EARTHQUAKES OR SNOWFLOWERS

BART O'BRIEN

The Controversy Over the Formation of Yosemite Valley

Yosemite Valley was first visited by white men in 1849. Public awareness of the Valley, however, did not come until 1851 when the Mariposa battalion chased a band of Indians into the "deep, grassy valley."[1] This incident coincided with a national movement involving the veneration of nature, and many transcendentalists and "nature lovers" became interested in California's spectacular canyon. As the number of Yosemite's pioneering tourists increased, so did speculation as to the origin of this great Valley.

The theory of Yosemite's geological origin proposed by Josiah Dwight Whitney, head of the California Geological Survey, was the first generally accepted answer to the riddle of the Valley's formation. His explanation, however, clashed with one later developed by John Muir, Yosemite's most famous publicist and student. Muir's writings on the spiritual values of wilderness are well known, but he was an observant amateur scientist as well; and Muir held his geological concepts as tenaciously as his beliefs on the glory of his beloved Sierra Nevada. Muir's explorations of the Yosemite region convinced him that the spectacular Valley had been carved by glacial action, and he defended that contention in numerous articles. The conflicting viewpoints of John Muir and Josiah D. Whitney grew into a national controversy, and the argument over the erosive power of ice continued into the twentieth century when the survey of Francois E. Matthes revealed the full story of Yosemite's beginnings.

Geology was actually an important issue to Californians before the arrival of either Muir or Whitney. It was the the discovery of gold along the American River that first piqued the geological interest of Californians. After the historic discovery, both neophytes and experienced miners were interested in how gold was transported and deposited, and where it had originated.

As early as 1849 a professional geologist visited the mining region of California. Philip T. Tyson came to California, toured the gold country, and sent back a report to the Topographical Bureau in Washington.[2] A second geologist, Dr. John B. Trask, came to

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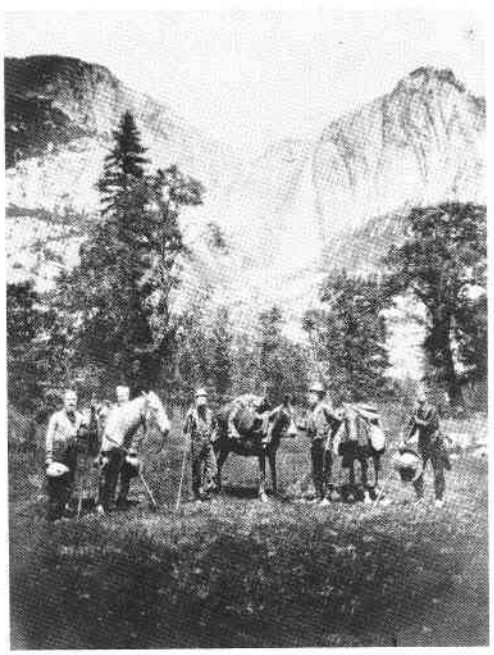
California in 1853, and at that time, the state senate requested that he submit a further report on the geology of California.[3]

These reports, however, even when augmented by those of the Pacific Railroad explorers, were completely inadequate. California legislators, therefore, were very receptive to the proposal, by several prominent eastern scientists, for an extensive state survey, and on April 21, 1860, a bill appointing Josiah Dwight Whitney to head the California Geological Survey was passed.[4]

Whitney was forty-one years old, and he brought to California the highest qualifications in both education and experience that were possible for a nineteenth century American. He had been educated at George Bancroft's Round Hill School, Yale College, and in Europe. His practical experience had been gained in the Great Lakes region, where he was co-director of the Michigan Surveys. Whitney's competence as a metallurgist, chemist, geologist and writer had established him in the highest scientific circles by the time of his trip to California.[5]

Whitney divided his exploration of California into four great north/south reconnaissances. The first encompassed the Coast Range; the second, the western slope of the Sierra; the third, the crest of the Sierra, and finally, the eastern slope of the Sierra. It was while exploring the third area, the High Sierra, that Whitney encountered Yosemite Valley and postulated his theory of its origin.



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Whitney survey team in the Yosemite Valley during the early 1860s. From left to right: Gabb, J.D. Whitney and W.H. Brewer, the others are unidentified.

The Whitney Survey came to Yosemite Valley in June of 1863. In the two months spent on this part of the survey, three weeks were devoted to the survey of the route between Big Oak Flat and Mono Lake, one week "in and about Yosemite Valley," and the remaining weeks in exploring the areas surrounding the Valley.[6] Although Whitney's colleagues (William H. Brewer, Clarence King and James T. Gardener) were to return to Yosemite in 1864, Whitney had completed his work. The single week spent exploring and observing the Yosemite Valley provided the basis for Whitney's explanation of how the valley was formed.

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Josiah Dwight Whitney (above) held the position of state geologist of California from 1860 to 1874 during which time he led the California Geological Survey. In 1863 the Whitney survey team came to the Yosemite Valley. Members of the team included William Henry Brewer (top), Clarence King (center), and James T. Gardener (bottom), all of whom had been educated at the Sheffield Scientific School of Yale. Brewer, a professor of chemistry and geology, was the first assistant on the geological survey from 1860 to 1864. King, a geologist, joined the survey in 1863 after crossing the continent on horseback from the Missouri River. For three years he carefully studied the gold belt of the Sierra Nevada and made paleontological discoveries that furnished the evidence upon which the accepted age of gold-bearing rocks was determined. Gardener, an engineer, was brought to the team as a topographer. He assisted in the survey of the Sierra Nevada, including the selection and mapping of the "big tree tracts" in the Yosemite Valley. All photographs taken circa 1863.

The "peculiar and almost unique type of scenery" in Yosemite, said Whitney, made it natural to ask "how these vertical cliffs have been formed, and to what geological causes does the Yosemite Valley owe its existence."[7] In formulating an hypothesis, Whitney drew on his observations of other California canyons. Most of the great canyons and valleys of California, Whitney had correctly observed, were the result of the long-continued action of rivers and streams. These canyons, however, were V-shaped, meaning that their walls were inclined, not vertical as those of Yosemite. Whitney, therefore, after apologizing for the limited study and stating that the future reports of King and Gardener might better explain the formation, conjectured that: "this mighty chasm has been roughly hewn into its present form by the same kind of forces which have raised the crest of the Sierra and molded the mountains into something like their present shapes."[8] By "the same kind of forces," Whitney was referring to the uplifting and down-faulting that had occurred along the fault line between the Sierra Nevada and the Owens Valley. There the crest of the Sierra was pushed up as the floor of the Owens Valley gradually dropped. In Yosemite Valley, Whitney believed, a similar type of cataclysm could explain the high and precipitous Valley walls, and the absence of talus, or exfoliated debris, along the base of the cliffs.

Whitney, however, did not ignore the past presence of a glacier in Yosemite. The 1864 survey by Clarence King and James T. Gardener, said Whitney, "obtained ample evidence of the former existence of a glacier in the Yosemite Valley."[9] While he did not dwell on the importance of glaciation, Whitney quoted King as saying that all the streams entering Yosemite are "beautifully polished and grooved by the glacial action," that the ice reached a thickness of "at least a thousand feet," and "four ridges in the Valley . . . without a doubt, are glacial moraines."[10]

Although Whitney's theory of the formation of Yosemite Valley has been refuted, it should be noted that his hypothesis was not totally unfounded. There are several well-authenticated instances of valleys that have been formed by the subsidence of portions of the earth's crust. In California, both the Owens Valley and the Tahoe Basin were formed in this way, and Whitney undoubtedly had such instances in mind when he outlined his theory.

John Muir first saw Yosemite Valley in the spring of 1868. His flowing and lyric rhetoric, describing the beauty of the mountains and calling for their preservation, remains popular today. Indeed, Muir, the nature lover and wilderness spokesman, has become something of a patron saint to thousands of conservationists, mountaineers and outdoor enthusiasts, yet Muir the scientist is little known.

While his credentials might not be as academically impressive as Whitney's, a great deal of evidence supports Muir's position as a scientist. He gathered and classified hundreds of plants and insects, and in the process of developing an insect collection in the Yosemite region, he discovered two species of butterflies that were previously unknown. He also used sophisticated scientific procedures in measuring the movement of glaciers in both California and Alaska, and more importantly, he was recognized as a scientist by many other nineteenth century professionals. Included in this group were Asa Gray, Joseph LeConte, and Louis Agassiz. Muir was even offered several teaching positions at eastern universities. The combination of experience and recognition certainly, as much as any academic qualifications, entitles John Muir to the title of "scientist."

John Muir's interest in science first appeared as an infatuation with mechanics on his father's farm at Fountain Lake, Wisconsin. Here, he constructed waterwheels, windmills, and an original double-rotary saw.[11] By the time the family had moved to Hickory Hill,

Muir had become an accomplished inventor. He had carved and assembled numerous clocks, the most elaborate of which had four faces, each with a fourteen foot minute hand.[12] This clock was built before he was twenty years old, and it was constructed without the aid of a model.

Two specific inventions were of importance to Muir's future because they eventually led to his attendance at the University of Wisconsin and his introduction to formal education. The first was a bed with a timer that, at the precise minute it was set, would rear up to an angle of forty-five degrees and drop the sleeper to his feet. The second was an incredibly accurate thermometer. This instrument was so sensitive that as an individual approached or stepped back, the dial registered changes in the temperature. Both of these devices were displayed at the Wisconsin State Fair, and Muir won an honorarium of fifteen dollars for their originality.[13] Muir's success at the State Fair gave him access to several jobs, but he chose to enroll in the University of Wisconsin.

"To please himself," according to biographer Linnie Marsh Wolfe, "Muir entered chemistry and geology classes taught by Dr. Ezra Slocum Carr."[14] Muir's interest in both fields was great and he later wrote, "I shall not forget the doctor, who first laid before me the great book of nature."[15] Before the end of his first term, he had a reputation as the best chemistry student at the university, and Muir used both the university's geology library and that of Dr. Carr to familiarize himself with the most current scientific literature.[16] This, along with his future studies in botany, geology and biology, were to provide Muir with the background that enabled him to write about a diversity of topics, to understand the complexity of man's relationship with the natural world, and to label himself a "poetico-trampo-geologist-bot, ornith-natural, etc., etc., !-!-!"[17]

Despite these rather well known facts about Muir's background, the question remains as to when he acquired the knowledge necessary to develop a new and accurate theory of glaciers and mountain building. There is no simple answer. Muir's correspondence indicates that his primary interest as a young man was botany. During his thousand mile walk and even after his arrival in California, Muir collected and dried a variety of plant species.[18] An interest in geology became more evident in Muir's letters the longer he remained in Yosemite. While botany was his main interest in 1869, by 1871 his letters were rife with accounts of ice, snow, and rock. Muir's personal library also hints that his introduction to geology was at the hand of Dr. Carr, but his real education was self-motivated. Muir's copy of Tyndall's *Hours of Exercise in the Alps* (published in 1871) contains dozens of annotations and makes a special note of page seventy-five, where Tyndall writes:

> Here and there angular pieces of quartz, held fast by the ice, inserted their edges into the rocks and scratched them like diamonds, the scratches varying in depth and width according to the magnitude of the cutting stone. Larger masses, held similarly captive, scooped longitudinal depressions in the rocks over which they passed, while in many cases the polishing must have been effected by the ice itself. A raindrop will wear a stone away; much more would an ice surface, squeezed into perfect contact by enormous pressure, rub away the asperities of the rocks over which for ages it was forced to slide. The rocks thus polished by the ice itself are so exceedingly smooth and slippery that it is impossible to stand on them where their inclination is at all considerable. But what a world it must have been when the valleys were thus filled![19]

This description sounds as if it pertained specifically to the rocks in and around the Yosemite Valley, and Muir certainly noted the similarity. Inside of the front cover of his copy of this book, Muir signed his name and "Yosemite Valley." Therefore, Muir probably acquired this book while he was still living in Yosemite and formulating his thesis as to

the valley's origin. Muir also corresponded with an ever-widening circle of scientists and scholars. His papers from the early 1870s include letters dealing with geology and observations about glaciers from Mrs. Carr, Joseph LeConte, of the University of California, M.W. Harrington, of the University of Michigan, and James Cross, of Oxford, England. It seems apparent, as with the clocks, that Muir's initiative, perceptivity, and diligence resulted in his acquisition of the knowledge that allowed him to describe correctly the formation of Yosemite and other California mountain valleys.

John Muir first went to the Yosemite high country as a sheepherder, and it was while herding sheep that he discovered the first signs of glaciation. On July 10, 1869, while camped on Tamarack Creek above the Merced Canyon, Muir examined the parallel scratches on some granite slabs. He next turned his attention to the composition and color of some large boulders scattered across these slabs and determined that they were erratics, "borne from a distance."[20] He quickly theorized that a glacier had swept over the region, and his ideas about the role of glaciers in the Sierra began to take shape. Later that summer, from the slopes of Mount Hoffmann, Muir saw:

> . . . the billowy glaciated fields of the upper Tuolumne and looked down on lake Tenaya, . . . the largest of the many glacier lakes in sight [situated in an] ice-sculptured lake-basin [which] seems to have been slowly excavated by the ancient glaciers. . . . [Beyond the basin were] huge shining domes on the east, over the tops of which the grinding, wasting, molding glacier must have swept as the wind does today.[21]

Muir continued his studies of glaciation that summer, and when he returned to Yosemite Valley in the fall, he looked for more evidence. Patches of glacial polish near Vernal Fall and along the broad smooth apron of Glacier Point convinced Muir that glaciers had entered Yosemite Valley from Tenaya Canyon, Little Yosemite, and Illilouette Gorge. Muir did not publish or even mention in correspondence his observations of 1869 and 1870, but he did, while showing tourists around Yosemite, say that Whitney's theory of cataclysm was false, and that the Valley was actually carved by massive glaciers.[22] Some of those who listened to Muir's lectures were converted to his arguments, and before long California newspapers were giving publicity to Muir's theories.[23] This was the beginning of the controversy which was to develop over the origins of Yosemite Valley.

John Muir's first article on glaciation was published by the *New York Daily Tribune* on December 5, 1871, under the title, "Yosemite Glaciers." The article, although clouded by nineteenth century rhetoric, is a basic statement of the past existence of glaciers in Yosemite Valley. In "Yosemite Glaciers," Muir makes his point when he says:

> . . . the great valley itself, together with all of its various domes and walls, was brought forth and fashioned by a grand combination of glaciers acting in certain directions against granite of peculiar physical structure. All of the rocks and mountains and lakes and meadows of the whole upper Merced basin received their specific forms and carvings almost entirely from the same agency of ice.[24]

The article launched Muir's career as a nature writer, and it was a prelude to his most important writings on the formation of the mountains and valleys of the Sierra Nevada.

Muir's most significant scientific writings appeared over a period of years in the *Overland Monthly*. His first *Overland* article, entitled "Living Glaciers of California," appeared in December, 1872. In it Muir related his discovery of a living glacier in the Yosemite high country. This glacier, according to Muir, was the remnant of the once great glacier that had flowed down Tenaya Canyon.[25]

In 1874 and 1875, Muir published several more articles in the *Overland Monthly*, and

seven of these were part of a series called "Studies in the Sierra." The "studies" were largely taken from the journals that Muir had kept while exploring the Yosemite region from 1869 to 1872. The articles covered several aspects of mountain building and denudation, but were primarily accounts of the role of glaciation. In "Studies in the Sierra" No. 1, Muir explained that the major eroding agent in forming the Sierra was "not the earthquake nor lightning to rend and split asunder, not the stormy torrent nor eroding rain, but the tender snowflowers, noiselessly falling through unnumbered seasons, the offspring of the sun and sea."[26] These "snowflowers," continued Muir, formed the great Sierra glaciers that could "not only wear and grind rocks by slipping over them . . . they also crush and break, carrying away vast quantities of rock, not only in the form of mud and sand, but of splinters and blocks, from a few inches to forty to fifty feet in diameter."[27]

By the January, 1875, publication of the seventh installment of his "Studies in the Sierra," Muir's views on the formation of the Sierra Nevada, and specifically Yosemite Valley, were well known by American geologists. It was also about this time that geologists began to take sides in the brewing battle between Whitney and Muir and their opposing theories on the formation of Yosemite Valley.

The roots of the controversy, however, had been planted in 1870. It was then that Whitney published, in the *Yosemite Guidebook*, a statement reconfirming his cataclysmic explanation and minimizing the evidence of glaciation in Yosemite. Whitney even went so far as to retract his earlier confidence in Clarence King's theory. Whitney wrote:

> Much less can it be supposed that the peculiar form of the Yosemite is due to the erosive action of ice. A more absurd theory was never advanced than that by which it was sought to ascribe to glaciers the sawing out of these vertical walls. . . . Nothing more unlike the real work of ice, as exhibited in the Alps, could be found. Besides, there is no reason to suppose, or at least no proof, that glaciers have ever occupied the Valley, or any portion of it . . . so that this theory, based on entire ignorance of the whole subject, may be dropped without wasting any more time upon it.[28]

In Muir's extant writings, his first written comment on Whitney's theory was contained in a letter to Mrs. Ezra Slocum Carr,[29] dated April 13, 1870, and it was only one sentence: "Whitney says that the bottom has fallen out of the rocks here — which I most devoutly disbelieve."[30] In August of 1870, Muir was to receive support for his glacial theories from a nationally known scientist. Joseph N. LeConte was a professor of natural history at the University of California, and he had come to Yosemite on a field trip with a group of college students. At the request of Mrs. Carr, LeConte sought out Muir and persuaded him to go along with the group on a trip into the high country. While they were traveling through what is now the central section of Yosemite National Park, Muir showed LeConte signs of glaciation and convinced him that the broad U-shaped canyons of the high country were the pathways of the great glaciers that excavated Yosemite.[31]

LeConte proved to be an important ally to Muir because of his association with the formal scientific community and because he published, in at least two separate places, statements of the role of glaciers in Yosemite. In a paper entitled "Some Ancient Glaciers of the Sierra," LeConte credited Muir with discovering the role of glaciers in the formation of Sierra Nevada canyons, and also in his geology text book, entitled *Elements of Geology*, LeConte stated:

> The wonderful falls of the Yosemite Valley, of which there are six in a radius of five miles, one of them 1,600 feet, three 600 to 700 feet, and two over 400 feet high, seem to be an exception . . . their perpendicularity seems to be the result of the comparative recency of the excavation of the Valley by an ancient glacier. . . .[32]

Courtesy, The Bancroft Library

Joseph LeConte of the University of California who became an important link between Muir and the formal scientific community.

The support from Professor LeConte brought other scientists to Muir's side. Louis Agassiz, professor of natural history at Harvard's Lawrence Scientific School and the world's leading glaciologist, wrote after reading Muir's accounts of the Yosemite glaciers: "Here is the first man who has any adequate conception of glacial action. . . . Muir is studying to a greater purpose and with greater results than anyone else has done."[33]

Professor Whitney's theory, however, was not cast aside. Clarence King and the other members of the California Survey rallied to the defense of the cataclysmic theory, as did several other prominent eastern scientists. Israel C. Russell, a member of the U.S. Geological Survey and professor of geology at the University of Michigan, after having studied the massive moraines outside of the glacial canyons along the eastern slope of the Sierra, declared that the absence of a similar formation outside of Yosemite provided strong evidence against the theory that the Valley had been mainly excavated by glaciers.[34] Another member of the U.S. Geological Survey who sided with Whitney was G.F. Becker. In an article entitled "The Structure of a Portion of the Sierra Nevada of California," published in 1891, Becker said: "Ice seems to have played a considerable part in clearing the canyons of fragments and in excavating shattered and decomposed patches . . . but the ice seems, nevertheless, to have been incapable of cutting into solid masses."[35]

Significantly, one scientist endeavoring to discover the main eroding agent in the formation of Yosemite Valley, developed another hypothesis. It was the theory of stream erosion, first proposed by H.W. Turner in "The Pleistocene Geology of the South-Central Sierra Nevada, with Especial Reference to the Origin of Yosemite Valley."[36] Turner maintained that Yosemite Valley is similar in many respects to certain other stream-worn canyons, and that Yosemite's unique features could be explained as products of stream erosion and weathering processes, facilitated by the jointed structure of the granite. Turner said that glaciers had done little more than clear the Valley of loose debris.[37]

The magnitude of the controversy generated by Whitney and Muir is revealed by its duration. It was still alive at the turn of the century, and as late as 1905 an article appeared in opposition to Muir's theories. H.L. Fairchild presented a paper at the 1905

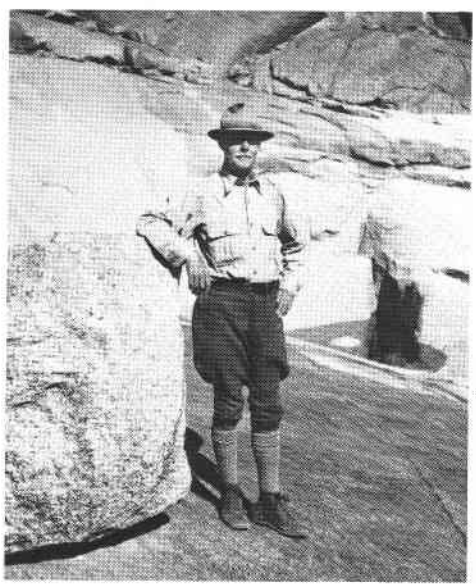
meeting of the American Geological Society entitled, "Ice Erosion Theory a Fallacy." The article, seventy-four pages in length, presented both the arguments for, and those against ice erosion, and concluded, after analyzing the role of glaciers in most of the mountainous regions of the world, that ice has not been established as a significant erosive element, and that "glaciers are ineffective agents in production of valleys or basins."[38]

The question "How was Yosemite Valley formed?" was answered conclusively in 1930 by Francois Matthes. In the *Geologic Origins of the Yosemite Valley*, Matthes described the formation of Yosemite Valley in three primary stages. In the first stage, the Merced River meandered through a broad, level valley floor flanked by rolling hills between 500 and 1,000 feet in height. The second stage involved a series of uplifts combined with increased stream erosion that resulted in the formation of a deep canyon. The final stage was one of glaciation when, according to Matthes, "The Valley had been broadened and deepened to essentially its present proportions."[39]

Thus, Muir's hypothesis of the formation of Yosemite Valley was not completely accurate. He claimed that the canyon had been solely excavated by glaciers and that these glaciers totally covered the Sierra Nevada mountains for a single prolonged period.[40] Dr. Matthes revealed, however, that while Muir's basic premise on the erosive power of ice was correct, the Valley was actually carved from an already existent canyon during at least four separate stages of glaciation. Muir's scientific investigations, therefore, had led him to put too much emphasis on glaciation, but his discovery of the importance of glaciers to the process of mountain building was, nevertheless, very significant.

One question remains unanswered, and that is, why did J.D. Whitney so tenaciously cling to his idea of a cataclysmic origin despite a later, more in-depth, study by such a prominent geologist as Joseph N. LeConte? Although there is no conclusive answer, an attempt at some type of rationalization of Whitney's reasoning seems imperative.

William E. Colby has written that it is not surprising that Whitney felt as he did. Whitney was at the peak of his fame, recognized as one of America's leading geologists, when, according to Colby:



Courtesy, The Bancroft Library

François Emile Matthes (1874-1948), born in Amsterdam and educated in Europe, came to the United States in 1891. Beginning in 1913 and continuing for fourteen years, he made a detailed study of the origins of Yosemite Valley. The principal results of this work were published as "The Geologic History of the Yosemite Valley." His avocation was working with Boy Scouts, as shown by his uniform in this photograph taken by a scout at the foot of Upper Yosemite Falls in September 1936.

> He wrote and published the first guidebooks of the valley and in these fully expounded his theory of its origin. Unquestionably, as chief geologist of a state survey of nation-wide interest, he had given the origin of Yosemite, already world-famous, his best considered thought. . . . For his mature conclusions to be questioned and even belittled by a mere youth who had no college degree . . . was *lese majeste*. Whitney proud and sensitive by nature, must have been galled beyond expression. . . .[41]

The key to understanding Whitney's perseverance in holding a false theory is manifest in Colby's last sentence. The professor was indeed "proud and sensitive" as well as stubborn. Whitney's tenacity in clinging to hastily produced conclusions was not without precedent. The well-known Calaveras skull incident, in which Whitney claimed a skull unearthed in a Mother Lode mine was of neolithic origin when, in fact, it had been planted as a joke by some local miners, is the most obvious example of the professor's uneven judgement.

The professor's course of action became even more perplexing, after one reads his remarks on the geology of the Hetch Hetchy canyon, a smaller but similar version of Yosemite located less than fifty miles away.

In the 1870 edition of their *Yosemite Guidebook*, Whitney wrote:

> Hetch Hetchy . . . is, in many respects, almost an exact counterpatt of the Yosemite. It is not on quite so grand a scale as that valley; but, if there were no Yosemite, the Hetch Hetchy would be fairly entitled to a world-wide fame. . . .[42]

Whitney continued:

> There is no doubt that the great glacier, which, as already mentioned, originated near Mt. Dana and Mt. Lyell, found its way down the Tuolumne Canyon, and passed through the Hetch Hetchy Valley. . . . Within the Valley, the tocks are beautifully polished, up to at least 800 feet above the rivet. Indeed, it is ptobable that the glaciet was much thicker than this. . . .[43]

These quotations illustrate Whitney's willingness to accept the occurrence of glaciation in Yosemite's "exact counterpart" while refusing to accept the occurrence of glaciation in Yosemite.

Perhaps, Whitney's actions in the Yosemite controversy can be understood in light of the drive toward institutionalization by nineteeth century science. The late nineteeth century marked the end of the self-educated amateur naturalists such as Audubon and Fremont and the development of college educated professionals such as O.C. Marsh and Asa Gray. Whitney and Muir, respectively, could be classified as representatives of each of these groups, and the professor perhaps felt a severe threat to the progress of institutionalized science if he should be out-researched by an amateur naturalist.

Professor Whitney was no stranger to glaciation, and he undoubtedly would have discerned its geologic significance in Yosemite had he invested more time actually working in that region. Both in his earlier career in Michigan and in his post-California efforts, Whitney studied glaciers, and he certainly understood their importance to landscape development. But, as he did at other times in his career, Whitney arrived at a hasty conclusion, and because of his stubbornness, he refused to admit his mistake and accept the opinion of another scientist.

The final irony in this whole controversy may rest in a midwestern cemetery. Upon the death of Professor Whitney in 1896, his family and admirers wished to erect a suitable monument to the man that they had loved and respected. They chose a beautiful rose quartzite erratic boulder,[44] that Muir would have identified as being "borne from a distance."

NOTES:

1. For an account of the discovery of Yosemite Valley see: Francis P. Farquhar, *The History of the Sierra Nevada* (Berkeley, CA: University of California Press, 1965), p. 74.
2. William H. Goetzmann, *Exploration and Empire* (New York: Alfred A. Knopf, Inc., 1966), p. 358.
3. Ibid.
4. Ibid., p. 360.
5. Ibid., pp. 357-360
6. Josiah Dwight Whitney, *Geology*, I (Published by the authority of the legislature of California, 1865), p. 404.
7. Ibid., p. 421.
8. Ibid.
9. Ibid., p. 422.
10. Ibid.
11. Linnie Marsh Wolfe, *Son of the Wilderness* (New York: Alfred A. Knopf, 1945), p. 52.
12. Ibid., p. 53.
13. Ibid., pp. 59-61.
14. Ibid., pp. 64-65.
15. Muir to Mrs. Carr, September 13, 1865, John Muir Papers, U.O.P.
16. Wolfe, *Son of the Wilderness* pp. 73-74.
17. Muir to Robert Underwood Johnson, September 13, 1889. This letter along with several other letters between Muir and Johnson was edited by William E. Colby and published in the article "The Creation of Yosemite National Park," *Sierra Club Bulletin*, XXXIX (1944), pp. 49-60.
18. John Muir, *Letters to a Friend* (Dunwoody, GA: Norman S. Berg, 1973) pp. 25-29, 41-43, and 99-100.
19. John Tyndall, *Hours of Exercise in the Alps* (New York: D. Appleton and Company, 1871). Muir's profusely annotated copy is at the University of the Pacific, Stockton, CA.
20. Wolfe, *Son of the Wilderness* p. 121.
21. John Muir, *Studies in the Sierra*, edited by William E. Colby (San Francisco, CA: Sierra Club, 1960), pp. xix.
22. Wolfe, *Son of the Wilderness* p. 132
23. Ibid., p. 133.
24. New York *Daily Tribune*, December 5, 1871, p. 8.
25. *Overland Monthly*, IX (December 1872), p. 547.
26. *Overland*, XII (May 1874), p. 373.
27. Ibid., p. 374.
28. Muir, *Studies*, p. xviii.
29. Mrs. Carr had come to Berkeley with her husband when he left the University of Wisconsin for a teaching position at the University of California. She and Muir remained lifelong correspondents.
30. William F. Badè, *Life and Letters of John Muir*, I (Cambridge: The Riverside Press, 1924), p. 215.
31. Wolfe, *Son of the Wilderness* pp. 133-136.
32. Joseph N. LeConte, *Elements of Geology*, (New York: D. Appleton and Company, 1891), p. 15.
33. Muir, *Studies*, p. xxii.
34. Francois Matthes, *Geology History of the Yosemite Valley*. Professional Paper 160 (Washington, D.C.: United States Government Printing Office, 1930), p. 5.
35. G.F. Becker, "The Structure of a Portion of the Sierra Nevada of California," *Bulletin of the Geological Society of America*, II (1891), pp. 49-74.
36. Matthes, p. 5.
37. Ibid.
38. H.L. Fairchild, "Ice Erosion Theory a Fallacy," *Bulletin of the Geological Society of America*, XVI (1905), p. 73.
39. Matthes, pp. 45-51 give an account of the geologic evolution of Yosemite Valley.
40. Muir, *Studies*, p. xxvii.
41. Ibid. p. xxiv.
42. Josiah Dwight Whitney, *Whitney's High Sierra* (reprinted from J.D. Whitney, Yosemite Guidebook, 1870), (Romona, CA: Sentinel Publications, 1971), p. 39.
43. Ibid. p. 40.
44. Edwin Tenny Brewster, *Life and Letters of Josiah Dwight Whitney* (Cambridge: The Riverside Press, 1909), p. 382.a