in pre-Cretaceous rocks in Virginia—altogether an argument that was not very convincing, or objective. Marcou also reported that Alpheus Hyatt (a prominent American student of cephalopods) had made an extended survey of the Tucumcari area in 1889 and, according to Marcou, had collected more than 60 species. Marcou examined the collection and reported, predictably (p. 374), that he did not see a single species that he would call Cretaceous.

Meanwhile, Cummins' 1892 paper had been favorably reviewed (Anonymous, 1892) in the "American Geologist." The reviewer discussed the correlation between Cummins' Tucumcari Mountain section and Marcou's Pyramid Mountain section—something that one would have expected Cummins to have done. Although misinterpreting the extent of Cummins' "Tucumcari beds" interval, the review made one very perceptive observation. Cummins had not precisely identified which level in the "Tucumcari beds" his Washita-age fossils had been collected from, although they probably originated from the shaly *G. tucumcarii* horizon near the top of the "Tucumcari beds." The reviewer pointed out that, although these fossils strongly indicated a Cretaceous age for these upper beds, the thick yellowish-sandstone beds (considered possibly equivalent to the Trinity sands of Texas) underlying the fossiliferous horizon might still be Jurassic. Anonymous (1892) also referred to Hyatt and Hill as supporting a Jurassic age for the "Tucumcari beds," which brought a quick response from Hill (1892b), stating that neither Hyatt nor himself had authorized such a statement. Hill (1892a) was now convinced that the interval was Cretaceous, and Hyatt "was cautiously working up his material" before rendering an opinion.

Marcou (1893a) then quoted Hyatt as expressing the opinion that his Tucumcari fauna was Jurassic, and went on to criticize Hill for assigning the upper massive sandstone above the *G. tucumcarii* horizon to the Dakota Formation, and sandstones B, C and D of the Pyramid Mountain section to the Trinity sands. Both Anonymous (1892) and Hill (1892b), however, were on the right track. They were beginning to realize that the individual units included within Marcou's Pyramid Mountain Jurassic section and Cummins' "Tucumcari beds" (assigned entirely to the Washita division) might correlate with different formations in the better known Texas sequence, and might also be of different ages.

Hyatt, who had spent the most time in the Tucumcari area and had the best collections of fossils, declined to become involved in the controversy. Feeling himself being drawn in by having his casual statement to Marcou quoted in the published literature, both by Marcou (1893a) and others, Hyatt moved to put a stop to it. He emphasized (Hyatt, 1893) that his opinion was verbally given, implied that he had not expected it to be published, and went on to state that "I do not at present consider myself qualified to give any opinion on this question" because "the evidence on either side [is] very conflicting and my in-

formation at present is far too limited." Hyatt was in the process of studying the Tucumcari fauna, but his manuscripts were never published, a fact that Marcou (1893b) implied was due to the efforts of his enemies to prevent acceptance of his views. In one of these manuscripts, quoted by Hill and Vaughan (1898, pp. 20–21), Hyatt stated that no European Jurassic species were present at Tucumcari, and *G. tucumcarii* had characteristics that allied it to Cretaceous rather than Jurassic species. Hyatt's reluctance to become involved in the debate was understandable, as he and Marcou had become friends during Hyatt's first year at Harvard. Hyatt would later write a biographical sketch of Marcou after his death in 1898 (Hyatt, 1899).

Despite the general ineffectiveness of Marcou's attempt to challenge Cummins' (1892) determination of the Washita age of the "Tucumcari beds" on scientific grounds, Marcou (1892) found a different avenue by which to attack Cummins' credibility. Marcou observed that Cummins had confused the names of several geographic features on the map that accompanied his report. Cummins erred by calling "Big Tucumcari Mountain" Monte Revuelto (actually a northern extension of the Llano to the east of the Tucumcari area, which appears in its correct position on Marcou's 1858 map); by calling the "Little Tucumcari" of Marcy, Simpson and Marcou "Big Tucumcari"; and by referring to the small unnamed mound between "Big" and "Little" Tucumcari (the present Bulldog Mesa) as "Little Tucumcari." Although Marcou was correct, he confused the issue by stating that "Big Tucumcari" is "called now only Tucumcari Mountain" (Marcou, 1892, p. 372). Cummins (1893b), ignoring Marcou's valid objections to his geographical nomenclature, dwelled instead on Marcou's one misstatement and spent eight printed pages proving that Marcou's "Big Tucumcari" could not be *the* Cerro Tucumcari of the early explorers. He asserted also that the peak believed by Marcy and Simpson to be Cerro Tucumcari (="Little Tucumcari" on their maps) was now called Big Tucumcari by the inhabitants of the area and was duly recorded under that name on Cummins' map. Marcou (1893c), in return, presented a detailed and generally accurate summary of the history of the geographic terminologies involved, rejected Cummins' names again, but declared that Simpson (1850) had actually *separated* Cerro Tucumcari in two, calling the northern peak "Little Tucumcari" and the southern one "Big Tucumcari." Actually, Simpson had clearly described Cerro Tucumcari and had called it "Little Tucumcari" on his map, and Marcy (1850) had designated "Little Tucumcari" as Cerro Tucumcari on his map.

One can only view the four papers in which this argument is tortuously played out with amazement. The pertinent federal maps of New Mexico had long since ceased the terms "Big" and "Little" Tucumcari, and from the 1870's the geographic feature called Sierra Tucumcari or Tucumcari Mountain on these maps is the peak that continues to be called Tucumcari Mountain today. That the exchanges by Cummins and Marcou were published at all perhaps is a reflection of the importance stratigraphers of the day attached to the Tucumcari Mountain area sequence. However, the argument recounted above was mainly a consequence of each man's desire to lessen the credibility of the other, and does not reflect favorably on either Cummins or Marcou.

Cummins (1893a) and Marcou (1893b) also exchanged diatribes in the pages of "Science" magazine. Cummins took pains to negate Marcou's (1892) suggestion that the labels on fossils Cummins collected from the Tucumcari area had become mixed up with specimens from other localities (an indication of how desperate Marcou was to explain away the Cretaceous age of Cummins' Tucumcari fauna). Cummins pointed out once again that, although *G. tucumcarii* resembled the Jurassic *G. dilatata* and might even be a variety of that species, it would "certainly not be considered sufficient to establish the Jurassic age of the beds when there is associated with it the other forms enumerated which are certainly Cretaceous" (Cummins, 1893a, p. 283).

Marcou (1893b) responded a month later with an article that revealed his frustration that the evidence for a Cretaceous age of the "Tucumcari beds" was solidly against his 40-year belief of their Jurassic age, and shows as well a touch of paranoia. He lashed out at his critics, attacking their qualifications as paleontologists. Of Cummins he wrote (p. 359):

> The value of determination of fossils depends much on the name of the paleontologist employed. To be sure anyone, even the greatest paleontologist, makes mistakes; but . . . they are less liable to errors than others. Mr. Cummins is unknown as a practical paleontologist. Until three years ago, he was regarded as a collector of fossils in Texas. . . .

C. A. White, who had examined fossils sent by Cummins to the U.S. National Museum and qualified, in Marcou's words, as "one of the experts," was made the subject of an anecdote recounting a visit by White to Marcou's home nine years before that belittled White's ability to discriminate Jurassic from Cretaceous fossils. Hill, whose work Marcou had regarded so favorably four years before, was dismissed with the comment that he "has not yet published anything reliable, only a few contradictory statements, without proofs and against plain stratigraphic and paleontologic facts."

Of his own efforts, Marcou (1893b, p. 359) stated:

> . . . it is forty years since I started from Boston for my exploration by the thirty-fifth parallel, for a Pacific railroad . . . ; and, although one concession has been made in my favor, by almost all my adversaries—the correctness of my reference of the lower beds of the Tucumcari to the Trias—the opposition continues, with a degree of intensity and, I am sorry to say, of unfairness never equalled.

In reality, both Hill and Cummins had been fair to Marcou in their publications by fully acknowledging his legitimate contributions. But neither man could ultimately accept Marcou's belief in the Jurassic age of the "Tucumcari beds," and Cummins, at least, eventually responded forcefully to Marcou's increasingly fervid polemics. In Marcou's mind it was not only his recent opponents who were to blame:

> My old adversaries, almost all alive now, with the exception of the two Shumards, Meek and Newberry, are still at work against me. But I have resisted their combined attacks during forty years, and I can continue very well the defense of my observations and opinions (Marcou, 1893b, p. 360).

Two weeks after Marcou's paper appeared in "Science," Hill (1893) published a note in the same journal. Admitting that initially he had fallen into the error of considering the "Tucumcari beds" Jurassic because of the Jurassic aspect of *G. tucumcarii*, Hill pointed out that additional fossils collected during his second trip to the Tucumcari area had convinced him of the Washita age of the unit. He maintained further that he had been the first to recognize its Washita age, in a paper (Hill, 1892a) that was published several months before that of Cummins (1892). Hill also accused Cummins of implying that Hill had held to the Jurassic age of the "Tucumcari beds" for several years, when in fact Hill had begun to abandon that position shortly after his first (1888) trip to the area. In some strange way the geology of the Tucumcari area seemed to arouse the combative instincts of all who studied it.

Of greater importance, Hill presented a stratigraphic section of Tucumcari "Mesa" (Fig. 13) that was more detailed than that reported by Cummins (1892). This section consisted, in ascending order, of pre-Cretaceous red beds (250 ft); white and red unconsolidated sands with thin quartzites and blue clays (Trinity, 150 ft); yellow sandstone, arenaceous clays and marls containing *G. dilatata* (=*G. tucumcarii*) (Washita, 115 ft); a massive yellow–brown sandstone (Dakota, 75 ft); and a 25–30-ft cap of Tertiary white, marly limestone. The thicknesses of Hill's and Cummins' sections are very close, as are the thicknesses of the interval between the Triassic and the massive "Dakota" sandstone. By assigning the lower sandstone interval to the Trinity and the upper one to the Dakota, Hill subdivided Cummins' "Tucumcari beds" into three units which were roughly the same as those recognized lithologically today. Thirteen taxa of fossils were identified from the Washita unit, only three of which had appeared in Cummins' (1892) faunal list. Hill was charitable regarding Marcou's initial identification of the Washita unit as Jurassic (Hill, 1893, p. 24):

> As I have previously maintained, *G. dilatata* Marcou is a good species, entirely distinct from *G. pitcheri* Morton, and, as has been said, has remarkable resemblance to the Jurassic *G. dilatata* of Sowerby. Under these conditions it is not strange, then, that before the stratigraphic and paleontologic position of the Washita Division was known, that the distant Tucumcari beds should have been adjudged Jurassic upon the evidence of the two species collected therefrom by Marcou, which certainly have, when considered alone, a most Jurassic aspect.

Marcou's next paper (1894) dealt mainly with minor historical items and criticism of other workers, for the most part subjects that he had

discussed in previous papers. Though agreeing that the Washita division in Texas was relatively high in the Cretaceous (Marcou put it in the "Middle Cretaceous"), Marcou continued to consider the "Tucumcari beds," as well as the Fredericksburg and Trinity groups in Texas, to be of Jurassic age. By now, however, Marcou's arguments had been repeated several times, and geologists actively working on the details of Lower Cretaceous stratigraphy in Texas and neighboring areas felt little need to pay much attention to them. Nearly simultaneously, Hill (1895) and Cragin (1895) published long biostratigraphic papers, dealing in a detailed way with the sequence and faunas of various Lower Cretaceous units in Texas, Oklahoma and Kansas. Both authors recorded the occurrence of *G. tucumcarii* at several localities throughout this area, and the zone marked by this species at some localities was found to lie stratigraphically *above* the interval containing Marcou's *G. pitcheri* (referred to in the literature of the time as *G. navia* or *G. roemeri*), which Marcou had always (and correctly) believed to be Lower Cretaceous. Vaughan (1897) finally relocated Marcou's Comet Creek locality, found both *G. tucumcarii* and Marcou's *"G. pitcheri"* there, and thus removed any possible doubt that the New Mexico *G. tucumcarii* horizon was virtually equivalent to the interval in Oklahoma that Marcou had called Lower Cretaceous.

Cragin (1895, p. 382) identified *G. tucumcarii* in southern Kansas and established the term Tucumcari shales for the zone characterized in part by the presence of *G. tucumcarii*. The name was derived from "Mount Tucumcari, New Mexico, where the zone of *Gryphaea tucumcarii* was originally discovered by Mr. Jules Marcou." This, of course, is not accurate, as Marcou did not examine Tucumcari Mountain but rather studied the section exposed at Pyramid Mountain, about 15 mi (24 km) to the southwest. However, Cragin, by implication, did restrict the term to a much narrower unit than had previous workers: in the Tucumcari area it could only refer to Bed E of Marcou's Pyramid Mountain section; to the 50-ft "shale" unit near the top of Cummins' (1892) "Tucumcari beds"; and to about the upper half of Hill's (1893) Washita unit. Cragin included the Tucumcari shales as the highest subdivision (member?) of the Kiowa shales, and even today the Tucumcari Shale in New Mexico is considered to be correlative with the upper part of the Kiowa in Kansas (Scott, 1970). The Kiowa shales were believed by Cragin to occupy a level intermediate between the Fredericksburg and Washita divisions of the Comanche (Lower Cretaceous) series, but Hill (1895) was closer to the truth in putting the Tucumcari shales securely within the Washita division.

By 1895, then, the exact stratigraphic position and age of the *Gryphaea tucumcarii* horizon was known, although the age of the thick, predominantly sandstone sequence between it and the underlying Triassic red beds was still in doubt because of the absence of fossils. Marcou (1897) wrote one last paper on the subject that had occupied so great a portion of his 50-year career in geology. He reviewed some of the recent literature and declared that the gryphaeas that Cragin and Hill had identified as *G. tucumcarii* above the interval that Marcou had called Neocomian was not that species at all, but a new one, to which he gave, without description, the name *G. kansana*. He also rejected Hyatt's finding of a Lower Cretaceous ammonoid in the *G. tucumcarii* zone, although he did relent to the extent of allowing the possibility that Lower Cretaceous strata might be present in the Tucumcari area at a level above the highest unit on Pyramid Mountain. About half a year after this paper was published Marcou died, three days short of his seventy-fourth birthday, with the belief in the Jurassic age of his "Tucumcari beds" unchanged.

GRYPHAEA TUCUMCARII

From the discussion above it is evident that much of the controversy surrounding the Jurassic or Cretaceous age of the upper part of the Pyramid Mountain section and elsewhere in the Tucumcari area centered around the identity of the large gryphaeas that Marcou identified either as *G. dilatata*, a European Jurassic species, or as *G. tucumcarii*, a new species or variety closely related to *G. dilatata*. Marcou's early opponents contended that these specimens represented *G. pitcheri*, a widely distributed Cretaceous species. A detailed resumé of the taxonomy of *Gryphaea* [now *Texigryphaea*] *tucumcarii* is given elsewhere in this guidebook (Kues et al., 1985), but a few brief comments here are appropriate.

Gryphaeids are a notoriously difficult group to deal with taxonomically (Stenzel, 1959), as there is much intraspecific variation and often large suites of specimens are required to obtain a full understanding of the differences between species. In the 1850's, most gryphaeids found in the Cretaceous of North America were routinely assigned to *G. pitcheri*, as Marcou had done with specimens from the Lower Cretaceous of Oklahoma. It was soon recognized by Marcou and others that the *G. pitcheri* from Oklahoma was a new species, which Hall called *G. navia* and to which Marcou (1861) applied the name *G. roemeri*. However, most paleontologists of the 1850's and 1860's continued to regard Marcou's *G. tucumcarii* specimens from Pyramid Mountain as being conspecific with the "true" *G. pitcheri* (e.g., Gabb, 1862). By the 1890's, with additional collections from the Tucumcari area, most workers became convinced of the validity of Marcou's *G. tucumcarii* as a separate species, but, based on other molluscs with which it occurred, considered it to be Lower Cretaceous rather than Jurassic. These workers (e.g., Cummins, 1892; Hill, 1893) did acknowledge the striking resemblance of *G. tucumcarii* to the Jurassic *G. dilatata*, to which Marcou in some papers referred *G. tucumcarii*, and did not fault Marcou for his original assignment of the *G. tucumcarii* horizon to the Jurassic. A glance at Figures 14 and 15 shows the close similarity between *G. dilatata* and *G. tucumcarii*.

Eventually, the Lower Cretaceous gryphaeids of North America were monographed by Hill and Vaughan (1898), who provided a detailed summary of the taxonomic histories of the various species, especially forms that had been called *G. pitcheri*. In that monograph, Hill and Vaughan showed that none of the purported occurrences of *G. pitcheri*

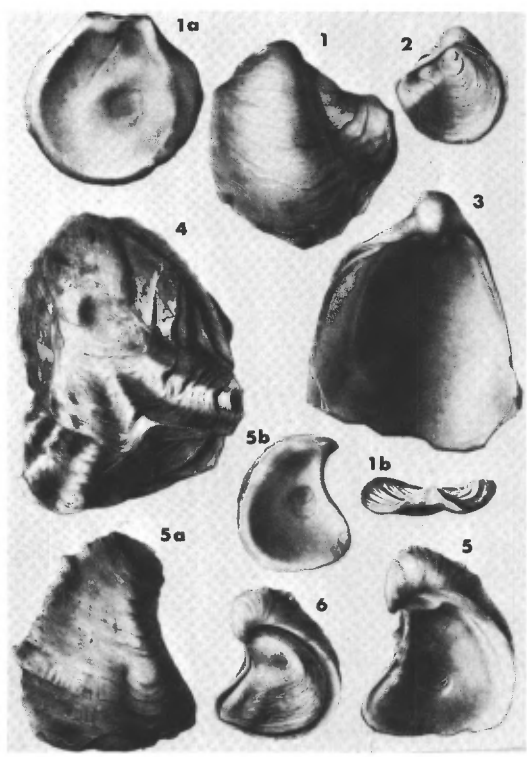


FIGURE 14. Plate IV of Marcou, 1858a (×0.4), showing *Texigryphaea tucumcarii* (as *Gryphaea dilatata* var. *tucumcarii*, figs. 1, 1a, 1b, 2, 3), *"Ostrea marshii" (fig. 4), and "Gryphaea pitcheri"* (figs. 5, 5a, 5b, 6). As Marcou's original figure numbers are very faint, darker numbers have been added for clarity. Marcou's description of the figures of *G. dilatata* var. *tucumcarii* (Marcou, 1858a, p. 43) are as follows: Fig. 1, lower valve of a fully grown individual; Figs. 1a, 1b, upper valve of the same; Fig. 2, young specimen with both valves, showing well the lobe upon the upper one; Fig. 3, lower valve of a very long, fully grown individual.

in Upper Cretaceous rocks contained specimens that were closely related to "the *G. pitcheri* group" of species from the Lower Cretaceous. Surprisingly, however (in view of Hill's earlier statements concerning the distinctiveness of *G. pitcheri* and *G. tucumcarii*), Hill and Vaughan (1898, p. 42) considered *G. tucumcarii* to be no more than a variety of *G. corrugata* (a name they used for *G. pitcheri*), effectively deemphasizing the differences between *G. tucumcarii* and *G. pitcheri*. Adkins (1927, 1928) and most subsequent workers have accepted *G. tucumcarii* as a valid species. With the recognition that European Jurassic species of *Gryphaea* differed in subtle but important ways from North American Cretaceous species assigned to that genus (e.g., Stenzel, 1959), several of the common North American Lower Cretaceous gryphaeids were assigned to the new genus *Texigryphaea*. This genus includes not only the typical *G. pitcheri*, but also the *"G. pitcheri"* that Marcou had used to indicate the presence of the Lower Cretaceous in North America, and *"G. tucumcarii,"* which he relied upon for the Jurassic age of the Tucumcari beds. The latter two species, ironically, occur at very nearly the same stratigraphic level.

As we have seen, Marcou placed great emphasis on the identification of *Gryphaea tucumcarii* as a species distinct from other North American Mesozoic gryphaeids, and his view has generally prevailed in that *Texigryphaea tucumcarii* is considered a valid species today. However, it is also true that some specimens of *T. tucumcarii* resemble *T. pitcheri* rather closely (see Kues et al., 1985), and his opponents cannot be faulted for believing them to be the same species. More importantly, Marcou's opponents realized, as Marcou did not, that the morphological similarity of *T. tucumcarii* to the European Jurassic species *G. dilatata* was of little significance in determining the age of the "Tucumcari beds." Given the typically wide variability of gryphaeid species, and the equally close resemblance of *T. tucumcarii* to the Cretaceous *T. pitcheri*, it was far more likely that the affinities of *T. tucumcarii* were with Cretaceous species known from neighboring states than with a European Jurassic species. This reasoning was strengthened by the clear identity of Marcou's other "Jurassic" species from Pyramid Mountain—*"Ostrea marshii"*—with *O. subovata*, a Lower Cretaceous species described in the mid-1850's from Texas. Thus, even in the 1850's, the purported Jurassic affinities of *T. tucumcarii* represented a highly questionable piece of evidence for the Jurassic age of the "Tucumcari beds," but it was the only support that Marcou had in the dispute, and he clung to it long after many other indisputably Cretaceous fossils were found in the Tucumcari area.

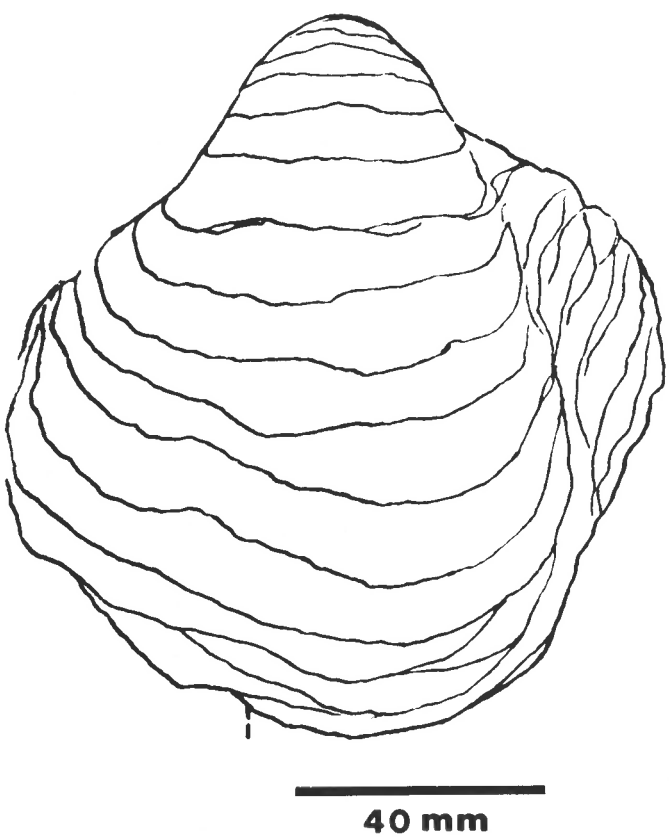


FIGURE 15. Sketch of *Gryphaea dilatata* from the Jurassic of England (from Arkell, 1932, p. 165).

THE TWENTIETH CENTURY

The remaining uncertainty in the stratigraphy of the Tucumcari area, namely the identity and age of the thick, predominately sandstone units between the underlying Triassic formations and the upper Lower Cretaceous Tucumcari Shale, was clarified gradually during the first decades of the twentieth century. The discussion here is confined to the development of the modern stratigraphic terminology, as detailed information on the formations involved is presented in other papers in this guidebook.

Lee (1902), working southward from Colorado, described a series of variegated shale and friable sandstone beneath the Dakota Formation along the Dry Cimarron River in northeastern New Mexico. A persistent, pink to white, unfossiliferous sandstone between the Triassic red beds and these shales was named the Exeter Sandstone. Lee noted the same sequence as far south as the Canadian River and suggested the possibility (p. 58) that the shale–sandstone unit above the Exeter represented the Morrison Formation, which he tentatively correlated with the Lower Cretaceous of Texas. Lee was unsure of the age of the Exeter, suggesting that it could be Triassic or as young as the Trinity sands (Lower Cretaceous).

In June 1905, T. W. Stanton joined Lee in eastern New Mexico and they examined Mesa Tucumcari. Stanton (1905, p. 665) reported that:

> . . . the Dakota sandstone, eighty feet in thickness, is underlain by sixty feet of fossiliferous Comanche shales and yellowish sandstones. . . . The Morrison formation was not recognized but its place in the section is occupied by a talus slope with no exposures. The lower part of the section is composed of Red Beds . . . , overlain by a friable, light-colored sandstone that is suggestive of the Exter [=Exeter].

About 10 mi (16 km) northwest of Tucumcari, Stanton observed 300 ft of variegated shale and sandstone that were very similar to the Morrison farther north and contained fragmentary dinosaur bones.

The same year, Keyes (1905a) reviewed the stratigraphy of the Tucumcari area and observed that each of the rock units included by Cummins (1892) in the "Tucumcari beds" represented a different formation. Keyes recognized an upper Dakota sandstone remnant (modern Mesa Rica Sandstone), agreed with the correlation of the fossiliferous shales below it with the Washita of Texas and considered the thick sandstone unit (the "so-called Trinity sandstone") between the Triassic below and the Washita shales above to be probably Jurassic. A month later, Keyes (1905b, p. 424) presented a list of formations in eastern New Mexico that included, in ascending order between the Triassic red beds and the Dakota, the "Amarillo sandstones" (200 ft), "Pyramid shales" (100 ft) and "Comanche sandstones" (300 ft). The "Amarillo sandstones" refers to the Jurassic part of the Tucumcari area sequence, as Keyes correlated it with the Wingate Sandstone in western New Mexico (part of this interval was indeed called the Wingate Sandstone by some later workers, e.g., Dobrovolny et al., 1946). The "Pyramid shales" were correlated with the Jurassic Zuni shales (actually sandstones) in western New Mexico, but must refer to the Washita-equivalent shales mentioned earlier by Keyes (1905a). What Keyes had in mind by 300 ft of "Comanche sandstones" immediately beneath the Dakota is unclear. None of these three names were formally established or discussed by Keyes. A year later, Keyes (1906) recognized only 250 ft of Jurassic "Morrisonian sandstones" overlain by 100 ft of "Comanchean shales" between the Triassic and the Dakota in northern New Mexico. This is an essentially correct view of the ages of the units in Cummins' "Tucumcari beds."

Keyes discussed the stratigraphy of the Tucumcari area in several other papers and even wrote a retrospective on Marcou's accomplishments in geology (Keyes, 1923). However, from the 1920's on, he

published almost exclusively in his own journal, the "Pan-American Geologist," and seems to have become obsessed with replacing the accepted stratigraphic nomenclature in New Mexico and elsewhere with terms of his own creation, which were seldom adequately defined or related to type sections. Few of his names were accepted by anyone but him. For the record, in Keyes' latest writings on Tucumcari stratigraphy, there is within a "Tucumcarian Series" a basal 250-foot sandstone unit ("Rodondo sandstone") overlain by 50 ft of "Pyramid shales" beneath the Dakota (Keyes, 1940a, b). Contrary to his earlier writings, in which the 250-ft sandstone unit was considered (correctly) Jurassic and called "Morrisonian," the entire "Tucumcarian series" was said by Keyes to be "Early Cretacic." Keyes (1940c) then replaced the name "Pyramid shales" with "Revuelto shales." None of these names has any validity.

The next geologist to examine Tucumcari Mountain (Baker, 1920) measured a stratigraphic section that was conceptually no improvement over those presented by Cummins and Hill in the 1890's. Baker reported 100 ft of purple to red sandy clays (Upper Triassic) overlain by 325 ft of "soft, cream-colored sands" and (in the upper 50 ft) clayey blue–gray sands containing *Gryphaea tucumcarii*. This 325-ft sequence was assigned to the upper Comanchean Tucumcari beds. Overlying it was 100 ft of Dakota Sandstone and 10 ft of Cenozoic caliche (Fig. 13). Curiously, Baker ignored the strong suggestions made earlier by Lee, Stanton and Keyes that much of the section was Jurassic. In the same year, Keyes (1920) reiterated that Marcou's identification of a thick Jurassic sequence in the Tucumcari area was correct, and noted that Marcou had erred only in including the Dakota (Mesa Rica) sandstone and the thin Comanchean shale unit immediately below it in his Jurassic. Garrett (1920) briefly discussed the stratigraphy of Tucumcari Mountain, including 30 ft of massive yellow sandstone overlain by 110 ft of gryphaeid-bearing yellow and blue shales in the Purgatoire Formation. This was overlain in turn by 90 ft of Dakota Sandstone.

A few years later, Darton (1928) discussed the stratigraphy of the Tucumcari area in the light of increasing information on the distribution of Jurassic and Cretaceous units throughout the eastern part of New Mexico. His sections near Montoya and along the west face of Mesa Rica included, in ascending order, Dockum (Triassic) red beds, Wingate Sandstone and Morrison Formation (Jurassic), Purgatoire Formation (including the interval of Washita age fossils), Dakota Sandstone and Tertiary caliche. With respect to Tucumcari "Butte," he was only tentative in his identification of the Morrison because it was largely covered by talus. Except for later refinement of stratigraphic names, the stratigraphy of the Tucumcari area reported by Darton is essentially the same as is recognized today.

Bullard (1928) also presented a stratigraphic section (Fig. 13) of Tucumcari Mountain and summarized, somewhat inaccurately, previous stratigraphic studies in the area. Bullard recognized, in ascending order, the Dockum beds (250 ft), Wingate Sandstone (100 ft), Purgatoire (70–80 ft), Dakota (60 ft) and 25 ft of white, marly limestone of Tertiary age. The Purgatoire was reported to include three units, a basal white, coarse-grained, crossbedded sandstone (20–30 ft), a middle sandy clay containing many specimens of *G. tucumcarii* (20 ft) and an upper, impure sandy and shaly zone with gastropods and pelecypods (30 ft). Strangely, Bullard's section is only 505–515-ft thick, in contrast to the approximately 600 ft measured by Cummins (1892) and Hill (1893) and the 700 ft measured later by Dobrovolny et al. (1946). As Bullard's Dockum, Dakota and upper Purgatoire units are of about the correct thickness, the shortened part of the section affected the Jurassic interval beneath the *G. tucumcarii* horizon. Most of the thickness of the Morrison Formation was omitted from the section.

Dobrovolny et al. (1946) produced the first modern, detailed geologic map of the Tucumcari area and measured a number of stratigraphic sections, including one of Tucumcari Mountain (Fig. 13). They referred the Triassic sequence to the Chinle Formation, establishing an upper Redonda Member above an unnamed lower member. The thick, cliff-forming sandstone above the Redonda was assigned questionably to the Wingate Sandstone, which was overlain by the equally thick Morrison Formation. The Lower Cretaceous Purgatoire Formation was divided regionally into three members: the basal, fossiliferous Tucumcari Shale, the Mesa Rica Sandstone (Dakota of earlier workers) and the Pajarito Shale (which is absent at Tucumcari Mountain). Dobrovolny et al. (1946) did not designate type sections for any of the new stratigraphic units they defined, and did not refer to Pyramid Mountain which appeared on their map as "Crazy Woman Butte." Later, Griggs and Read (1959) raised the Redonda Member to formational rank, rejected usage of Wingate Formation in favor of the Entrada Sandstone and raised the three members of the Purgatoire to formations, discarding usage of Purgatoire in this area (Fig. 13).

With the changes recommended by Griggs and Read, the stratigraphic nomenclature of the Tucumcari area assumed its present status, 101 years after the publication of Marcou's "Geology of North America." Nomenclature of some Jurassic units is still unsettled, and there are different opinions on the relationship between the Mesa Rica Sandstone and Dakota Formation. Recent research, including a number of studies emphasizing depositional environments, regional distribution and paleontology of the Triassic through Lower Cretaceous formations in the Tucumcari area, is summarized in other papers in this guidebook.

MARCOU IN RETROSPECT

It is perhaps easier after nearly a century to assess objectively the views of those involved in the Tucumcari controversy than it was when the central personalities were still alive. As is often the case in such arguments, each side was partly right and partly wrong in its opinions. Marcou, the most enduring and dogmatic figure in the controversy, was a complex and stubborn person of strong opinions, and his personality is at least partly responsible for the reactions against his views by other geologists.

Marcou came to the United States in 1848 as a sort of *Wunderkind* under the sponsorship of Agassiz and de Verneuil. Previously, in 1845, he had published at the age of 21 an innovative study of the Jurassic faunas of the Salins region near his birthplace. As a consequence, and with Agassiz's support, Marcou was appointed Professor of Mineralogy at the Sorbonne in 1846 and curator of fossil conchology at the Jardins des Plantes in 1847. After exploring the Lake Superior region with Agassiz in 1848–1849, he married Jane Belknap, and this association with a distinguished New England family made him independent of financial concerns and left him free to pursue a career as a gentleman naturalist (Lurie, 1974). His successes at a young age created in him a high opinion of his own abilities which certainly affected the manner in which he viewed criticism of his work.

Publication of his first geologic map of North America (Marcou, 1853) was mainly responsible for his securing, at the age of 29, the position of geologist with the Whipple expedition. His appointment came shortly after this map was published, but before criticism of it began to appear in the literature. It is probable that American geologists had their own candidates for the position and were annoyed to see a European chosen to help explore the American frontier. Marcou's tendency to selectively cite the studies of previous workers in his publications, and omit or disparage the work of those he was not in agreement with, also created bad feelings, especially as some of those slighted, like James Hall, were among the leading American geologists. It seems clear that Marcou's 1853 map was considered a presumptuous effort, done by one who was not familiar enough with American geology to accomplish such an ambitious undertaking competently.

One of the reasons Marcou came to the United States was probably the opportunities the young country offered for making important discoveries in geology. Virtually nothing was known of the geology of vast expanses of the western U.S. and, to an ambitious young geologist, the possibility of being the first to study unknown regions, and make a name for oneself while doing so, must have been very appealing. Marcou was always very much concerned about receiving proper credit for his geological discoveries; questions of priority and complaints that his work was not adequately recognized form a refrain that runs through his published papers from early in his career to the very end. He claimed credit for discovering the Permian, Triassic, Jurassic and Lower Cretaceous in the western U.S. and the desire to be accorded priority in these discoveries undoubtedly influenced his ability to view objectively challenges to his claims.

The fault was not entirely confined to Marcou, however. Criticism of his work in the 1850's and 1860's was overly severe and sometimes couched in personal terms; it is not surprising that Marcou responded to his critics in the same manner. His critics did not limit themselves to pointing out his errors, but also attacked him for conclusions that followed logically from the often limited evidence available to him. In some instances, his critics had less evidence to support their opposing views than Marcou had in support of his conclusions, and, as in the case of the Triassic age of the east-central New Mexico red beds, it was Marcou who was later proven to be correct.

Marcou referred a number of times to what he perceived as an attitude of anti-Europeanism that ran through some of the criticism of his work (e.g., Anonymous, 1855, 1859b; Dana, 1858). This, however, was a reaction to Marcou himself, rather than to Europeans in general. Such noted European geologists as Agassiz, de Verneuil and Lyell were welcomed enthusiastically by American geologists when they visited. The science of geology in the United States was in its infancy, and, while deferring to European geologists, Americans were also with increasing confidence beginning to assert their intellectual independence in attacking a wide variety of distinctively American geological problems. Marcou needlessly antagonized them by inadequately recognizing their efforts and by comparing their work unfavorably with that of European geologists. His attitude seems to have been supercilious and arrogant, and he persistently called upon the authority of European geologists, with presumption of its superiority, to support his opinions against those of his American critics. In addition, as noted previously, Marcou's geological maps of North America pre-empted the planned map of Hall, and his initial refusal to leave his Whipple expedition collections in the U.S., coupled with his subsequent return of only part of these collections, undoubtedly angered American geologists. Their view of his geological studies in North America must have been colored by the perception that he was interested mainly in being the first to chart the geology of vast unstudied areas of the western U.S. for the purpose of enhancing his own reputation, and in doing so was infringing on the prerogatives that rightfully belonged to American geologists.

All of these factors led inevitably to a growing polarization in the views of each side in the Tucumcari controversy. In the heated atmosphere generated by the dispute, Marcou's opinion regarding the Jurassic age of the "Tucumcari beds" and the significance of *Gryphaea tucumcarii* as an indicator of that age became solidified. His opponents maintained the Cretaceous age of these strata and used that argument, together with many others, to challenge Marcou's capabilities as a geologist and to disparage his work on North American geology. What should have been only a minor stratigraphic disagreement became incorporated into a larger confrontation characterized by bitterness, ill will, and highly personal attacks by each side, which made it impossible for the evidence of both sides to be considered dispassionately and synthesized into a consistent body of information about the Mesozoic of western North America.

In the 1850's and early 1860's Marcou knew as much or more about the Mesozoic stratigraphy of New Mexico and neighboring areas to the east as any of his opponents, and his criticisms of their statements on this subject were often firmly based, as in his critique of Shumard's Texas Cretaceous section. Moreover, he had correctly and perceptively differentiated between Lower Cretaceous (Comet Creek, Oklahoma) and Upper Cretaceous (e.g., Galisteo and Rio Puerco areas, New Mexico) faunas in his 35th-parallel studies, which put him ahead of his contemporaries in understanding the Mesozoic stratigraphic relationships of the southern Western Interior. Marcou's Mesozoic section, for example, was far more accurate that Hall's (1857a, b), which correlated the entire Pyramid Mountain section (Triassic–Cretaceous) with the Upper Cretaceous Nebraska Unit 1 (Dakota Formation). Marcou's assignment of the lower part of the Pyramid Mountain section to the Triassic, strongly challenged at first, gradually became accepted. In the end, however, these genuine contributions were overshadowed by the Jurassic–Cretaceous controversy.

Ironically, Marcou's original field notes from 1853 (Blake, 1856b) show that he was on the verge of recognizing the upper "Tucumcari beds" as Lower Cretaceous. His assignment of these strata to the Jurassic instead was based on the resemblance of *Gryphaea tucumcarii* and *"Ostrea marshii"* from Bed E of Pyramid Mountain to species from the Jurassic of Europe. In view of the knowledge available at the time, these fossils could have been as easily considered Cretaceous as Jurassic. A conservative investigator probably would have been inclined towards a Cretaceous interpretation because of the large areas of known Cretaceous exposures in Texas that had yielded similar fossils, whereas no undoubted Jurassic rocks had been identified anywhere in the United States. While it is true that Marcou genuinely believed he had found Jurassic fossils at Pyramid Mountain, it would be consistent with his personality and objectives to suppose that he was also aware that discovering marine Jurassic rocks in the western U.S. would have brought him more prestige and fame than merely discovering another Cretaceous locality. Indeed, in his major work on the geology of the 35th parallel, Marcou (1858a, p. 19) carefully pointed out at great length the importance of his discovery at Pyramid Mountain of the first Jurassic strata in the continental United States. And he viewed the criticisms of his opponents in part as an attempt to deny him credit for the discovery.

As controversy intensified in the late 1850's, with his reputation as a geologist and his discoveries in the West being attacked, it is perhaps not surprising that Marcou developed a defensive, emotional interest in the correctness of his views. Unable to dispassionately evaluate the evidence for and against his conclusions, and unwilling to obtain more information by returning to the Tucumcari area to collect additional fossils that would unequivocally establish the age of the *Gryphaea* beds, Marcou's writings became increasingly directed towards attacking the work and credibility of others rather than strengthening his own case with more evidence. His attempts to discredit his opponents led him to seize upon any means to attack them. Some of his assertions of this nature, such as the partly Jurassic and partly Miocene age of Meek and Hayden's Cretaceous strata along the Missouri River, were clearly ridiculous and led to a lessening of his own credibility as a scientist, with the result that after the early 1860's his views on Mesozoic stratigraphy were largely ignored. His opponents, like Meek and Newberry, were open-minded enough to incorporate what was correct in Marcou's work (e.g., the Triassic age of the New Mexico red beds) into their view of western Mesozoic stratigraphy, but Marcou was never able to admit that his opponents were correct on any major point. When in the 1890's the Cretaceous age of the upper "Tucumcari beds" was firmly established on the basis of numerous diagnostic fossils, Marcou, old and still embittered, could play only an obstructive role. By that time no amount of evidence could have changed his mind about the Jurassic age of the *Gryphaea tucumcarii* beds.

It is not appropriate to assess the entire body of Marcou's work here, but the feeling of most American geologists is probably well represented in Merrill's (1924, p. 604) brief summary of Marcou's career:

> . . . however conclusive and convincing the writings of Marcou may appear, the arguments he advanced were founded almost altogether upon the works of others, or, in some cases, upon no other basis than prejudice in favor of or against certain individuals. From the time of his Pacific Railroad survey work Marcou did little in the field, but contented himself with sitting in judgment upon the work of others. For this reason he was of little actual service to American geology . . . although unquestionably many of his suggestions were of value.

Although Merrill's opinion has much validity to it, it is a generalization that is not accurate for Marcou's studies of the stratigraphy of the Tucumcari area, which he had examined in the field. The value of Marcou's efforts in this area can better be judged from a perspective that encompasses many decades of subsequent geologic studies of this area.

Marcou was the first geologist to examine the strata along much of the 35th parallel in the western U.S., and his observations were necessarily brief and made in conditions that were not conducive to leisurely and complete surveys of an area. In general, Marcou's descriptions and maps of the geology along Whipple's route were accurate. For his time, and within the constraints imposed upon him, he proved himself to be a competent field geologist. Some of his geological observations and interpretations in eastern and central New Mexico were superficial, however, and stand in poor contrast to those of Newberry, who examined

the geology along part of Whipple's route in 1858 and 1859. Marcou was criticized for widely extending conclusions based on observations of strata in limited areas and for correlating too much on the basis of lithology rather than paleontology, but such practices were unavoidable in regions such as New Mexico that were far removed from adequately known stratigraphic sequences. Where fossils occurred, he used them for correlation, but in unfossiliferous formations, such as the Triassic red beds, he was forced to rely on guesses based on his experience elsewhere, particularly in Europe. Perhaps Marcou's main shortcoming in his Tucumcari area studies was not the quality of his data or interpretations—mistakes were inevitable in the conditions in which he worked—but rather his inability to go beyond his initial conclusions and modify them in accordance with new data brought forth by others.

In retrospect, Marcou was correct on most of the disputed issues relating to the stratigraphy of the Tucumcari area. The lower part of his Pyramid Mountain section, identified as Upper Triassic on the basis of lithological similarity to the Keuper of Europe, is accepted today as Upper Triassic. The great areas of Triassic exposures east of the Rocky Mountains shown on his maps have become drastically reduced, in part because he assigned red beds now recognized as Permian to the Triassic. DeFord (1972) pointed out, however, that a Triassic age for these Permian units was seriously advocated as recently as the 1930's.

Marcou was also correct in his identification of *Gryphaea tucumcarii* as a species distinct from other gryphaeids known from the southern Western Interior, and he produced an accurate stratigraphic section (the first ever compiled in New Mexico) for the Tucumcari area. His assignment of a Jurassic age to the post-Triassic part of the section (the "Tucumcari beds") is partially correct; it was not until the 1890's, with additional paleontological information, that the Early Cretaceous age of the upper part of this sequence became well established. The age of the lower part of the "Tucumcari beds" (Marcou's Beds B, C and D of his Pyramid Mountain section) was not established until the opening decades of the twentieth century, when it was realized that the greater part of the thickness of the post-Triassic "Tucumcari beds" is Jurassic, just as Marcou had always maintained. It is sobering and perhaps instructive to realize that the entire Tucumcari controversy, which generated so much antagonism and hundreds of pages in the published literature over a 40-year period, evolved from a scant four hours of fieldwork by Marcou at Pyramid Mountain.

Marcou's efforts in western New Mexico with the Whipple Survey were praised by Dutton (1885, p. 123), who stated that:

> Mr. Marcou proved himself to be a diligent investigator, and brought back a considerable amount of valuable information. . . . The want of a good topographic map prevented the greater degree of accuracy which Mr. Marcou would otherwise have given to his delineations, but the material for making one did not then exist. He has shown much skill and acumen, and the modifications which fuller and more detailed information, with much better maps, requires us to make in his conclusions are not radical.

The same can be said, a hundred years later, for Marcou's work in the Tucumcari area.

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