and the Marks of Time: Yosemite and the High Sierra (1962) by

François E. Matthes

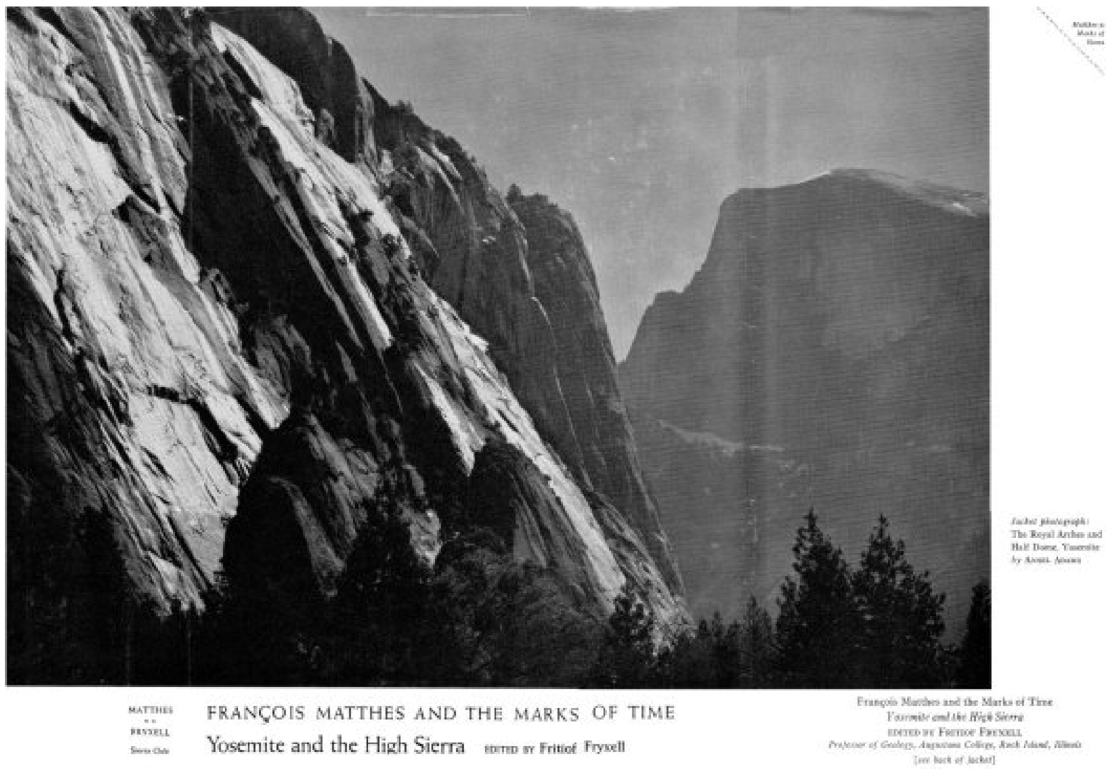
Table of Contents

Table of Contents

Table of Contents

François Matthes and the Marks of Time: Yosemite and the High Sierra (1962) by François E. Matthes

r r r



r r r

r r r

r r *Dust jacket*r

r r r

rr r r

r r

About the Author

r r

r  r

r *r François E. Matthesr*
r (photograph byr
r Ernest A. Bachrach)r r

r r

r François Matthes (pronounced *france-wah mat-hes*)r was born in Amsterdam March 16, 1874 and spent much of his youth in Switzerland,r where he became interested in mountains and glaciers, then Frankfurt, Germany.r He came to the US in 1891 to study at Massachusetts Institute of Technology (MIT) and graduated as a Civil Engineer.r Geology and glaciology was his hobby and became his work.r Matthes joined the U.S. Geological Survey (USGS) in 1896,r where he mapped and surveyed several National Parks, including Yosemite.r In the 1920s he set out to determine ifr r John Muir's Yosemite glacier theories were correct.r Matthes found that glaciers were a major force in creating Yosemite Valley and other features and published his findings asr *Geologic History of the Yosemite Valley*r USGS Professional Paper 160 (1930).r Matthes also published several popular articles inr r *Yosemite Nature Notes*.r Although Matthes never received an earned Doctorate,r he received an honorary LL.D. degree in 1947 from University of Californiar for his life-long accomplishments.r

r r

r Matthes died June 21, 1948,r while he was working on a popular book interpreting Yosemite geology.r Matthes widow, Edith Lovell Matthes, and a colleague,r Dr. Fritiof Fryxell,r edited the unpublished manuscript and published it asr *The Incomparable Valley: A Geologic Interpretation of the Yosemite*r (1950).r They also edited this book,r *François Matthes and the Marks of Time* (1962),r a selection of articles that appeared inr *Sierra Club Bulletin* and elsewhere.r

r r

r
- r r Donald E. McHenry,r “Francois E. Matthes Honored—Retires,”r *Yosemite Nature Notes* 27(2):54-55,57 (February 1948) [PDF]r

r
- r r Donald E. McHenry,r “Francois Emile Matthes” [obituary],r *Yosemite Nature Notes* 27(7):97-98 (July 1948) [PDF]r

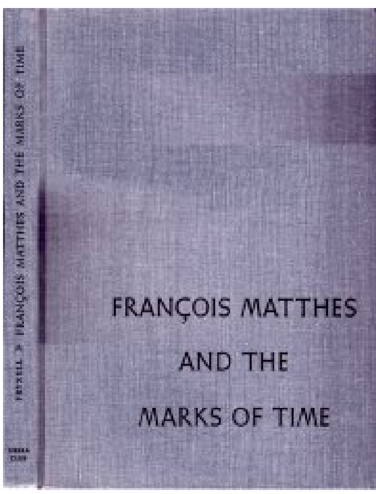
rr r r

---

r r

Bibliographical Information

r r r r

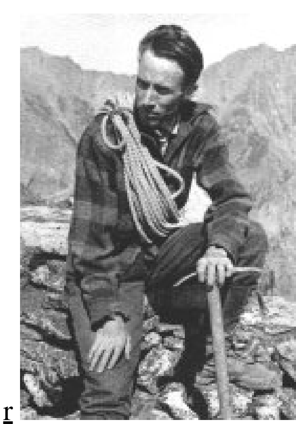
r r 

r

r r r

r r *Cover*r

r r

r r  r

r r r

r *r Dr. Fritiof Fryxellr*
r (editor) climbing in ther
r Grand Teton range,r
r Wyomingr r

r r

r François E. Matthes (1874-1948),r *François Matthes and the Marks of Time: Yosemite and the High Sierra*r (San Francisco: Sierra Club, 1962),r Edited by Fritiof Fryxell (1900-1986).r Copyright 1962 by the Sierra Club.r LCCN 62011763.r 189 pages. Illustrated. 26 cm. Bound in charcoal cloth board.r Library of Congress call number QE89.M3.r

r r

r
- r r Keith A. Trexler,r "Francois Matthes—the Master Interpreter" [review of *François Matthes and the Marks of Time*], *Yosemite Nature Notes* 40(6):148 [PDF]

r
- r Another review of this book appears inr E. H. Brown, *The Geographical Journal* 128(4):537 (Dec. 1962).r

rr r

r Converted to HTML by Dan Anderson, September 2007,r from a personal copy.r These files may be used for any non-commercial purpose,r provided this notice is left intact.r
r —Dan Anderson, www.yosemite.ca.usr

r r r
r

---

r r

r **r Next: Title Pager** r

r r r r r

r

r r

r

r r

r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r Title Page >r

r r

r

r r r

r **Next: Preface •r Contentsr** r

r r r r

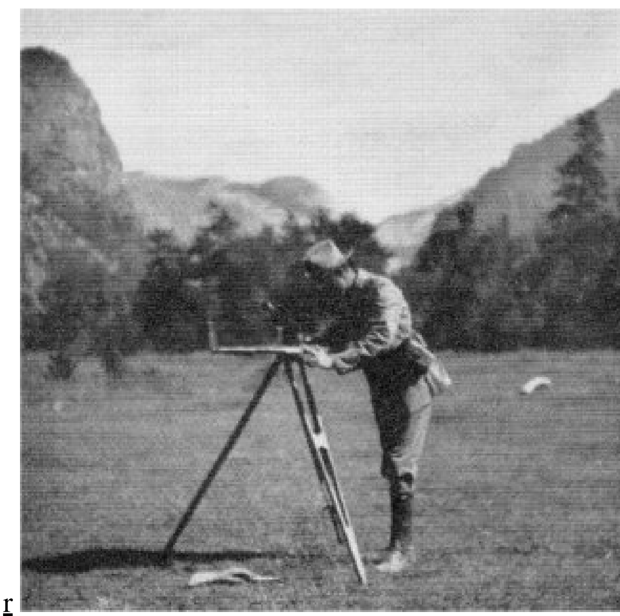
r r r r r

r

FRANÇOIS MATTHESr r AND THE MARKS OF TIME

r

r r r

r r  r

r r r

r r r

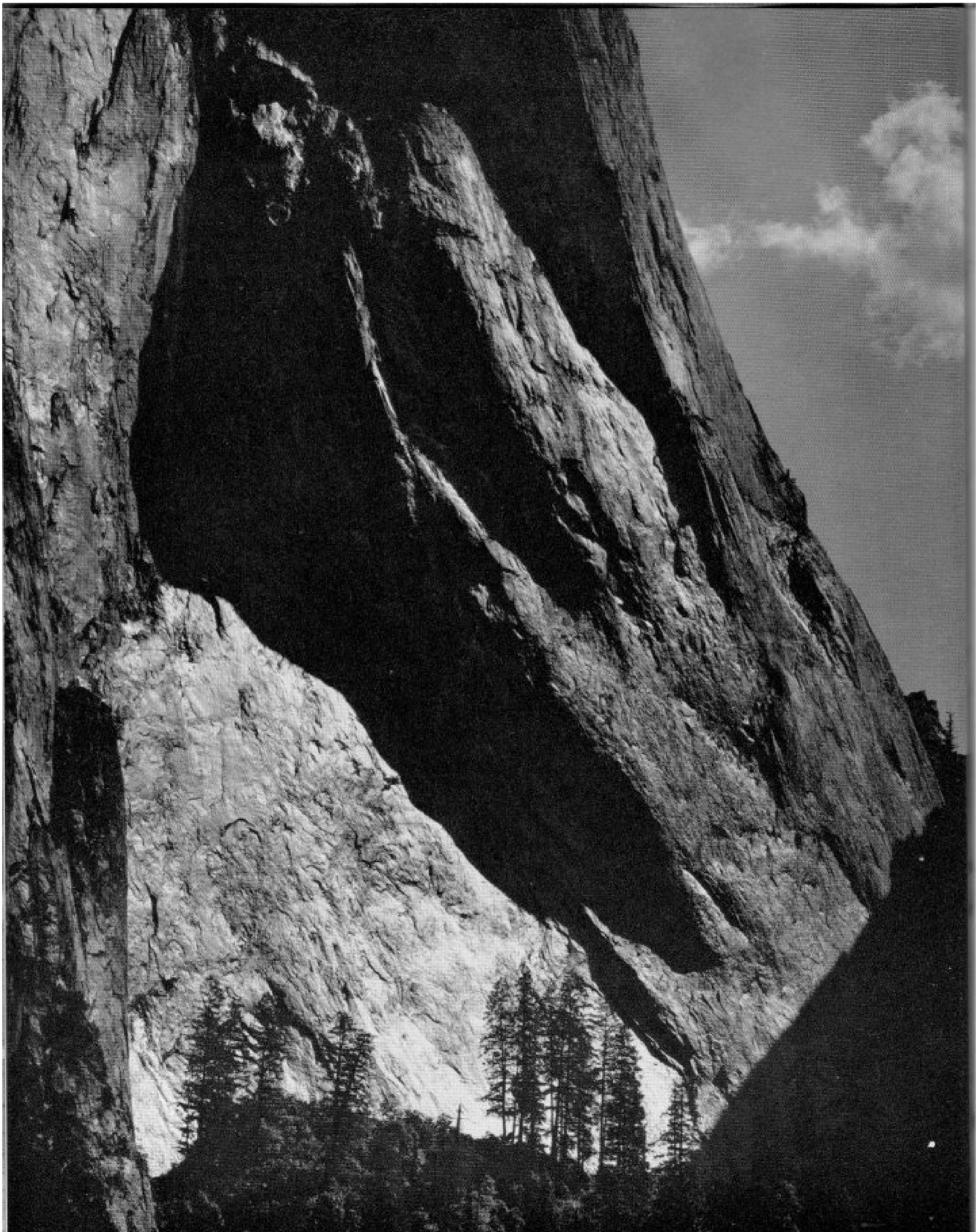
r

r r r

r

r r r r r r

r r



r

r r r
r r Middle Cathedral Rock, Yosemite. By Ansel Adamsr

r r r r

r r r r

r r r r r

r FRANÇOIS MATTHESr
r AND THE MARKS OF TIMEr

r r

r ***Yosemite and the High Sierra*r**

r

r
r r r

r EDITED BY FRITIOF FRYXELLr

r r

r SIERRA CLUB » SAN FRANCISCOr

r r r

---

r r r r

r Library of Congress Catalog Card Number 62-11763r r

r r

r Manufactured in the United States of Americar
r by Gillick Printing, Inc.r
r Designed by Mark Robertsonr

r r

r The Sierra Club, founded in 1892 by John Muir, has devoted itself to the studyr
r and protection of national scenic resources, particularly those of mountain regions.r
r All Sierra Club publications are part of the nonprofit publishing effortr
r the Club carries on as a public trust. Participation is invited in the programr
r to enjoy and preserve wilderness, wildlife, forests, and streams.r
r *Address:* Mills Tower, San Francisco 4.r

r r

---

r r r r

r r r r  r

r r r

r r r r

r DEDICATED TOr

r EDITH LOVELL MATTHESr

r r

r r

---

r r

r **Next: Preface •r Contentsr** r

r r r

r

r r

r

r r

r r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r Preface >r

r r

r

r r r

r **Next: Table of Contents** •r **Contents**r • **Previous: Title Page**r r

r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

---

r r r r

PREFACE

r r

r François Matthes,r said Robert Gordon Sproul, President of the University ofr California, “interpreted the beauty of the Western American Landscape to ther mind as well as eyes of all who love the mountains.”r

r r

r Dr. Sproul spoke for many: those who could testify that Matthes had mader them more than just spectators of land forms, by giving them a fresh and deeperr insight into the meaning of what they saw, so that, under his tutelage, intelligentr understanding was added to their initial admiration and wonder.r

r r

r As an interpreter of the western scene, Matthes was without peer amongr contemporary American geologists. Even when writing technical papers he keptr in mind the interested laymen who shared his interests. Recently a Sierra Clubr leader wrote me, with reference to a friend and himself (neither of them geologists),r “We have both carriedr r Professional Paper 160r in our knapsacks whenr every ounce of weight was precious.” This tribute would have meant much tor Matthes. His concern with the general public netted him little in terms of professional standing, but this did not deter him from giving unstintingly of hisr time and effort to such “extracurricular” activities. The latter were important,r he knew, because they enriched the lives of others. This was sufficient.r

r r

r Matthes’ eagerness to impart to others what he himself perceived in landscapes led him, very early in his career, to contribute geological essays to mountaineering and other journals. Some of his finest essays were written about ther National Parks—Mount Rainier, Yosemite, Grand Canyon, and Crater Lake—r and were printed on the reverse side of the topographic maps of these areas.r This use assured them exceptionally wide distribution, and it put them in ther hands of those most likely to read them with profit and appreciation. Ther literary charm of these essays, coupled with their high level of scientific reliability, made them—and continues to make them—uniquely effective in the interpretative program of the National Park Service. Most of Matthes’ essays,r however, were written for the *Bulletin* of the Sierra Club, and were addressedr primarily to his fellow members in that group.r

r r r

r The present volume brings together fifteen representative essays writtenr between 1911 and 1938. This twenty-seven year period spans only a part of ther time which Matthes devoted to Sierra studies, as that time extended, with onlyr a few interruptions, from 1905 until his death in 1948. The choice of essays wasr made with a view to achieving unity in the collection (all of the essays relate tor the Sierra Nevada, and all have general appeal as regards subject matter andr treatment) while also illustrating the diversity to be found in the descriptiver and expository writings of this author. Five of the essays are here published forr the first time.r

r r

r It is possible that when Matthes began writing his Sierra essays he contemplated a series, dealing mainly with the Yosemite, which eventually might ber assembled in book form. At any rate, between 1910 and 1914 he wrote fiver essays for the *Sierra Club Bulletin* all entitled "Little Studies in the Yosemiter Valley," each with an appropriate subtitle and numbered, consecutively, I to V.r His next Sierra essay did not appear until 1920, and it was entitled simplyr "Cockscomb Crest." The six year gap in the series resulted, at least in part,r from World War I, but abandonment of the general title and plan for numberingr may be attributed to other circumstances. Most of the essays written after 1920r were hardly "Little Studies," as were the earlier ones, nor did they relate onlyr to the Yosemite region.r (Publication of Professional Paper 160,r *Geologic History of Yosemite Valley*,r in 1930 provided adequately for Matthes' Yosemite studies.)r Rather, they dealt with many and widely scattered geomorphic features in ther Sierra Nevada, and they reflected the vastly broadened sweep of his interests,r which by this time encompassed some of the most fundamental problems of ther Sierra as a whole.r

r r

r Some repetition will be found in this book—necessarily so—overlappingr being inescapable since each essay was written to be a unit complete in itself.r However, the amount of repetition is relatively small, and if the essays are readr individually, as will generally be the case, it should not prove disturbing. Ther essays have been arranged chronologically for the most part, a few have beenr shortened slightly, and editorial annotations (signed "Ed." to distinguish themr from the author's own footnotes) have been kept to a minimum. In some instances, recent photographs have been substituted for the original photographsr which now seem archaic—for photography and the techniques of reproducingr photographic illustrations have come a long way since the early volumes of ther *Sierra Club Bulletin* were printed. Features mentioned in these essays are shownr on the topographic maps of Yosemite Valley and Yosemite National Park,r r r Sequoia and Kings Canyon National Parks, and the Mount Lyell, Mount Morrison, Mount Goddard, and Kaiser quadrangles. Elevations used in the bookr come from editions of these U.S. Geological Survey topographic maps (scaler 1:125,000) which preceded the more accurate, photogrammetrically based mapsr now being issued (scale 1:62,500). There were minor interim adjustments ofr elevations in the course of the study period represented in the Matthes essays;r no attempt has been made to correct the essays accordingly.r Readers wishing to go farther afield with Matthes, through the medium ofr other essays and more technical papers, may consult the Selected Bibliographyr referred to onr page 39r for specific suggestions. In particular they may wish tor seek acquaintance with the monograph already alluded to,r r Professional Paperr 160, and two posthumous books, *The Incomparable Valley: a geologic interpretationr of the Yosemite*, and *Sequoia National Park: a geological album*, published in 1950 by the University of California Press. Mention may be mader of another posthumous work, Professional Paper 329, *Reconnaissance of ther Geomorphology and Glacial Geology of the San Joaquin Basin, Sierra Nevada,r California*, published in 1960.r

r r

r This volume, like its predecessors, *The Incomparable Valley* and *Sequoiar National Park*, embodies the vision and planning of August Fruge and Davidr Brower of the Sierra Club. Encouraged by these friends, I undertook to preparer the book in the summer of 1953, as a joint venture with my oldest son, John,r then 22, who gladly did the essential preliminary copying of the essays, checkedr the typescript against the original texts, and critically reviewed my first draft ofr the biographical account. With John's death that fall, the work ceased. Later Ir returned to the project and this time, with the help of my other sons, Roald andr Redwood, completed it. Carol Broline and Lois Wittbecker also aided me, withr the retyping of parts of the final manuscript and Mona Goranson assisted withr proofreading.r

r r

r Ansel Adams, with typical generosity, allowed the Sierra Club to explorer his files of Sierra photographs and donated all that would be particularly appropriate to the book. Special thanks are also due George Mauger, of the Sequoiar and Kings Canyon National Parks Company, for photographs in the Tokopahr Valley chapter. All of the François Matthes photographs are used here by permission of the U.S. Geological Survey. Other illustrations were originally publishedr in early *Sierra Club Bulletins* or have been taken from the club's photographic collection. Robert V. Golden, of the club's staff, aided in their selectionr and identification. Mark Robertson, the book's designer, contributed above andr r r beyond the call of duty in his concern about content as well as form. Professorr William Putnam, at the University of California, Los Angeles, encouraged ther final effort to bring the book into print, and Bruce M. Kilgore, as Managingr Editor for the Sierra Club, staunchly carried it through its final stages at a timer when conservation crises were making extraordinary demands.r

r r

r Readers will share the gratitude I feel to those who helped, in these variousr ways, to give this selection of "Matthes gem-like essays" a place among ther admirable books bearing the distinguished imprint of the Sierra Club.r

r r

r F. F.r

r r

r *r Rock Island, Illinoisr*
r November 30, 1961r r

r r r
r r

---

r r

r **r Next: Table of Contents •r Contentsr • Previous: Title Pager** r

r r r

r

r r

r

r r

r r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r Contents >r

r r

r

r r r

r **Next: François Emile Matthes •r Contentsr • Previous: Prefacer** r

r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

r r r

CONTENTS

r r

r r r
r r

r r

r **r Next: François Emile Matthes •r Contentsr • Previous: Prefacer** r

r r r

r

r r

r

r r

r r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r François Emile Matthes >r

r r

r

r r r

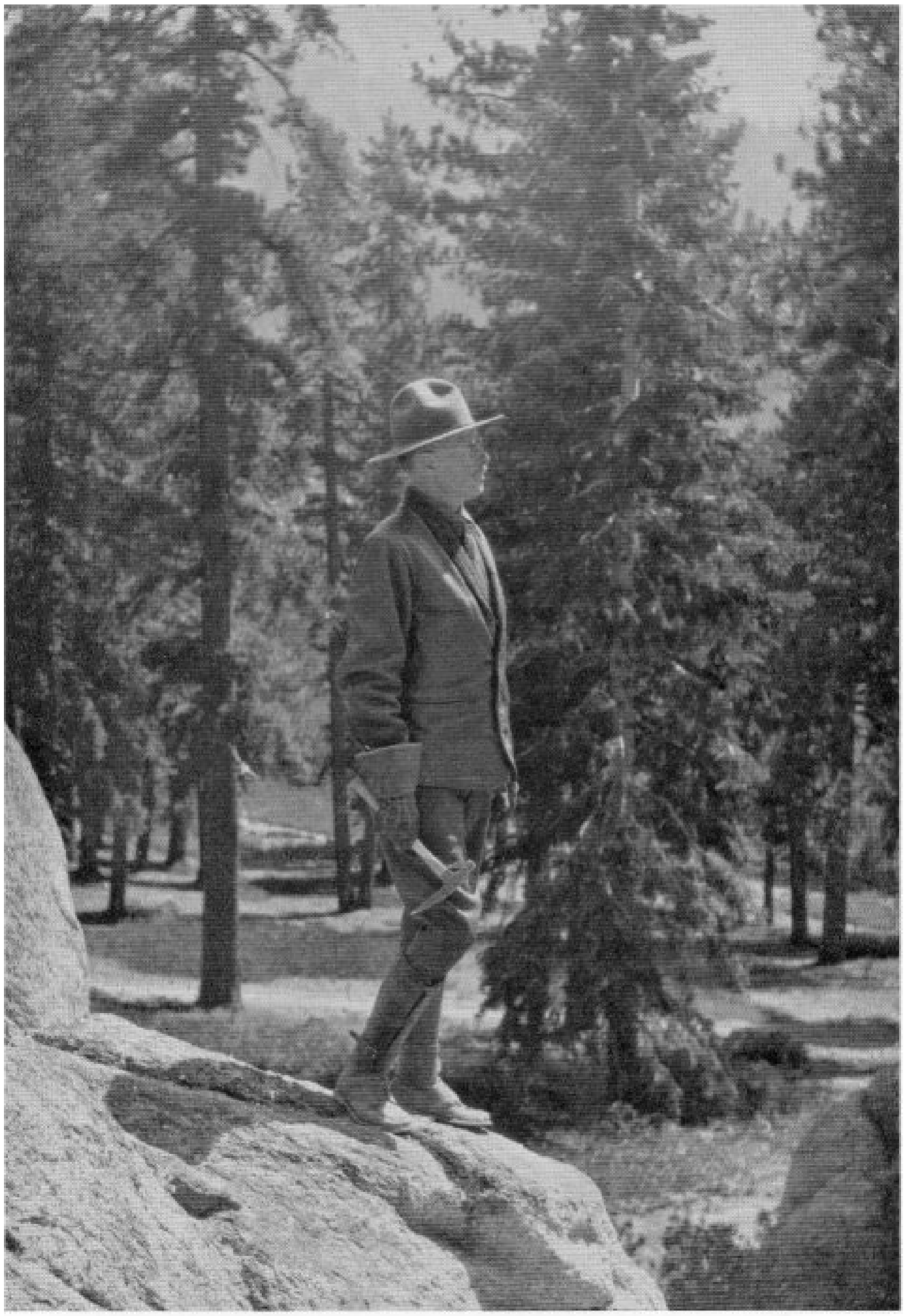
r **r Next: Winds of the Yosemite Valley •r Contentsr • Previous: Table of Contentsr** r

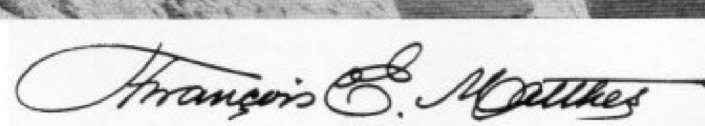
r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

r r r





r r r

r r r

r r r

r r r r r r

FRANÇOIS EMILE MATTHES

r r

r r François Emiler r and Gerard Henrik Matthes, twin brothers, were bornr in Amsterdam, Holland, March 16, 1874. Their parents both belonged to old,r distinguished families of the Netherlands.r

r r

r Willem Ernst Matthes, the father, was a well-to-do merchant, member ofr the firm of Matthes and Bormeester, dealers in colonial products such as rubber,r indigo, and hemp, the firm that had the contract to furnish India rubber for ther first transatlantic cable, laid in 1866. He had traveled widely throughout Europer and was a man of broad culture and many interests. He was the founder andr first president of an academy of arts and sciences, known as “Felix Meritis,”r which was inaugurated by William III of Orange, King of Holland; and he wasr also a director of the “Natura Artis Magistra,” the famous Amsterdam Zoological Gardens. Fond of horseback riding, he owned several saddle horses, was oner of the organizers of the riding academy of Amsterdam, and, as a Lieutenantr Colonel in the National Guard, commanded the artillery unit of Amsterdam.r

r r

r The mother, Jonkvrouw Johanna Suzanna Matthes, nee van der Does der Bije, was a delicate but singularly beautiful and refined woman, with a keenr mind and a flair for history. She was the youngest of thirteen children, sixr brothers and seven sisters, who were brought up in the old university town ofr Leiden, and mingled in court circles at the Hague. The clan, van der Does, tor which she belonged, was of the nobility of Holland and well deserved the surname of “de Bije” the bees). Johanna—Nancy as she was usually called—r was a lineal descendant of Janus van der Does, the patriot Commandant of ther City of Leiden in its epic resistance to the Spaniards in the siege of 1574.r

r r

r The Matthes home, on the Heeren Gracht near the corner of Vijzel Straat,r was a stately mansion facing one of Amsterdam’s canals. It was the center ofr numerous social affairs, dazzling with decorations, uniforms, and sabers. Ther little twins could peek at all this splendor but themselves had no part in it.r However, life-size marble busts of the boys, made when they were five, gracedr the banquet hall of the home.r

r r r r

r Gerard vividly remembers the vacations which the family spent at Trouviller and Biarritz, France. At Biarritz, where the ocean tides were dangerously high,r the shore was lined with sheer cliffs, and the beach was strewn with boulders.r The twins, then eight, discovered that these boulders contained fossils, and theyr proceeded to chisel them out with little hammers. Their collection became sor big (and heavy) that, at time of departure, the mother refused to pack it in theirr r r r François Emile Matthes at age sixr r

r r r

r r

r r r  r r

r r r

r Willem Ernst Matthesr

 r

r r r trunks, and dumped it all out, to their great dismay. Perhaps this early venturer in fossil collecting should be regarded as prophetic of the geologic interestsr which both boys manifested later, in mature years. At Biarritz, Willem Matthesr engaged a two-horse landau and a driver, and took his family on trips into ther Pyrenees and the country of the Basques, and even down the coast to Irun,r in Spain.rr r

r When about eight years of age, the twins began to be troubled with malaria.r The disease was common in Amsterdam, but since its cause was not understoodr no measures were taken to check the breeding of mosquitoes in the canals. Ther family doctor, Van Wezel, an able man for his time, recommended for the boysr r r a sojourn of several years in the Alps, which were known to be malaria-free.r Accordingly, when the twins were nearly ten, it was decided that the motherr should take them to Switzerland, there to lay the foundations of health andr cosmopolitan education,—a decision which, Gerard affirms, was a turning pointr in their lives. As a result of it, François, though born below the level of the sea,r became a lover of the mountains and gave most of his life to their study.r

r r r

r r  r

r r r

r r Gerard and François, with their mother,r
r about 1886r

r r r r

r At Courgevaux, a few miles from Lac Morat, the mother found a schoolr suitable for foreigners, and they took residence near by in a wing of the castle ofr the Count of Pourtal, who was away. It was an enchanting abode, set amidstr immaculate, spacious gardens; and the twins thoroughly enjoyed their mile-longr walk from the castle to school. In Lac Morat they could see rows of stumps,r remnants of the piles which in ancient times supported the homes of the Laker Dwellers. Wading in the lake they found relics of the army of Charles *ler Temeraire* (last Duke of Burgundy), which at this spot was overwhelmed byr r r the Swiss in 1476. From the nearest town, Murten, the boys could hike to ther ruins of a Roman amphitheater.r

r r

r Gerard recalls,r r

> r We lived in the castle more than a year. The pupils at school were of all ages and spoker many languages. There were English, Germans, Americans, Italians, a Spaniard, ar Greek, and an Egyptian prince, and other nationalities. The young boys were placedr under the supervision of the more mature ones; our mentor was a bright young Englishman. He taught us boxing, running races, and playing cricket. We learned to speakr French fluently, and picked up a smattering of German (spoken throughout Switzerland) and some English words.r

r

> r In 1885-1886, when we were eleven, we lived first at Montreux in a first-class hotelr overlooking Lake Geneva, and later in a smaller hotel called “Montfleuri,” perched onr the steep mountain side and affording gorgeous views of the lake and the snow-cappedr mountains to the southeast, the Dent-du-Midi. Life at Montfleuri, too, was a joy tor us boys. We fell to sketching Lake Geneva, the steamers on it, and the Dent-du-Midi.r We learned swimming in the lake near the picturesque Castle of Chilton.r

r

> r Living half-way up the mountain meant going down to lake level to attend a privater school at Territet; where the pupils were mostly English boys. This called for a dailyr mountaineering stunt. I attribute our capacity for climbing mountains later in life tor our excellent lung capacity developed by this daily exercise. We learned to run uphillr when chasing butterflies, and climbed to high altitudes to collect rare species. We studiedr the ways of different kinds of ants.r

r

> r Father spent a week or two with us each summer. His hobby was mountaineering,r and we enjoyed it with him. At Montfleuri our favorite climb was to the top of ther nearby Dent de Jaman, 5000 feet above lake level. Father brought us cloth-mountedr military maps (General Dufour's series) which showed all triangulation stations. On ther ground these stations were marked by tall white timber pyramids. The maps had nor contours, but were beautifully finished with hatchures, which brought out the relief inr great detail. Father taught us to read the maps and we learned to locate ourselves.r After he left we always carried the maps in our blouses, and roamed about without fearr of getting lost.r

r r

r Becoming "map wise" as boys was to prove of tremendous help to the twinsr in later years.r

r r

r Vacations were spent at various alpine resorts. One of these was noted for itsr fine St. Bernard dogs, and on their expeditions the boys always took one or twor of the dogs along. On their final trip to a resort in the Alps, they crossed ther border to celebrated Chamonix, in France. Here they visited the great glaciersr of Mont Blanc. Standing upon *Le Glacier des Bossons*, they marveled at ther intense blue green of the ice deep down in its crevasses.r

r r

r Little wonder that, after four years of such idyllic boyhood, frail bodiesr r r became strong; bright, inquiring minds were stimulated; and as the twigs werer bent the trees inclined.r

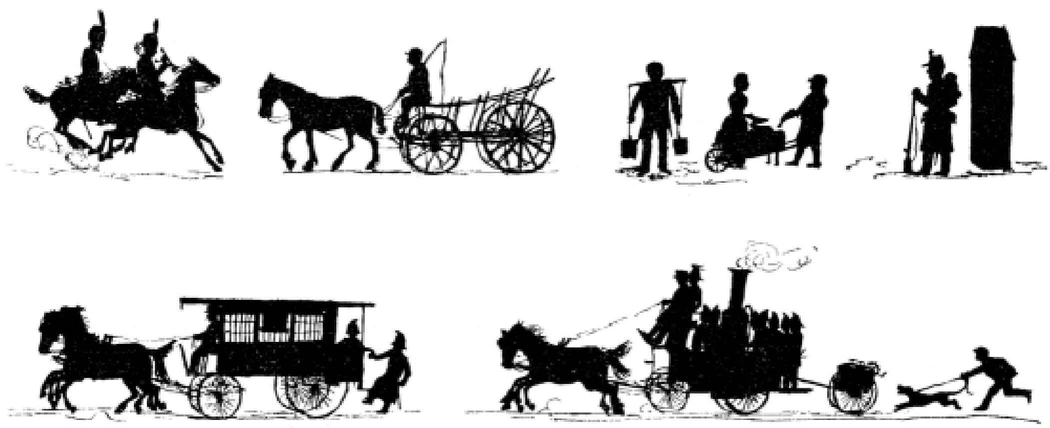
r r

r Themselves patrons and collectors of art, the parents saw to it that from ther age of nine on the twins received instruction in drawing with pencil, charcoal,r and drawing inks. François revealed a native talent for art which amazed everyone. The boy was fascinated by the work of the American artist, Frederickr Remington, which he studied until he, too, became adept at drawing animals,r particularly horses. François' boyhood sketch books have been preserved, andr leafing through their pages, crowded with exquisitely drawn horses, in everyr imaginable pace and attitude, one cannot but wonder whether, had he pursuedr the career of an artist, he might not have rivaled Remington, or the noted Frenchr contemporary painter of animals, Rosa Bonheur. However, the education of ther Matthes twins had been planned along quite different lines, as is evident fromr the fact that, beginning also at the age of nine, they were taught to draw onr tracing linen, with use of triangles, T-square, and drawing pens.r

r r

r In 1887 the twins, now thirteen, procured German grammars and began serious study of the German language. That fall their mother brought them to Frankfurt am Main, in Germany. Here they were left in care of one Professor Goedeke,r and in his home shared quarters with four other school boys. Their studies werer now continued at the Klingerschule, a technical high school ("Ober-realschule").r Besides German, they received excellent instruction in both French and English,r —in accordance with Willem Matthes' wish that his sons "learn 'live' languagesr thoroughly and skip Latin and Greek." Gymnastics and out-of-doors sports werer also taught, including swimming, in the River Main.r

r r r



r r r

r r r

r r r r r

r Refreshing changes from school life were provided by the summer months,r when they visited their home in Amsterdam; traveled through France, Germany,r and Switzerland; or stayed at Villa Favorita, the summer residence of ther family at Baarn (near the beaches and dunes of Holland), or visited at Chateaur Einthout, near Brussels, Belgium, the country estate of the Baroness van derr Elst, a great friend of the Matthes family for whose deceased husband Françoisr Emile had been named. On their trips between Amsterdam and Frankfurt, ther boys traveled by train along the Rhine, going down one side and back along ther other, so as not to miss any of the fine scenery.r

r r

r The studies at Frankfurt were intended as preparation for an engineeringr course at a German university; but after the twins had spent four years inr Germany, their plans underwent another momentous change, when fate intervened—in the person of a traveling Harvard professor—and instead, in September 1891 they set out on a long voyage, to *Amerika*. At the outset of the voyage,r a violent storm disabled their ship, so that the adventure all but ended inr disaster, but eventually, though days behind schedule, they reached New Yorkr harbor. When they sought admission to the Massachusetts Institute of Technology, the semester was already under way, but the president, General Francisr A. Walker, becoming interested in the twins, permitted them to take the entrancer examinations. These showed them to be far ahead of requirements in modernr language and mathematics, and deficient only in American History. They werer admitted at once to the civil engineering course, as freshmen, but were excusedr from taking French and (being foreigners) from military drill.r

r r

r Thus, in all the strangeness of a foreign land the twins began life anew andr in their fourth language, English. With the writing of English they had littler difficulty, as they were actually better prepared than most of their Americanr classmates, so thorough had been their instruction at the Ober-realschule; andr their rapid progress in the mastery of spoken English is evidenced by the factr that they were soon giving talks to the Civil Engineering Society of the Instituter and other groups, on various technical subjects. Some of these subjects, thoughr very familiar to them, must have been novel to their fellow students. François,r for instance, spoke on “The Draining of the Zuider Zee” and “The Use ofr Mattresses in Dike Construction.” Their early training in drawing and draftingr now stood them in good stead; François soon became the outstanding draftsmanr in his class. At the advice of a professor who had formerly been connected withr the U. S. Coast and Geodetic Survey, the boys elected the geodetic course,r which would prepare them for careers with that Survey.r

r r r r

r Both boys became active members of the Agassiz Association of Boston;r Gerard, as a senior, was elected president of the society. Their large insect collection from Switzerland they presented to the Museum of Natural History inr Boston and, in return, were allowed free use of the museum library. Theirr interest in entomology continued. François, in autobiographical notes from ther period, refers to illustrated talks which he gave to the Agassiz Association andr other groups in Boston and elsewhere on “Coleoptera”; “Parasitic Insects”;r “Insect Life in Winter”, and other entomological topics.r

r r

r Their first summer in the United States, 1892, the boys pursued their favoriter pastimes—camping, mountaineering, and collecting insects—in the White Mountains. The second summer they were employed by an insurance company tor make drawings of the fire-protection devices used in various eastern factories.r With their earnings they paid their way to Chicago, to see that city’s first Worldr Fair. The third summer, spent at the M.I.T. field school in the Adirondacks,r they learned mapping with plane table and alidade, and, in the Ausable River,r measuring stream flow with different kinds of current meters.r

r r

r General Walker proved their constant warm friend and counselor; Gerardr reciprocated by writing the “Military Career of General Walker” (in the Civilr War) for the college annual. The busy college years sped swiftly and happilyr by. In 1895 the twins both graduated with honors, receiving the degree Bachelorr of Science, and the next year they proudly became citizens of the United States.r

r r

r At this point we must separate the twins, Gerard and François. Each wentr his way to climb to the top of his profession. Gerard distinguished himself inr the field of hydrographic engineering (see *Who’s Who in America* andr *American Men of Science*); François for many years expressed his talent for drawing,r as well as for precise, analytical scientific work, in the making of topographicr maps. Eventually, however, he became a geomorphologist and a glacial geologist.r As the latter specialty came to include the study of existing glaciers it, in turn,r led him far into the related fields of meteorology and climatology.r

r r

r Following graduation, on June 1, 1895, François entered upon the duties ofr his first position, which was as instrument man and draftsman in the city engineer’s office at Rutland, Vermont, and was assigned to the making of detailedr topographic surveys for the city. Exactly one year later he joined the organization with which he was to be connected for fifty-one years: the United Statesr Geological Survey. From June 1 to November 1, 1896, he was traversemanr with topographic parties in New York and Vermont. He then became fieldr assistant in Indian Territory (now a section of Oklahoma), part of the timer r r serving as acting chief draftsman, part of the time being in charge of revisionr work in the field. On April 1, 1898, having passed the federal Civil Servicer examination, he was advanced to assistant topographer, a grade which qualifiedr him for the larger opportunities now at hand.r

r r

r In the summer of 1898, the United States was at war with Spain, butr pressing domestic projects were under way also. Little-known areas of the Westr were being mapped by the Geological Survey. Early in the summer, Matthesr received his first assignment as a party chief, in connection with surveying ther Cloud Peak quadrangle in Wyoming. The lower, western third of the quadrangler had been surveyed by H. S. Wallace in 1897; it remained for Matthes to surveyr the remainder of the quadrangle, including all the main crest of the Bighornr Mountains, in 1898 and 1899. From Washington he went west by train, arriving,r on July 20, 1898, at the frontier town of Sheridan, where he proceeded tor organize the personnel and equipment of his party. It was no task for a weakling,r either with respect to the exploration of these trackless mountains or the problems involved in the mapping; but the physical difficulties were, of course,r simply part of the day’s work. The map was the thing!r

r r

r Of Matthes’ work as topographer, it has been said that he “contributedr notably to the effectiveness of mapping rugged mountain areas,” and that thisr method, which involved multiple sights through the telescopic alidade and ther sketching of provisional form lines, has become standard procedure (Visher).r (Prior to about 1935, all the topographic maps produced by the Geologicalr Survey were made with the use of the alidade and plane table.) Matthes’ successr as a topographer stemmed not only from mastery of technical principles andr methods, and from his skill in drawing, but also from his keen analysis of landr forms and his consuming desire to understand them. The Bighorn Mountainsr provided him with his first opportunity to delineate, with contour lines, ther varied patterns of mountain landscapes, especially those resulting from alpiner glaciation; and as he brought out the topographic features on his maps her pondered over their origin. Thus, following his field work, in 1899, he renderedr a service beyond the call of duty as topographer when, in the evenings, afterr long days of drafting at the Washington office, he wroter *Glacial Sculpture of the Bighorn Mountains, Wyoming*.r This was his first scientific publication, and it isr still a standard reference. In it Matthes distinguished from the land forms sculptured by glaciers other features produced by persistent snow fields, and her applied the now-familiar term “nivation” to the previously unrecognizedr geomorphic processes which were involved.r

r r r r

r From his initial assignment in the Rocky Mountains, Matthes emerged ar seasoned topographer of recognized skill, and a first-rate horseman and packer,r with experience which was to prove all but indispensable to him in his futurer work. On July 1, 1899, he was promoted to the rank of full topographer. In ther spring of 1900 he made a hydrographic reconnaissance of the Blackfoot Indianr Reservation in Montana. There followed a succession of assignments whichr included two areas in Montana (the Chief Mountain quadrangle and part ofr the adjacent Browning quadrangle, surveyed in the summers of 1900 and 1901),r two areas in Arizona (the Bradshaw Mountains quadrangle, surveyed in ther winter of 1900-1901, and the Jerome quadrangle, surveyed in the winter ofr 1902-1903), and several other areas which, from the standpoint of the topographer, were as difficult and spectacular, and therefore as challenging, as anyr to be found in the entire Far West.r

r r

r Matthes, albeit sturdily built, was a man of rather small stature, and therer was little in his appearance to suggest his capacity for enduring hardships andr strenuous activity of the kind that these assignments necessitated. That her became a master of reconnaissance mapping—first topographic and later geologic, much of it carried out in exceedingly difficult terrain without benefit ofr roads, or, for that matter, even trails, at a time when modern aids to mappingr such as aerial photography were unheard of—may be attributed not only tor hardihood and perseverence but also to his consummate skill in planning andr executing long pack trips, and to his great resourcefulness in solving the problems posed by exploration in wilderness country.r

r r

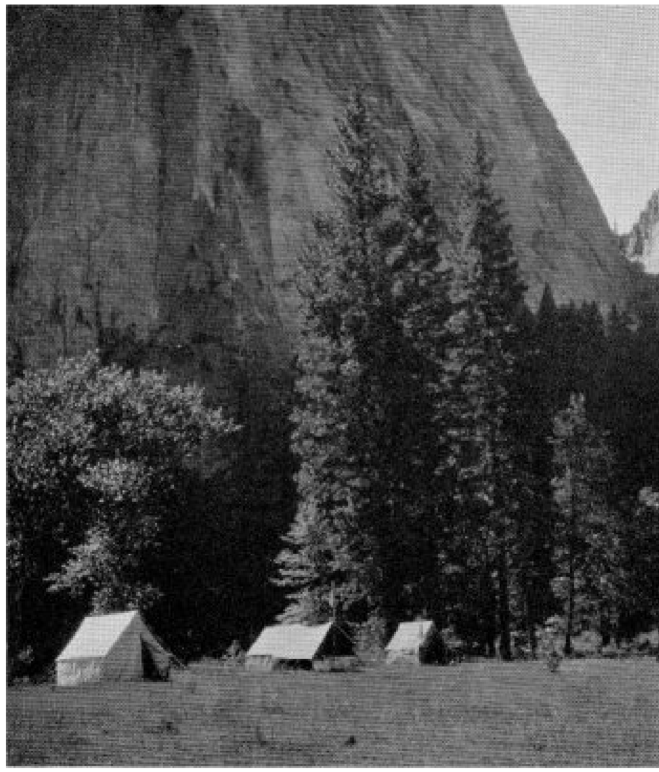
r In the Chief Mountain quadrange, as in the Cloud Peak quadrangle, Matthesr found glacial sculpturing illustrated on a grand scale and with remarkabler clarity; and there was even better opportunity to study small but interestingr existing glaciers. He established stations on a number of the principal summitsr and determined the elevations of the peaks. It became evident, as the map grew,r that what had heretofore been "just Rocky Mountains," insofar as officialr Washington knew, was a veritable "Alps." Conservation was to the fore, enthusiasm grew, and the superb Chief Mountain quadrangle, together with Matthes'r photographic records and his publications, gave telling impetus to the movementr which culminated in 1910 in the act of Congress establishing Glacier Nationalr Park.r

r r

r In February 1902 came orders to begin the mapping of the upper half of ther Grand Canyon of the Colorado River, in Arizona, the scenically more remarkabler section of the canyon which was destined later (1919) to become Grand Canyonr r r National Park. Aside from the difficulties of getting about in, and mapping,r some 500 square miles of almost incredibly rugged country—country dissectedr with labryinthine complexity and traversed by a mile-deep chasm consideredr impassable—and of maintaining the life of men and animals in a forbidding,r practically uninhabited region, largely devoid of usable water supply, the assignment was a staggering undertaking, the full details of which have yet to be told.[1]r Suffice it to say that the mapping was done wholly by means of the plane table,r the Grand Canyon providing, in Matthes' words, "an extreme test of the efficiency of that instrument." It was the original intention to publish the maps inr 15-minute quadrangles, on the standard scale of 1:62,500 and with 100-footr contour intervals. However, preliminary experimentation convinced Matthesr that while his field map, made on the scale of 1:48,000, with 50-foot contourr intervals, best expressed the significant topographic elements, this map wouldr not stand reduction to the standard scale. He therefore traced a detail of his fieldr map (delineating Zoroaster Temple) and sent it to Washington, with the recommendation that the Grand Canyon quadrangle be made an exception to usualr practice and be published on the scale of 1:48,000, with 50-foot contour intervals. The recommendation was approved. It followed that the field maps had tor be drawn with such accuracy and neatness that they could serve, unreduced, asr copy for the engraver. This necessitated the most painstaking kind of drafting,r first in pencil and later in ink, but as a result the maps were published with ther scale and contour interval best adapted to bringing out the distinctive topography of the Grand Canyon.r

r r

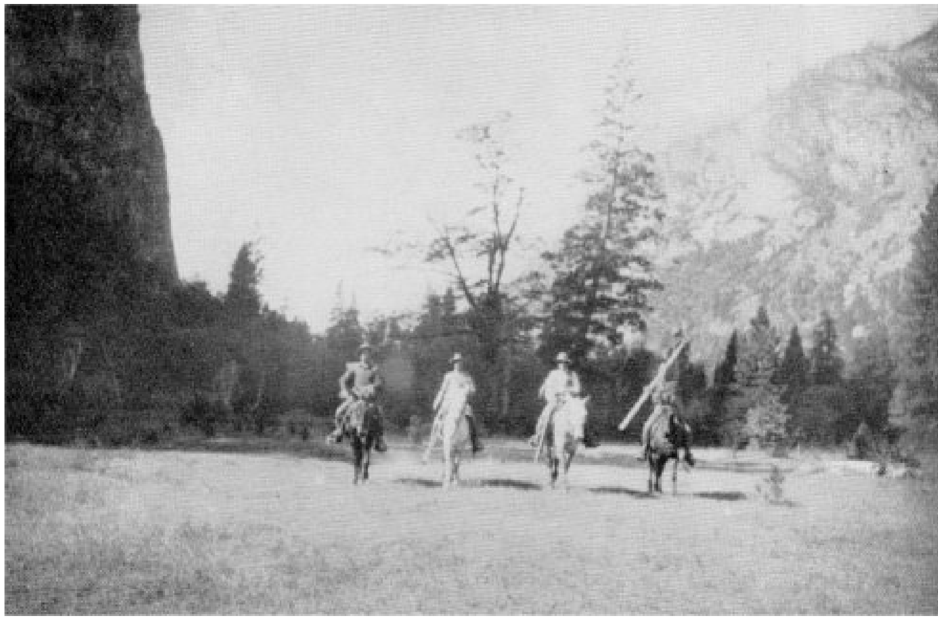
r Matthes began the survey, the first summer, by crossing the canyon with hisr pack train to the north rim, and working on the high northern plateaus. As ther mapping progressed, he studied out through his telescope the details of ar remarkably long, straight side canyon, that of Bright Angel Creek, which her recognized as marking the trace of a fault, and along which the cliffs hadr disintegrated into loose talus. As winter approached, the men hastily built ar trail down this talus, while Matthes himself worked from dawn to dark to finishr the mapping before the heavy snows would set in. Early on November 9, withr work on the Kaibab Plateau finally finished, they broke camp and descendedr the improvised trail into Bright Angel Canyon. The sky was ominous, and thatr night it rained at their camp. The next morning the Kaibab was white with snow.r r r As Matthes noted succinctly, they had "left none too soon." The route whichr they then blazed through Bright Angel Canyon is, in all essential points, ther one today followed by the Kaibab Trail, now the principal tourist route acrossr the Grand Canyon (the spectacular inner gorge has been spanned by a steelr suspension bridge). On November 16, when work in lower Bright Angel Canyonr r r

r r  r

r r r

r r U.S.G.S. Camp in El Capitan Meadow, Yosemite Valley, 1906r

r r r was completed, they recrossed the Colorado River by swimming their horsesr behind a boat found on the banks. Next day they climbed out of the Grandr Canyon and made camp on the south rim. They were hailed as conqueringr heroes.[2]rr r

r The mapping of the Grand Canyon continued in 1903, and only on Januaryr r r r 26, 1904, after nearly two years of practically continuous field work, did Matthesr leave by train for Washington. There remained the task of inking the mapsr and supervising the engraving, eye-straining work which permanently impairedr Matthes' sight. The end products of this labor, however, the Bright Angel andr Vishnu quadrangles, stand as examples of topographic excellence which haver never been surpassed. Many years later, in 1933, when the geologists participatingr r r r r  r

r r r

r r Yosemite, 1906. F. C. North, F. E. Matthes, F. Austin, and L. V. Degnanr

r r r in an excursion of the Sixteenth International Geological Congress stoppedr at the Grand Canyon, the members of the group affixed their autographs to ther back of a panoramic view of the canyon and sent it to Matthes with the message,r "We have been using your maps and have marvelled at them. There are no otherr such topographic maps in all the world."rr r

r In June 1903 Matthes interrupted his work at the Grand Canyon to travelr by train and stage coach to Yosemite National Park, California. The entry inr his tiny diary on Sunday, June 14, reads, ". . . had front seats on stage comingr into Valley. First view from Inspiration Point overwhelming." Though he hadr gone to Yosemite for a rest, his brief entries for the next four days—the entirer r r duration of his "vacation"—would seem to indicate that his object was notr attained. Such a rushing about on foot from the Valley to Glacier Point andr Sentinel Dome; to Vernal and Nevada Falls; to the brink of Yosemite Fallsr and back again to the valley! But of the fact that mind and body were refreshedr we are left in not the slightest doubt. He had dreamed of Yosemite ever sincer coming to America, Now he had beheld it at the height of its springtime beauty,r and he was never to forget.r

r r

r In the winter of 1904-1905, Matthes took a postgraduate course in geologyr at Harvard University, majoring in geomorphology under Professor Williamr Morris Davis. While at Harvard he also lectured on "topographic field methodsr for advanced students in geology," under an Austin Teaching Fellowship. Ther winter in Cambridge was profitable and stimulating at the University, while, onr the outside, there was opportunity for some social life as well as for culturalr diversions—lectures, the theater, and music—for which, by this time, he wasr fairly starving.r

r r

r Matthes had almost fulfilled requirements for the M.S. degree when therer came the offer from the Survey to make a large-scale (1:24,000) map of ther Yosemite Valley. This was an opportunity he could not forego, but he inquiredr if he might not be allowed the few weeks of university work necessary for completion of his course. The reply was negative: the season for field work in ther Sierra Nevada was short, and if he wished to undertake the assignment he mustr start at the earliest possible date. He hesitated no longer. There was but oner Yosemite Valley. The chance to map it was worth far more than an additionalr degree. On June 14 he stood once more in the Yosemite Valley. Camp was setr up on the valley floor that afternoon.r

r r

r If the Grand Canyon had been intricate and involved, the Yosemite Valleyr was far more difficult to map, for, where the Canyon was all angles and pointsr which were natural "targets" for the triangulator, the valley presented curvesr and even overhanging arches. Matthes worked out his own system of expressingr these features in contour lines, and as he worked his wonder grew that such ar diversity of rock forms could be found in so small an area, and that side valleysr could hang at such great and varied heights above the main stream. What factorsr were these that had contrived to produce so amazing a spectacle?r

r r

r Two seasons were necessary to complete the field work on the Yosemiter map. On October 30, 1906, Matthes began inking the map at the Sacramentor office of the Survey, and, with the beautiful work of the engravers at Washingtonr completed, in July of 1907 the "Yosemite Special" was an accomplished fact.r r r In 1923 Matthes wrote an interpretative text for the reverse side of this map—r one of a number of such essays which, at various times, he wrote for the maps ofr National Parks and other areas, and which have been greatly appreciated byr the general public.r

r r

r Matthes spent the spring of 1906 at Berkeley, California, assisting Grover Karl Gilbert in a study of the transportation of sediment by rivers, aiding bothr with the laboratory experiments and by reviewing the extensive Dutch literature relating to silt deposition in the rivers of Holland.r

r r

r On April 18 occurred the great San Francisco earthquake. Thus it chancedr that Gilbert and Matthes were among those who, from the Berkeley Hills, witnessed the conflagration which in the following days spread further disasterr through the city across the bay. The earthquake provided more than an unforeseen interruption of their scheduled work. Gilbert was appointed to the California State Earthquake Investigating Commission, and Matthes, assigned tor the field almost immediately on behalf of this Commission, traced out andr mapped the San Andreas Rift through the northern half of the State. He alsor made a special detailed map of the rift in the vicinity of Fort Ross, in Sonomar County. His maps were published in the atlas prepared by the Commission, andr his field observations, relating particularly to the rift as a geomorphic feature,r were embodied in the Commission's two-volume report.r

r r

r From 1907 to 1913, Matthes served as an Inspector of Maps for the Geological Survey. The several Inspectors visited their widely scattered field partiesr during the summer months; in winter, at Washington, they supervised the workr of the topographers, as the latter completed the drafting and inking of their fieldr manuscripts. In January 1908 Matthes and four associates founded the Quadrangle Club, for senior topographers; the same month the junior topographersr likewise organized, forming the Triangle Club. Richard T. Evans, veteranr topographer, recalls that in the winter of 1907-1908 were held the first of ther many meetings—frequently three or four a month—sponsored by the Topographic Branch as a whole, or by these clubs, for purposes of instruction, andr for the exchange of experiences and views. These meetings (some held at ther Cosmos Club) were continued until 1917, when the ranks of the topographersr at Washington became depleted during the War.r

r r

r Matthes was a leading spirit in planning these sessions, and also in givingr papers at them. His discourses, according to Evans, “brought us new and stimulating ideas that deepened our understanding and appreciation of the science ofr topographic mapping.” These ideas were the outgrowth of his own rich experiencer r r and of his acquaintance with mapping practices abroad and the currentr European literature. In his talks he reiterated his firm conviction that “topography is something more than engineering”; it partakes of “an interpretativer and synthetic art.” He insisted that “no topographer who would aspire to giver maximum value to his work can hope to do so if he lacks an intelligent insightr into the nature of land forms.” The lack of such understanding on the part ofr the delineator “speaks from every line he draws; it betrays itself in the meaningless,r r r

r r  r

r r r

r r François and Edith Matthes on Pinnacle Peak, nearr
r Mount Rainier, Washington, August 12, 1911r

r r r r wooden forms that characterize his sketches, in the evident crudeness ofr his conceptions of nature’s work. These defects may pass unnoticed by the undiscerning, but they are nothing short of galling to those to whom every curve andr flexure in a contour has a meaning.”rr r

r In 1910 came Matthes’ last major field assignment for the Topographicr Branch, when he was put in charge of the mapping of yet another Nationalr Park, Mount Rainier, Washington. Once more he found himself working amongr glaciers, in this case the largest number to be found on any peak in the Unitedr States, many of them 6-8 miles long and covering, in the aggregate, 48 squarer r r miles. In his words, they “radiated like the arms of a great starfish.” The rockr cleavers between the glaciers offered a challenge to map maker and mountainr climber alike. Inevitably his interest in glaciers and their work received freshr stimulus, and he again wrote several geological papers as the by-products of ar topographic assignment.r

r r

r Matthes made two ascents of Mount Rainier, each time back packing ther heavy alidade and other equipment to the summit. On the first ascent, in 1910,r he could accomplish little, as subfreezing temperatures and high winds made user of instruments impossible. On the second ascent, in 1911, he did a long day’sr work on the summit and made the perilous descent as darkness fell. Because ofr poor visibility, resulting from bad weather and forest fires, the field seasons ofr 1910 and 1911 permitted Matthes to complete little more than a fourth of ther map (the southwestern part). The remaining part was completed in 1913 byr others. The altitude of the mountain could then be determined. It proved to ber 14,408 feet, the fourth highest peak in the continental United States.[3]r

r r

r On June 7, 1911, François Matthes married Edith Lovell Coyle, a native ofr Washington, D. C., and a descendant of some of the founders and prominentr citizens of the Virginia and Maryland colonies.r

r r

r Edith Matthes was no stranger to the scientific world into which her marriager brought her, for she had been a librarian's assistant at the Smithsonian Institution. Among the interests which she and François had in common were love ofr the out-of-doors and appreciation of the beautiful in nature. Edith's wondermentr and delight never ceased at François' ability to read nature as an open book,r and their walks together, whether in the western mountains, over the sand dunesr of Cape Cod, or through the by-paths of Rock Creek Park, at Washington, D. C.,r drew them together in an ever closer bond. Though never the thorough linguistr that her husband was, Edith was well grounded in French and German, and inr one other language, alien to François, Russian. Through travel abroad, includingr a sojourn of nearly two years in the capital of Russia, she had acquired a cosmopolitanismr r r r akin to that of his. Most important of the influences she brought intor his life were those stemming from warm sympathy and an intuitive understanding of his motivating hopes and purposes, as well as a home life unknown to himr during the long years spent in western explorations.r

r r

r For this bride now began a life very different from the one she had knownr in Washington and St. Petersburg. Immediately after their marriage, she accompanied her husband to Longmire, Washington, and all that field season sharedr with him the rigors of camp life on Mount Rainier. She learned to ride a horser and climb mountains, and she sat for long hours on the promontory stationsr taking down angles and working out elevations so as to permit the one paidr assistant to map the streams and trails. In subsequent field seasons, wheneverr possible, Edith accompanied her husband on his pack-train expeditions, or sher took up her abode at the farthest outpost of communications, there receivingr the mail, attending to correspondence, and forwarding supplies to the camp.r When the work was on the east front of the Sierra Nevada, more accessible byr roads, she served unofficially as "chauffeur" of their personal car, specializing,r as she put it, "in the business of navigating mountain passes and rutted roads,"r —and, it should be added, thereby leaving her husband free to study the landscape. Many an evening she spent in some lonely canyon as darkness fell, waitingr in the car for François to come down off the mountains. By agreement the carr doors were locked, and beside her on the seat lay the geologist's pick, her weaponr of defense.r

r r

r Matthes' concern with geomorphology had grown, year by year, and he hadr written and lectured extensively in this field. The series of charming geologicalr essays he contributed to the Bulletin of the Sierra Club drew the attention ofr that organization to his work, especially since it related to the origin of Yosemiter Valley, long a controversial question. On July 1, 1913, Matthes was transferredr from the Topographic Branch of the Geological Survey to the Geologic Branch.r It was the first such transfer to be made, and, though Matthes was now nearingr forty, he welcomed the change as one which would enable him to give undividedr attention to geologic problems, which by this time had become his primaryr interest. The many years he had devoted to topographic mapping gave him anr unusual and, from many standpoints, an enviable background for the secondr phase of his career. Indeed, it may even be said that without that backgroundr some of his most significant contributions to geology could not have been made.r

r r

r Matthes' interest in topographic mapping remained keen throughout his life.r In taking geological field notes, as well as in other connections, he always foundr r r it most natural to resort to contour lines in depicting land forms. In 1919 her presented a paper before the Washington Academy of Sciences on "Relief Shading on Topographic Maps," a subject very near his heart and one in which he hadr long sought to arouse interest. When, eventually, the Geological Survey beganr publishing shaded topographic maps as standard practice, it was a source ofr great satisfaction to him.r

r r

r Shortly before his death, Matthes presented to the Survey Library copies ofr the topographic maps of Yosemite Valley, and of the Yosemite and Mountr Rainier National Parks, which he had shaded in pencil. The members of ther map-shading unit of the Survey wrote him on this occasion, to express theirr appreciation of his skill, which, they held:r

r r

> r . . . despite much effort and study by contemporary advocates of the idea, has yet to ber exceeded. It is with wonder and admiration that we, who now carry on this work, lookr upon the masterful understanding and quality exhibited in your work. . . . We just wantr you to know that you have real kindred spirits in our group who understand and appreciate what a pioneer you were in this field.r

r r

r To the spokesman for this group, Matthes sent this message from his sickr bed, on May 22, "I have never had a finer letter of appreciation from anyone andr I want him to be sure to know how deeply touched I am by it."r

r r

r Matthes' first geologic assignment was to study the origin of the Yosemiter Valley and, what was without precedent, to report his findings in languager understandable not only to scientists but to any intelligent and interestedr readers. He could hardly have dreamed, at the outset, how far afield thisr investigation would take him before he could reconstruct the sequence ofr dramatic events which had played a part in the making of what he liked tor call "The Incomparable Valley." Not until sixteen years later, in the fall ofr 1930, did his completed report, ther r *Geologic history of the Yosemite Valley*,r Professional Paper 160, come off the press. Professor Kirk Bryan,[4] in reviewingr this most widely acclaimed of Matthes' publications, wrote, "Occasionally inr the history of science there appears a work so excellent, so comprehensive, thatr it becomes immediately a classic. Such a newborn classic is the long-awaitedr 'professional paper' by Matthes on the Yosemite Valley."r

r r

r It is not possible here to summarize Matthes' great monograph adequately;r for that Professor Bryan's review should be consulted. It may be observed,r however, that inr r Professional Paper 160r Matthes goes far beyond the limitationsr set by his title, for he interprets the Yosemite Valley in its relation to ther r r geologic history of the entire Sierra Nevada, giving special emphasis to problems of structure, geomorphology, and glacial geology. This he does, as Professorr Bryan remarks, "with great breadth of insight and a wealth of detail, largelyr of a quantitative nature." It should be added that clues to the genesis of manyr geomorphic features of the Yosemite Valley, and thereby of other regions inr the Sierra, were provided by the detailed petrographic studies of F. C. Calkins,r published as a part of the report.r

r r

r Matthes' attempt to address the widest possible circle of readers, by reducing to a minimum the use of "scientific jargon," was so successful that it hasr been emulated by many other writers; nevertheless,r r Professional Paper 160r remains the model in its field. It is not surprising, therefore, that the demandr for this volume has exceeded that for any other Professional Paper. Copies ofr the first printing are now coveted by collectors of Californiana. The literary excellence of this work and Matthes' other writings is remarkable considering hisr late start in English; however, as he himself once observed, this was not whollyr a handicap, for familiarity with other languages made one sensitive to subtler nuances of English which otherwise might pass undetected.r

r r

r World War I brought Matthes special assignments, such as describing ther geologic environments of Camp McClellan, Alabama, and Camp Gordon,r Georgia. After the war, in the summer of 1919, the University of California Extension Division sponsored a series of lectures at Yosemite National Park,r named after the noted professor, Joseph LeConte. Matthes was invited to present the geologic lectures and gave these on three successive days, July 8-10.r The first and third lectures ("The Origin of the Yosemite Valley as Indicated inr the History of Its Waterfalls," and "The Origin of the Granite Domes of ther Yosemite") were given in the government pavilion in the valley, but the secondr lecture ("The Highest Ice Flood in the Yosemite Valley") was delivered out ofr doors to an audience which gathered at Glacier Point, 3200 feet above the valleyr floor, where use of lantern slides was needless as the landscape itself furnishedr the illustrations of the theme.[5]r

r r

r r Professional Paper 160, though a large volume, did not contain all the datar which Matthes had gathered in the Sierra Nevada, for from the Merced andr Tuolumne basins he had extended his investigations southward into the upperr San Joaquin basin and even as far as the Kings Canyon and Sequoia Nationalr r r Park. Through these reconnaissances he had become engrossed in the largerr problems of Sierran geology and he was eager to pursue these further.r

r r

r But there followed the "Mississippi Valley interlude," from 1928 to 1934,r during which he was assigned to geologic problems in the Middle West. Theser put him far behind in his Sierran work—one reason why a number of his Sierranr studies never were finished. In 1933 he did have opportunity to contribute twor papers on the Sierra to Guidebook 16, prepared for an excursion of the Sixteenthr International Geological Congress; and in 1935, to his great happiness, he wasr returned to California, this time through a co-operative agreement with ther National Park Service, for a reconnaissance of Sequoia National Park. He completed this reconnaissance in 1936 and that summer also made investigations inr the northern part of Yosemite National Park. The Sequoia data were urgentlyr needed by the National Park Service, and to meet this need Matthes, pendingr opportunity to write a formal report, assembled three volumes which summarized the geology of the park by means of annotated photographs. Theser "Sequoia albums" proved invaluable and eventually, though not until two yearsr after Matthes' death, were published in book form. Matthes was able to complete only one other major paper on Sequoia National Park, namely,r *The Geologic History of Mount Whitney*, published in 1937.r

r r

r In 1937 Matthes continued field work in Yosemite National Park and later in the summer began to investigate the east front of the Sierra Nevada. Ther resulting study he came to regard as the most important of his Sierran work,r for it led him to conclude that the great eastern escarpment of the range hadr been formed as a result of early Pleistocene faulting, and hence was of muchr more recent origin than had been supposed. In 1938 and 1939 he was able tor round out his evidence, at least in part. In July 1939, following meetings of ther Cordilleran Section of The Geological Society of America, in Berkeley, where her presented his findings, he led a party, including several interested laymen, intor the Yosemite Valley and thence across the range to the eastern escarpment itself,r where the evidence could be reviewed on the spot. This was destined to be hisr last excursion into the Sierra Nevada.r

r r r r r

r Although in his later years Matthes published many papers, his time andr strength were increasingly consumed by the demands of various scientificr organizations. As chairman of the Committee on Glaciers of the Americanr Geophysical Union, he organized and supervised a program for conductingr co-operative studies and measurements of the existing glaciers in the Unitedr States and abroad, a work which made him an international leader in deciphering “the elusive record of pre-historic, post-Pleistocene fluctuations of climate.”[6]r As a part of this program, he began assembling a collection of dated photographs and other records relating to the existing glaciers in the United States.r This file has grown through the years and has become increasingly valuabler for reference, revealing the changes in extent and volume which the glaciersr have undergone. Also, Matthes prepared detailed reports summarizing andr analyzing the data on glaciers, particularly with reference to their year-to-yearr changes, and these reports were published annually from 1932 to 1946 in ther *Transactions* of the American Geophysical Union.r

r r

r Matthes returned to Washington in the fall of 1939 at a time of world crisis.r Hitler’s hordes had invaded Poland, and the war in Europe was on. Delegatesr to the triennial assembly of the International Association of Scientific Hydrology were convening in the nation’s capital. When the French secretary abruptlyr departed for his native land, Matthes—the only available linguist in the American delegation—was drafted to take his place. So he was burdened not onlyr at these meetings but for years afterward with the responsibility for the activities of this group, one of the largest of international scientific organizations.r He was also made secretary of the International Commission of Snow andr Glaciers, another division of the Association, and this position likewise calledr for a tremendous amount of correspondence with scientific colleagues throughout the world.r

r r

r On top of all this, Matthes was invited to write a chapter on glaciers, forr r r

r r

r

r r r

r r r r the volume on “Hydrology,” Number IX, “Physics of the Earth” series, ofr the National Research Council. Review of the world-wide literature on glaciers,r and the writing of the chapter, which itself grew to the size of a book, tookr practically all of 1941. This treatise, referred to in the *Quarterly Journal* ofr the

Royal Meteorological Society (June 1949) as “a masterly summary of ther characteristics and behavior of glaciers,” Matthes himself considered to be hisr principal contribution to glaciology. In it, some of the ideas which had longr been maturing in his mind received their fullest exposition, such as the view,r now widely accepted, that most of the glaciers in the western United States arer not the remnants of Pleistocene ice bodies, as previously assumed, but insteadr are “modern” glaciers which became re-ëstablished in post-Pleistocene time,r probably as recently as within the last 4000 years, in what he aptly termed ther “Little Ice Age.”rr r

r During World War II, Matthes was called on to make many contributionsr to the war effort, including the work of the Military Geology Unit of the Geological Survey, by reason of his broad geographic knowledge and his commandr of foreign languages. In 1945, reluctantly but as a patriotic duty, he undertookr a critical re-ëxamination of W. H. Hobb’s doctrine of glacial anticyclones,r which he regarded as scientifically untenable and indeed dangerous in that itr afforded a false premise for the use of Greenland as an air base. In Part Ir of this study, published in 1946, he concluded that “there is no evidence of ar virtually permanent ‘glacial anticyclone’ centered over the Greenland ice sheet.r On the contrary . . . weather over the ice sheet is controlled by alternatingr cyclonic and anticyclonic movements. . . . Aviators need not expect so muchr as a fifty-fifty chance of meeting with good weather on flights across centralr Greenland, except for a few weeks in midsummer.” Part II of this study wasr completed, after Matthes’ death, by Arthur D. Belmont.r

r r

r Matthes’ versatility and manifold interests were not unmixed blessings.r For instance, many of the innumerable requests for information received byr the Geological Survey eventually found their way to his desk for reply. Suchr interruptions, although oft-times rewarding, were nevertheless distractions fromr his principal interests and could hardly do other than induce a certain senser of frustration. The brief years slipped away with the growing feeling that therer was “so little time, so much to do.”r

r r

r Because of heavy demands made on the Geological Survey during andr after the war, Matthes was continued on the active rolls somewhat more thanr three years beyond the statutory age of retirement (70 years), but on June 30,r r r 1947, he retired. The summer was spent in Washington, winding up official andr personal affairs. Finally, in September, François and Edith drove across ther country to the little home in El Cerrito, California, which they had bought forr the retirement years.r

r r

r Matthes gave himself feverishly to the task of arranging his library andr professional materials, took vigorous walks over the Berkeley Hills, and workedr in the garden to “keep fit.” In February, 1948, with long-deferred writingr projects scarcely begun, he was handed a tremendous organizational task: tor plan the program of the Committee on Snow and Glaciers for the sessions ofr the International Scientific Congress, scheduled to meet in August, at Oslo.r He felt he would be derelict in his duty if he did not accept this task which,r he knew, would require all his time and energies for months to come, but her did so with a heavy heart, seeming to sense that now his hopes for “the retirement years” might never be realized.r

r r

r In the early morning hours of Sunday, April 18, Matthes was stricken withr a heart attack. Nine weeks later, June 21, he died. On June 25, services werer held at sunset in the El Cerrito home, high on the Berkeley Hills facing ther Golden Gate, and later the ashes of François Matthes were brought to hisr beloved Yosemite. There, on September 18, in accordance with the wish her had expressed, that which was mortal of François Matthes was committed tor “The Incomparable Valley.”[7]r

r r

r In the course of his life, recognition came to Matthes from many sources.r He was starred in *American Men of Science*, and he served as president of ther Geological Society of Washington in 1932 and of the American Association ofr Geographers in 1933. The long list of his affiliations with learned societies,r mountaineering clubs, and other organizations, both domestic and foreign, canr be found in *Who's Who in America*, and in *American Men of Science*, and needr not be repeated here. Four honors may be mentioned as representative of ther varied facets of his interests and work:r

r r

r He was decorated Chevalier, Order of Leopold II, by King Albert ofr Belgium, in 1920, in appreciation of the account which he gave to the Kingr and his party of the origin of Yosemite Valley, when they visited Yosemite inr the autumn of 1919. He was awarded the Order of the Silver Beaver in 1931,r r r by the Council of the Boy Scouts of America, for "distinguished service to boyhood." This was the honor he cherished most dearly. At commencement exercises in the great stadium of the University of California in 1937 he was givenr the honorary degree of L.L.D. President Robert Gordon Sproul, in conferringr the degree upon Matthes, said, in part, " . . . by your artistry in the delineationr of land forms and your clear, scientific description, you have interpreted ther beauty of the Western American Landscape to the mind as well as the eyes ofr all who love the mountains." Finally, on April 28, 1948, he was awarded ther gold medal of the Department of the Interior for 51 years of distinguishedr service to the United States Government. The citation accompanying the awardr reached Matthes less than a month before his death, when he was gravely illr but not too ill to experience a glow of happiness when it was shown to him.r The beautiful gold medal—a replica of the insignia of the Department of ther Interior, showing in the foreground a bison in bas-relief, in the background ar chain of mountain peaks silhouetted against the rays of the setting sun—didr not come in time.r

r r

r In 1949 the Sierra Club, which had been ever appreciative of its distinguishedr honorary vice-president, took measures to give the names "Matthes Crest" andr "Matthes Lake" to two suitable geographic features in central Yosemite National Park.[8]r

r r

r The place which François Matthes holds in American science is secure and,r in certain respects, unique. He stands alone in having attained eminence firstr as topographer and later as geologist, and he is one of the relatively few whoser writings rank as both science and literature. His colleagues held him in highestr esteem not only for the originality and importance of his contributions to sciencer but also because they knew him to be, at all times, a gentleman. Those whor recall him from professional meetings will not forget the earnestness whichr distinguished his presentation of papers, his participation in discussions, andr his assumption of the responsibilities so often entrusted to him.r

r r

r Physically and intellectually alike, Matthes was impelled by a tremendousr inner drive and tenacity of purpose; and his ideals with respect to workmanshipr were so high he was never willing to compromise short of the best results her could achieve. He was meticulous with respect to details, and conscientious andr orderly to an extraordinary degree—traits well illustrated by his personalr diary, which he began with an entry on January 1, 1897, the day he reportedr r r for duty in Indian Territory, and continued uninterruptedly for more than fifty-one years. The final entry was made but two hours before he suffered the fatalr heart attack.r

r r

r In speech and manner, François Matthes retained a quaint suggestion of hisr rich inheritance of old-world culture, which clung to him like a fragrance. Therer was a certain dignity and courtliness about him; it might be described as ar refinement which instinctively expressed itself in innate good taste and courtesy.r He was aristocratic, but in the best sense of the word, for there was no snobberyr about him. Through a long lifetime, he associated on terms of democratic equality with "all sorts and conditions of men," from kings to cooks.r

r r

r François Matthes may have seemed, to some of his co-workers, a shy, almostr aloof man; for he quietly went about his affairs, had no time or inclination forr "small talk" during office hours, and worked with absorbed intensity at hisr desk or drafting table. Often he dined alone, seeming to be—as he actuallyr was—deep in thought. But how his face brightened, and how animated his conversation became, when a former field associate called upon him, or someoner broached a subject close to his heart!r

r r

r There were facets to his personality which many colleagues never suspected,r and relatively few understood, even among those who knew him intimately inr a professional way. He was a highly sensitive person who rarely disclosed hisr innermost thoughts and feelings, and who, when he did so, could express himself better with pen than in speech. The aesthetic played a dominant part inr his life; he was not only a scientist, but a poet, and an artist to the core. To ar friend he confided, "I simply cannot be happy unless my work is conducted inr country of inspirational beauty." During the "Mississippi valley interlude" her wrote to W. M. Davis, "I am temperamentally not well fitted for work on ther monotonous flats of the Mississippi valley. . . . I should much prefer returningr to the mountains and carrying on there as long as I am physically fit,—ther more so if, coupled with the mountain work, there should be opportunity forr contact with the public."r

r r

r Among kindred spirits, Matthes was not shy. Actually, he loved people,r especially young people; and in the many years of service he gave to scouting,r Sierra Club activities, and the interpretative programs of the National Parkr Service, he found inner satisfactions which meant much to him. In his personalr notes he recurs frequently to a theme expressed thus in one of his letters,r "Nothing makes me happier than when I can share the results of my scientificr studies with laymen." Those who knew Matthes only as the serious scholarr r r might have been astonished at the gusto and enjoyment with which, on request,r he would address tourists who packed the Yosemite Museum or gathered atr an evening campfire to hear him recount the geologic history of Yosemite. Her was a born teacher and might have accepted the teaching opportunities thatr came to him repeatedly had he not found the riddles of Sierra geology irresistibly fascinating. Francis P. Farquhar, California historian and former President of the Sierra Club, has written of Matthes that it was "a rare privileger to be with him and listen to his discourse. He was always glowing withr enthusiasm and always eager to impart it to others. The beauty of the earth,r particularly of mountains, moved him deeply, for he saw all around him manifestations of the orderly processes of creation."r

r r

r In what someone once described as his "beautiful continental hand"—ther hand in which he wrote out and painstakingly revised all his manuscripts, andr which never lost its beauty or firmness despite the swiftness with which her wrote—Matthes was wont to copy those poems and passages which especiallyr appealed to his thoughtful, beauty-loving, and deeply religious nature. Theser selections, and thoughts of his own which he jotted down on any piece of paperr at hand, as they came to him, reveal the man. Thus, for a paper on

Yosemiter Valley he wrote a foreword (never published):r

r r

> r There are those who still fear that science will crush religion one hears not a littler these days about 'those Godless scientists.' But pray, in what way can research of thisr sort possibly lead away from religion? Is it not, rather, a source of inspiration andr spiritual growth which our very ignorance heretofore kept hidden from us? And doesr it not inevitably enhance our reverence for the Author of the universe?r

r r

r On the wall of his room there hung, for almost four decades, a framed,r illuminated copy of "The Footpath to Peace," by Henry Van Dyke, one of hisr favorite writers:r

r r

> r To be glad of life because it gives you the chance to love and to work and to play andr to look up at the stars; to be satisfied with your possessions but not contented withr yourself until you have made the best of them; to despise nothing in the world exceptr falsehood and meanness, and to fear nothing except cowardice; to be governed by yourr admirations rather than by your disgusts; to covet nothing that is your neighbor'sr except his kindness of heart and gentleness of manners; to think seldom of your enemies,r often of your friends, and every day of Christ; and to spend as much time as you can,r with body and spirit, in God's out-of-doors—these are little guideposts to the pathr of peace.r

r r r r

r In one of his notebooks François Matthes printed, with exquisite neatness,r this verse by Irene Hardy:r

r r

r I follow the trailr
r To find truth ere I rest.r
r I follow the trail:r
r Men say I shall failr
r In this measureless questr
r To find truth ere I rest.r
r What though I fail?r
r I follow the trail.r
r

r r

r Fritiof Fryxellr

r r

r *r Reprinted from Proceedings Volume of the Geological Society of America, Annual Report forr 1955, pages 153-168. July, 1956. The sources on which this biographical account is based are givenr on page 153 of the Proceedings Volume, and a Selected Bibliography of the* *writings of Dr. Matthesr appears on pages 166-168.r* r

r r

r [1]The account here given is summarized mainly from the paper by François E. Matthes andr Richard T. Evans, Map of Grand Canyon National Park. *The Military Engineer*, volume 18, 1926,r pages 188-201.r

r r

r [2]History and exploration of the Grand Canyon Region: *Natural History Bulletin No. 2*,r Grand Canyon Natural History Association, November, 1935, pages 18-22.r

r r

r [3]The altitude of Mount Rainier was resurveyed in the summer of 1956 by a special joint surveyr party of the U.S. Geological Survey and the National Park Service. As a result, the altitude ofr Columbia Crest, the highest point on the mountain, was found to be 14,410 feet, rather than 14,408r feet. This left Mountain Rainier in fifth place, a position to which it was dropped in 1955 when ar resurvey of Mount Harvard changed the altitude of that mountain from 14,399 feet to 14,420 feet.r The order of the five highest peaks in the United States, exclusive of Alaska, is now as follows:r Mount Whitney (14,495 feet), Mount Elbert (14,431 feet), Mount Harvard (14,420 feet), Mountr Massive (14,418 feet), and Mount Rainier (14,410 feet). With the exception of Mount Whitney inr California and Mount Rainier in Washington, these peaks are all in Colorado. (*Appalachia*, December,r 1956, page 239.)r

r r

r [4]*Journal of Geology*, volume 40, 1932, pages 84-87.r

r r

r [5]The LeConte Memorial Lectures were never published, as intended, but Matthes' contributionsr were in part included inr r Professional Paper 160r and in part published many years later (1910) inr the posthumous volume, *The Incomparable Valley*.r

r r

r [6]Citation accompanying the Department of Interior honor award for distinguished service, withr gold medal, conferred on François Matthes in April, 1948. The citation is published in ther *Sierra Club Bulletin*, volume 33, 1948, page 8.r

r r

r [7]François' twin brother, Gerard, outlived him by eleven years. His death occurred on April 8,r 1959. "Memorial to Gerard Henrik Matthes, A Reclaimer of Rivers" (28 pages), by David E. Donley,r was privately published by Mrs. Gerard H. Matthes in March, 1960. It includes a Selected Bibliography.r A two-page abstract of this Memorial, prepared by Mrs. Gerard H. Matthes, was published by ther American Society of Civil Engineers, as Memoir No. 2255.r

r r

r [8]Moran, Reid V., Matthes Crest. *Sierra Club Bulletin*, volume 34, 1949, pages 110—111 An illustration of Matthes Crest appears in this volume,r page 76.r

r r r r
r r

---

r r

r **Next: Winds of the Yosemite Valley •r Contentsr • Previous: Table of Contentsr** r

r r r

r

r r

r

r r

r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r The Winds of the Yosemite Valley >r

r r

r

r r r

r **Next: Striped Rock Floor •r Contentsr • Previous: François Emile Matthesr** r

r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

r r r
r

r

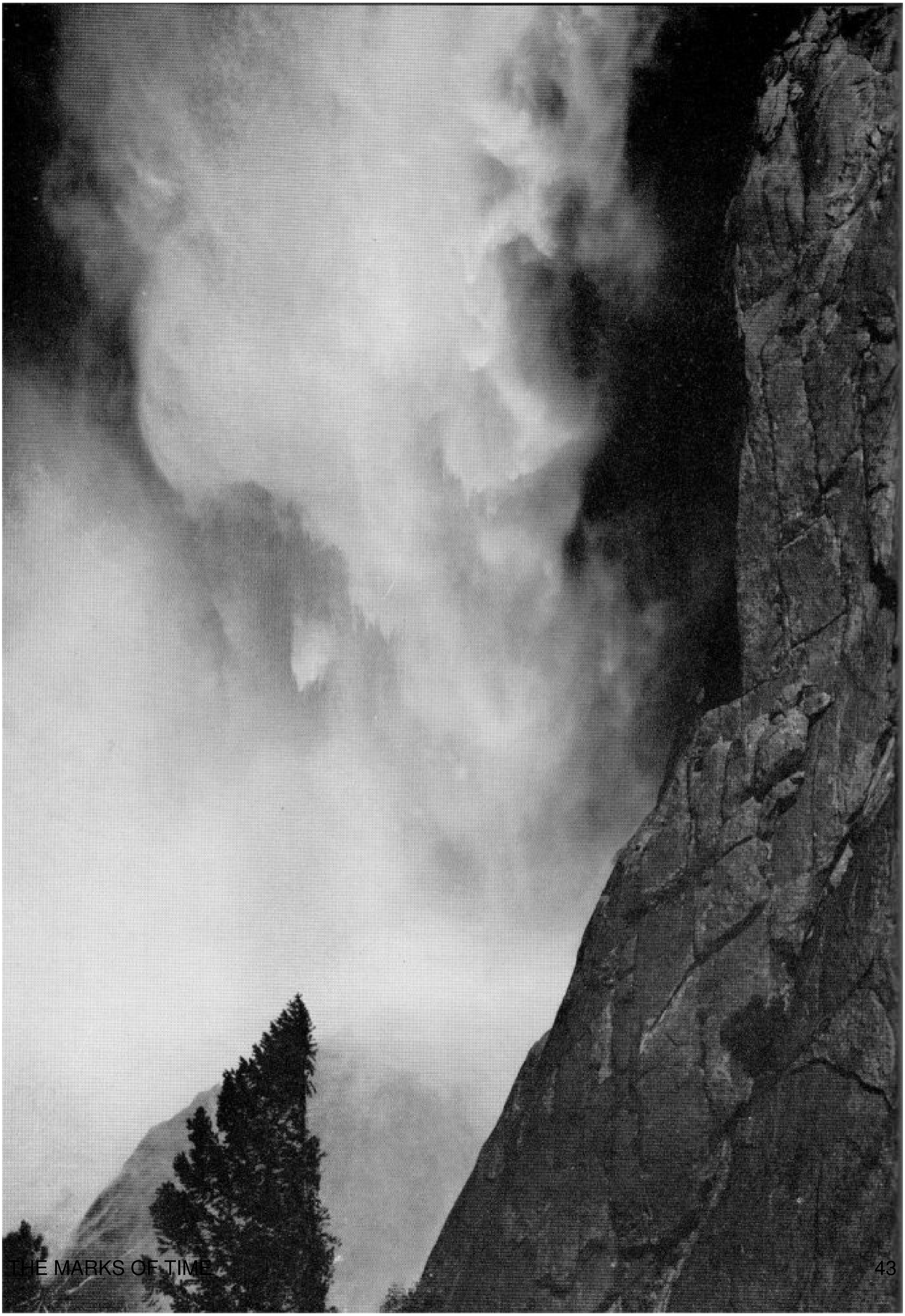
THE MARKS OF TIME

r

r r
r

r r r r

r r



r

r r r

r r Upper Yosemite Fall. By Ansel Adamsr

r r r r r

THE WINDS OF THE YOSEMITE VALLEY

r r r r

r r To most peopler r roaming about the Yosemite Valley its winds andr breezes seem a matter of small interest or consequence. They come and go, nowr one way, now another, apparently without regularity or system—moody, capricious beyond analysis. In the midst of the grand tumult of the Yosemite landscape, our senses fairly bewildered with its many glories, we cannot stop to consider these little breaths that blow about us, and let them puff by unheeded. Ther Yosemite region is not a windy country anyway; but once or twice in a seasonr does a gale arise to disturb its wonted tranquillity, and its daily zephyrs arer such light, airy little nothings as to scarcely seem worthy of downright study.r And yet they become singularly interesting when once rightly understood. Theyr turn out to be surprisingly systematic and withal so intimately connected withr the configuration of the valley itself, that, to one who has at length masteredr their secret they grow to be one of its immanent features, as characteristic andr inseparable as El Capitan or the Yosemite Falls.r

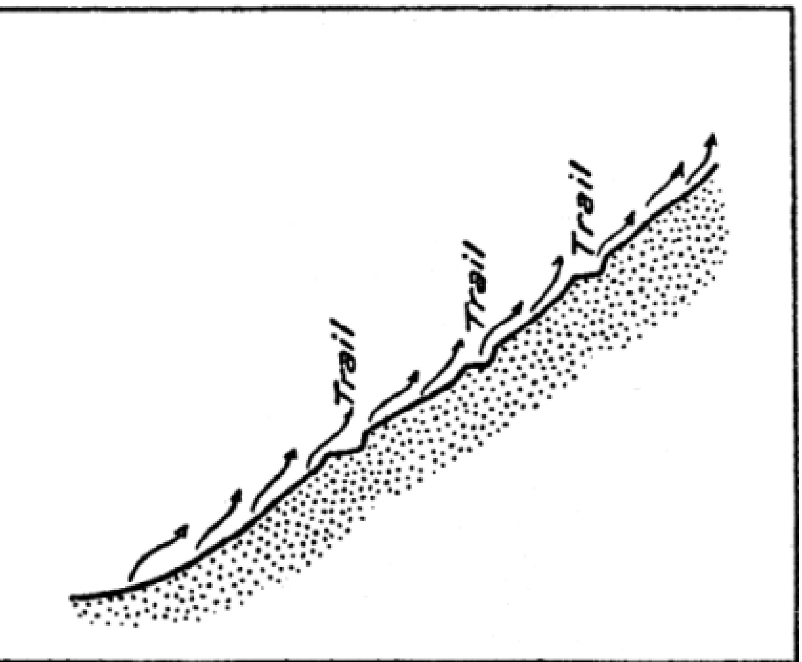
r r

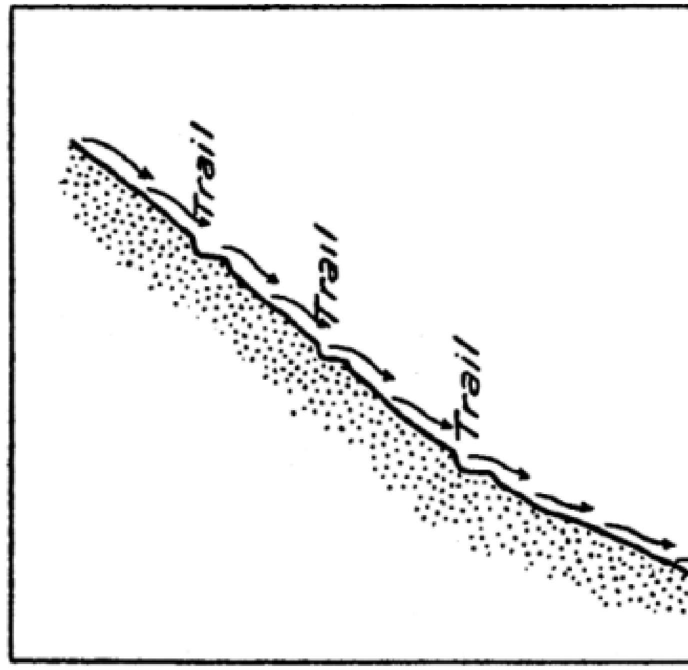
r It happens to be so ordained in nature that the sun shall heat the groundr more rapidly than the air. And so it comes that every slope or hillside baskingr in the morning sun soon becomes itself a source of heat. It gradually warms ther air immediately over it, and the latter, becoming lighter, begins to rise. Butr not vertically upward, for above it is still the cool air pressing down. Up alongr the warm slope it ascends, much as shown by the arrows in the accompanyingr diagram (Fig. 1). Few visitors to the valley but will remember toiling upr some never-ending zigzags on a hot and breathless day, with the sun on theirr backs and their own dust floating upward with them in an exasperating, chokingr r r r cloud. Perhaps they thought it was simply their misfortune that the dust shouldr happen to rise on that particular day. It always does on a sun-warmed slope.r

r r

r But again, memories may arise of another occasion when, on coming downr a certain trail the dust ever descended with the travelers, wafting down uponr them from zigzag to zigzag as if with malicious pleasure. That, however,r undoubtedly happened on the shady side of the valley. For there the conditionsr are exactly reversed. When the sun leaves a slope the latter begins at once tor lose its heat by radiation, and in a short time is colder than the air. The layerr next to the ground then gradually chills by contact, and, becoming heavierr r r r r

r r





r
r r r
r Figure 1r r r r r Figure 2r

r
r r as it condenses, begins to creep down along the slope (Fig. 2). There is, thus,r normally a warm updraft on a sunlit slope and a cold downdraft on a shadedr slope—and that rule one may depend on almost any day in a windless regionr like the Yosemite. Indeed, one might readily take advantage of it and plan hisr trips so as to have a dust-free journey. One might time his ascent for an hourr when the route lies wholly in the shadow; the dust will then obligingly pourr over the edge of the trail, perhaps upon others following on a lower zigzag, butr that, of course, is their lookout. Conversely one might time the descent for anr hour when the trail is wholly in the sun. The dust will then float up behind one,r leaving ever a clear path ahead. The writer, in fact, did deliberately put thisr in practice on more than one occasion during his sojourn in the valley, whenever the choice of hours mattered little otherwise—always with the desiredr result. Thus, he would be careful to make the ascent of the short trail to Glacierr r r Point before its zigzags emerged from the morning shadows, and to descendr again before the sun had set on them. But the casual tourist is seldom favoredr in this way. His sight-seeing trips are laid out for him with little regard forr any rules like these, and as a consequence, he eats Yosemite dust a good sharer of the time.rr r

r But, it may be objected, the valley sides lie ever part in the sun, part inr shadow. The very lay and configuration of the valley are such that at no hourr of the day is either of its slopes entirely sunlit; what with the many cliffs andr headlands and recesses there is always a shadow here or there. Is there, then,r really an updraft wherever the sun shines and a downdraft in every shadowr patch? Most assuredly there is. That is one of the peculiarities of the valley,r the immediate outcome of its exceptionally bold cliff topography. Every cliffr that casts a shadow thereby creates a downward breeze. And thus, there arer in spots throughout the valley local breezes that recur daily at certain hoursr as the shadows come and go. One may readily test this to his satisfaction on ar place like Glacier Point. In the morning, when the great cliff is still in shadow,r a bit of paper tossed over the brink at once disappears, sucked down by ar descending current, but at noon when the sun beats on the cliff, the very opposite will happen; instead of sailing down, the paper shoots upward, and continuing upward, disappears like a tiny white speck in the blue.r

r r

r But let it not be thought that there are none but local air currents in ther valley. There is also a great general movement, itself the resultant of all ther lesser ones. How it is brought about is not difficult to explain. As the afternoonr wears on and the lengthening shadows advance over the landscape, the downward breezes progressively gain in force, extinguishing one after another ther upward currents, until at last with the lowering of the sun they become generalr over the entire surface of the cooling land. Sliding down from every slope andr cliff, they join in the bottom of the valley, there to form a broad airstream orr river that flows on toward the plains below. Every side valley or canyon, moreover, sends its reinforcements, for in every one of them the same thing is happening; and thus, with nightfall there is organized a great system of confluent airstreams corresponding closely to the valley system of the land.r

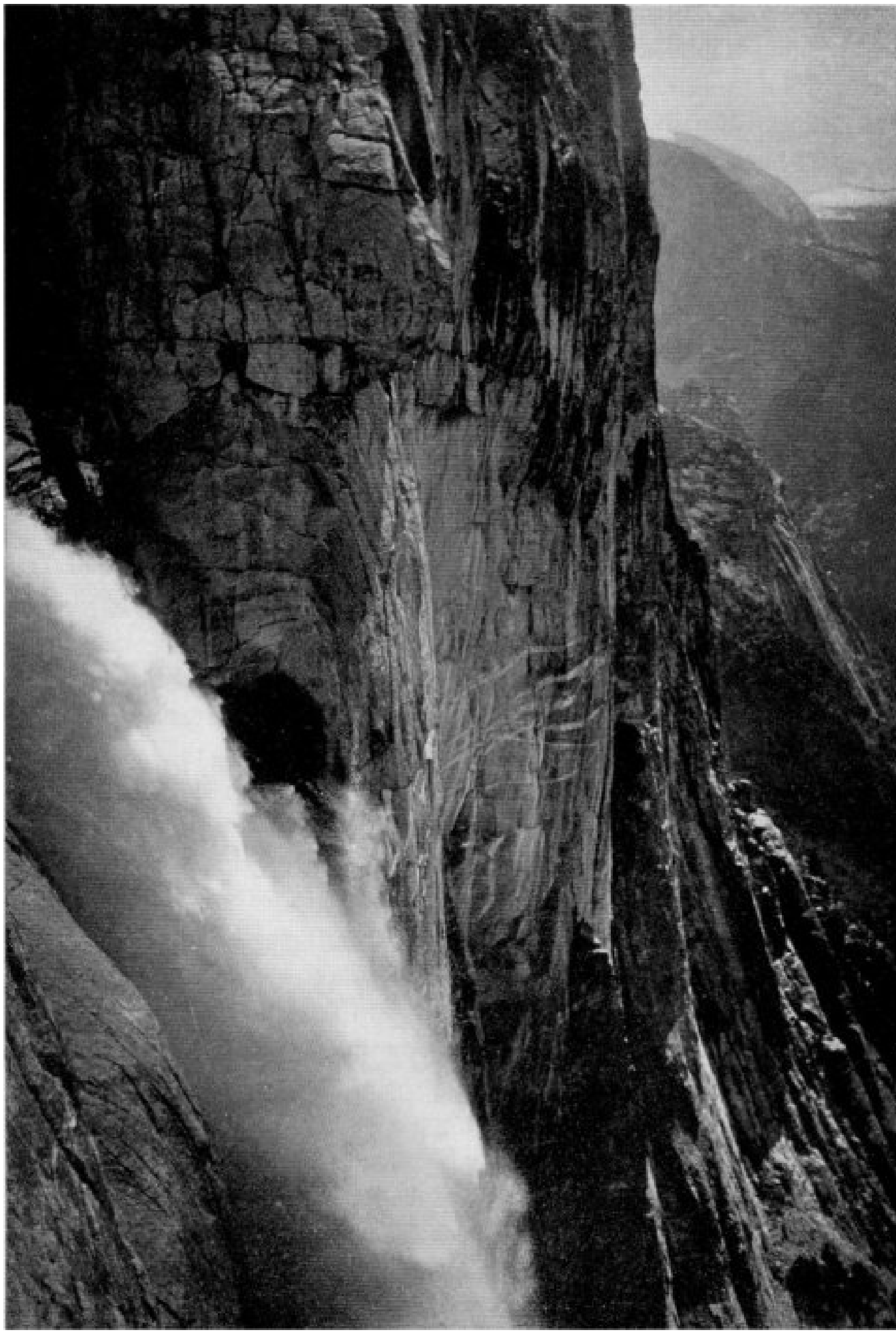
r r

r All night long this down-valley movement continues, until at length ther morning brings the warming sun again. Then as summit after summit, and sloper after slope is heated—insolated is the technical term—the warm updrafts arer revived again. At first feeble and in spots only, they soon wax stronger and morer r r general, and, as the shadows retreat and dwindle before the oncoming lightr invasion, they finally gain the upper hand. The nocturnal airstreams cease tor flow and a general movement is inaugurated in the opposite direction, up towardr the highlands at the valley head. It is not usually so noticeable as the night wind,r for its tendency is naturally to spread and diffuse upward, while the nocturnalr movement is one of condensation and concentration, especially vigorous alongr the valley floor. But it is none the less a well-defined, characteristic movementr that continues throughout the day. Late in the afternoon, with the growing ofr the shadows it gradually comes to a stop and the tide turns back again. Thusr the air of the Yosemite Valley goes through a daily ebb and flood, reversingr early every morning and again late in the afternoon.r

r r

r Most mountain valleys have similar alternating night and day winds, butr those of the Yosemite Valley are exceptionally pronounced. All conditions in itsr case favor the orderly consummation of the process and conspire to accentuater each phase. No general winds sweep over the country to interfere with the localr up- or downdrafts, except at intervals of many weeks; and so exceedingly dryr and pure is the atmosphere of the Sierra, so few particles of dust or moisture doesr it hold, that the sun's rays plunge through it almost without let or hindrance.r Insolation, consequently, is particularly intense and begins almost immediatelyr with the rising of the sun, while radiation is equally rapid and sets in promptlyr the moment the sun disappears. And thus it comes that the reversals in ther Yosemite Valley take place with clock-like regularity, and the entire movementr assumes the rhythmic swing of a pendulum. Nothing was better calculated tor make this visible to the eye than the smoke column from the forest fires thatr raged persistently at the lower end of the valley during the summer of 1905.r Every morning the valley was clear, having been swept out, so to speak, by ther nocturnal down-valley current, and the smoke pall could be seen floating off tor the southwest, low down on the Sierra flank. But with the rising of the warm dayr breezes the smoke would gradually advance up the valley, becoming denser byr degrees, until by nine or ten o'clock one could scarcely see across from rim tor rim. This condition would prevail all day until with the afternoon reversal ther down-valley wind would set in again and take the smoke back with it. Much tor the chagrin of the writer, who at the time was engaged in the survey of the valleyr and depended on the clearness of the air for his long distance sights, this dailyr smoke invasion persisted for four long months with scarce an interruption. Itr may be imagined that he came to understand the phenomenon right well.r

r r r r

r r  r

r r r

r r Half Dome from the top of Yosemite Falls. By J. N. LeConter

r r r

r Oddly enough, it is precisely upon this daily atmospheric seesaw that one ofr the Yosemite’s chief attractions depends. As is well known, one must go tor Mirror Lake at an early morning hour, if he wishes to see it at its best. Ther surprised and usually somewhat vexed tourist who finds he must arise at anr impossible hour in order to enjoy a perfect reflection, little dreams that what he isr undertaking really amounts to keeping a tryst with the early morning reversalr out on the shores of Mirror Lake; and that, unless he be quite punctual he willr miss it because of its almost momentary briefness. Yet such is actually the case.r The stillness of the water surface sets in just as the down-valley draft dies out;r but as soon as the upper cliffs or Tenaya Canyon become sufficiently insolated,r updrafts begin to stir the air again, and a faint tremor forthwith steals over ther lake. Accepting the correctness of this explanation, one is tempted to believer there might be another calm corresponding to the afternoon reversal,—an everr so much more convenient hour for the tourist. But alas, experience has shownr that this cannot always be depended on. The reason is, no doubt, that in ther afternoon there is no well-defined pause in the circulation of the air of Tenayar Canyon, because of the presence of great shadows on its north side which sendr down eddying breezes at various times.r This discussion of the winds of the Yosemite Valley would scarcely be complete without a word about the breezes that play near the great waterfalls. Eachr of these, it will be remembered, leaps from the mouth of an elevated hangingr valley. At night, when the down-valley currents are organized, the stream issuingr from each of these valleys plunges down over the cliff very much like a waterfall. Few people probably are aware of the existence of these—shall we callr them “air falls”? Nevertheless, they are by no means imaginary, as one mayr readily find out by ascending either the Yosemite Falls trail or the Nevada Fallr trail in the evening. The writer had occasion to do so many times when returningr to his high-level camps above the valley, and the unpleasant memory of ther chilling downdrafts that poured upon him on these evening trips is with him yet.r During the daytime, on the other hand, the air rises vertically along the cliffsr and up into the hanging valleys, taking part of the spray from the falls alongr with it. A pretty example of this may be seen at the Bridalveil Fall, where twor little combs of spray, one on each side of the stream, steadily curve upward overr the brink. As soon as the sun is off the cliff, however, they at once cease to exist.r

r r

r *Reprinted from* Sierra Club Bulletin, *June, 1911, pages 91-95*.r

r r r
r r

---

r r

r **r Next: Striped Rock Floor •r Contentsr • Previous: François Emile Matthesr** r

r r r

r

r r

r

r r

r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r The Striped Rock Floor of the Little Yosemite Valley >r

r r

r

r r r

r **Next: El Capitan Moraine and Lake Yosemite •r Contentsr • Previous: Winds of the Yosemite Valleyr** r

r r r

r r r

THE STRIPED ROCK FLOOR OF THE LITTLE YOSEMITE VALLEY

r r r

r r Aboutr r a stone’s throw from where the Clouds Rest Trail leaves the flat ofr the Little Yosemite Valley, there is a curious expanse of smooth, bare granite,r an acre or more in extent. It is a part of the solid rock floor of the valley, which,r buried under river gravel and glacial material elsewhere, is here exposed tor view, cleared of all debris. Indeed, so scrupulously clean swept does it look, oner might fancy some cyclopian broom had been at work on it—and a new oner at that.r

r r

r Round about, in all directions lie glacial boulders, some singly, some inr clusters, some in heaps mixed with fine debris. Sparse pines and cedars rise fromr what few cracks the stone floor affords as a root-hold, giving the place a singularly genial, parklike aspect. But the cleared tract itself has not a tree on it—itsr surface stretches unbroken and continuous, unmarred by a single fissure.r

r r

r As one approaches from the lower end and looks up the gentle slope—forr the floor inclines appreciably—the eye is almost at once held by the peculiarr “painted” appearance of the space. Irregular, blotchy white ribbons set offr conspicuously against the prevailingly gray tint of the rock floor, sprawl over itr here and there. Wholly unlike the dark water stains that stripe most of ther Yosemite cliffs, they seem, even to one thoroughly familiar with the variousr markings common to the rock surfaces of the region, altogether novel andr enigmatic. All trend downward with the slope, but beyond this there seems nor discoverable law in their arrangement, nor anything else immediately suggestiver of their mode of origin. The majority occur in loosely connected groups, butr some lie off by themselves, like pale islands in a dark ocean. As the view onr r r page 51r well shows, they generally commence abruptly and terminate abruptly,r without definite relation to the unevenesses of the floor itself. Some divide, othersr merge downward; some gain in width, others taper down toward their lower ends.r

r r

r In dimensions they are equally varied. While they average between four andr five feet in length and from two to three inches in breadth, there are individualsr among them but a fraction of a foot long and others exceeding twelve or evenr fifteen feet; and some are less than an inch across, while others—like those inr the immediate foreground of the view—span six inches and over. Nor is ther breadth always proportionate to the length: Some of the longest are very narrow,r some of the shortest very broad.r

r r

r On closer inspection they are seen to consist simply of narrow tracts fromr which the lichens that otherwise uniformly mottle the rock have been removed,r and it becomes plain that it is merely the light color of the unweathered graniter thus exposed that makes them prominent. These stripes, then, are not stains atr all; rather, they owe their brilliancy to their very stainlessness—to the absencer of coloring matter of any sort.r

r r

r By what agent the lichens were cleared off, however, seems at first a mystery.r That it was some substance that moved downhill under the influence of gravityr is patent from the invariable downhill trend of all the stripes, but what ther nature of that substance was, is not easily guessed. One feels tempted to believer it was some corrosive fluid that was poured out upon the rock and flowed downr slowly, eating away the lichens as it went. There are places in the Yosemiter Valley where such a thing has actually happened, so the theory is not so utterlyr absurd as at first blush it may seem. On the road to Mirror Lake, for instance,r there is a great block of granite on the flat side of which some enterprising individual once painted him an advertisement in bold, glaring type. The true historyr of the affair may be better known to some of the readers of this journal thanr to the writer, but he gathers from a casual look that the “ad” was subsequentlyr effaced by a zealous guardian. Whatever material the latter employed to remover the paint, removed the lichens too, running down in vertical, blotchy stripesr remarkably similar to those on the Little Yosemite floor. Again, at the site ofr the “Old Blacksmith Shop,” near the foot of the Coulterville Road, a space hasr been cleared on a huge rock by means of some caustic, and the same streakyr effect has been produced.r

r r

r But the stripes in the Little Yosemite Valley clearly were not the work ofr marring man. Besides, the same sort of markings exist in many other places inr r r the Yosemite region, in seldom frequented spots too, as a rule. It was on such ar spot, in fact—on the north slope of Liberty Cap that the writer first found ar clue to their mode of origin. A small rock fragment, derived from a disintegrating shell of the great rock hump, had evidently slid here several feet from itsr place of starting, and, extending from it, pointing up the slope, was a little whiter path cleared of lichens. Not far away were other fragments each likewise leavingr a flaming trail. The width of the stripe produced corresponded in each case tor the dimensions of the fragment. A tiny bit of granite, no larger than a thimble,r lay at the end of a delicate white ribbon, and an uptorn tree stump had made ar dozen markings, one with each of its dragging root tips and a broad swathr with its heavy broken end. Surely, here was the key to the enigma! Here werer the stripes in process of being made.r

r r

r What, however, impelled the rocks and the tree stump downward? None ofr them appeared in motion, and none when dislodged, would slip or roll. The sloper was not steep enough for that. Observation further showed that no stripes everr occur on very steep slopes—they are restricted to surfaces of moderate inclination such as the crowning portions of the domes, and wherever the declivityr approaches the “angle of repose” the stripes invariably come to an end. A prettyr and striking instance was seen on a small dome spur in the Little Yosemiter Valley. Here the stripes, diverging downward like meridians on a globe, all terminated abruptly as by concert at the same level, the same parallel of latitude.r Below that line, evidently, the debris had slid or rolled away. The inclinationr here, it should be noted, was too great to stand on safely, but farther up, amongr the stripes, one could walk even with hobnails by exercising a little care.r

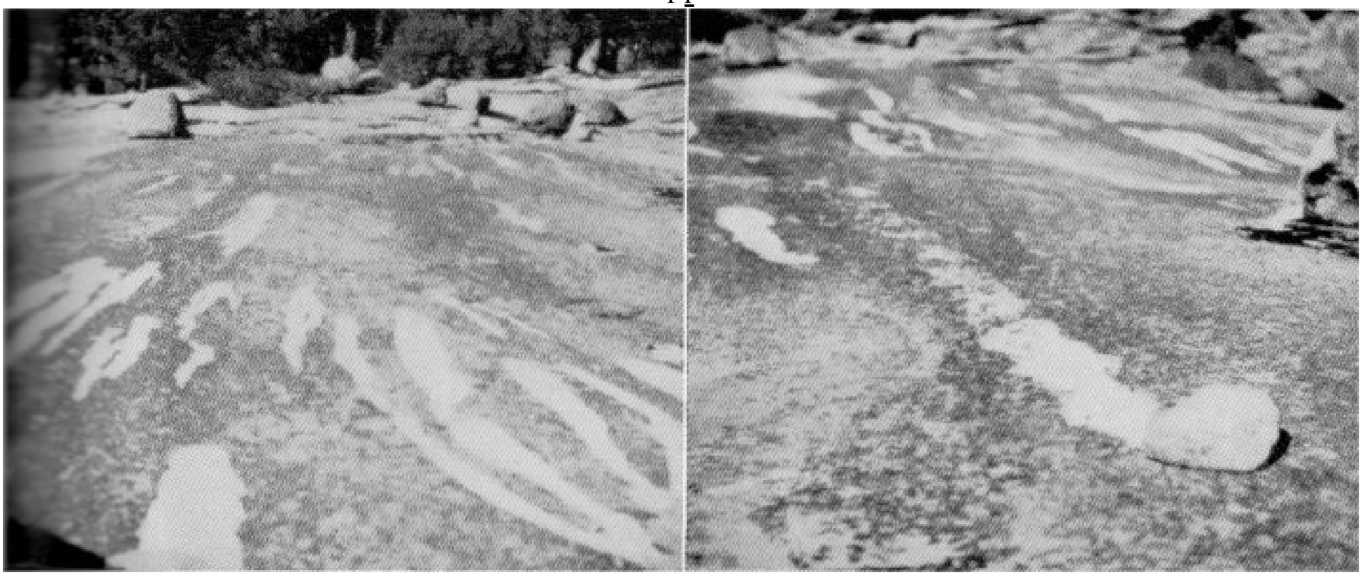
r r

r It is to be inferred from the above that a slow motion of the debris is essentialr for the production of the stripes. The explanation is here offered that the debrisr r r r

r These mysterious stripes on the floor of Little Yosemiter
r Valley are narrow paths from which slow-growing lichensr
r been removed.r

r Snow and running water have slowly pushed this smallr
r boulder across the gently sloping granite, wearing awayr
r the lichens.r

r r



r
r r r

r r r r is urged down little by little by snow and running water and even the rockgrainsr washing from above, in fact by all agents cooperating with gravity to overcomer the frictional resistance of the floor. Most potent, no doubt, are the heavy snowsr of winter, and there is good reason to believe the greatest progress is made underr their influence. For, on inclined surfaces of this sort, snow does not lie whollyr inert, but almost imperceptibly creeps downward—the same as it does on ther roofs of barns and sheds. As the entire layer advances, it naturally tends tor drag the debris with it.rr r

r The total progress thus effected may not exceed an inch or two per year, andr this estimate, if it is at all correct, lends additional significance to the stripes:r they indicate not merely the route traveled over by each fragment, they alsor embody a time record of the journey. Some of them represent a lapse of manyr years, the more impressive when it is reflected that during all that time no being,r human or other, happened by in this solitude to interfere with the orderly continuance of the process.r

r r

r The explanation above, however, accounts only for the movement of ther debris. It does not yet make clear the production of the stripes themselves. Thatr a heavy boulder might grind off the lichens from the bed it passes over seemsr quite natural, but that a bit of rock weighing an ounce or two should clear ar path does not seem at all self-evident. The weight of the fragment, if it is ar factor in the process, apparently plays but a minor role.r

r r

r On picking up one of these traveling fragments, one finds it invariablyr imbedded in a small pad of loose rock grains that have collected under it. Nowr lichens cannot thrive under the thinnest veneer of sand or soil, as may ber observed in a thousand places throughout the Sierra. Slanting rocks uncoveredr by the grading of a wagon road, for instance, show plainly by the boundary ofr their lichen growth where the surface of the ground used to be. Shallow basinsr in a rock floor or on large boulders that tend to accumulate sand, pine needles,r and other litter, similarly remain white and bare of lichens. It is safe to say,r therefore, that it is the sand pad under the fragments rather than the fragmentsr themselves that clears the lichens from the stripes. And here, again, is substantiation of the view expressed regarding the slowness of the process. For, were ther movement at all rapid, the lichens in any one spot would not remain covered forr a sufficient length of time to utterly die and loose their hold. As a matter of factr there are places where they were not entirely stamped out and the stripes appearr dim or interrupted. The debris must have advanced here with more than usualr r r rapidity, owing to some local acceleration of the gradient, or perhaps throughr the pressure of an exceptionally heavy snow fall.r

r r

r To come back now to the floor of the Little Yosemite Valley equipped withr this insight into the stripe-producing process, let us look it over somewhatr more closely. The feature that strikes us as most puzzling is the total absencer of debris of any kind. Whatever material once traveled over the floor has in somer manner disappeared. But not wholly, for here, near the east edge of the tract,r lies a boulder weighing some twelve or fifteen pounds at the end of a long andr glorious stripe. More than twenty feet it stretches, gradually fading in ther distance like the smoke trail of a locomotive. A finer example would be difficultr to find. The upward dimming of the stripe is in itself significant: so excessivelyr slow has the progress of the boulder been that the lichens are already beginningr to encroach again on the upper end, slow-growing plants though they be. Whenr it is considered that rocks uncovered by road grading a score of years ago showr scarcely any new lichens today, the great span of time represented by this striper become doubly impressive. Its upper end, indeed, may date back to the time ther Yosemite Valley was discovered.r

r r

r But this stripe, after all, differs somewhat from the others on the floor. Ther rank and file are shorter and narrower; many split or fork irregularly, and allr have ceased to grow in length through the removal of the debris that made them.r Yet that material did not roll away, for the floor maintains about the same grader throughout and many stripes begin in the same latitude where others end. How,r then, are these traits to be interpreted?r

r r

r In the first place it seems certain that the material in question consisted ofr small, light fragments that were easily disturbed and thrown from their pathr by the feet of passing men or animals. That this must have happened morer than once seems likely in view of the fact that the Little Yosemite is muchr frequented and in former days was inhabited by Indians, as the round holes inr which they ground their acorns, near by, amply attest.r

r r

r Again, the assumption seems legitimate that the fragments were in an advanced state of disintegration, and broke down and crumbled on the way. Muchr of the debris that litters the valley floor today is in just such a crumbly state.r It has lain exposed so long to strong diurnal and seasonal temperature changesr that the individual crystals in the granite, each expanding and contracting withr a coefficient of expansion peculiar to the mineral composing it—feldspar, quartz,r mica or hornblende have gradually worked loose and are ready to part company.r r r Those readers who have mountaineered in the Sierra may have had ther experience of picking up a rock that would break in the hand and run like sandr through the fingers. This suggests an explanation for the forking of the stripes:r A decomposing fragment, after having advanced some distance, would break inr two. From then on there would be a double trail. Later, each of the pieces wouldr divide, and the trail would split again. Some fragments broke down by degreesr into an aggregate of half-loose crystals, and their trails widened out progressively. The end in each case came no doubt, when there was nothing left but ar little heap of rock grains which the melting waters of springtime carried offr with a rush.r

r r

r *Reprinted from* Sierra Club Bulletin, *January, 1911, pages 3-9. See also Matthes' paper "Debrisr Tracks on the Domes of the Yosemite Region," Science, n.s., Volume XXX, Number 758, pagesr 61-64, 1909.*r

r r r r
r r

---

r r

r **Next: El Capitan Moraine and Lake Yosemite •r Contentsr • Previous: Winds of the Yosemite Valleyr** r

r r r

r

r r

r

r r

r http://www.yosemite.ca.us/library/matthes/striped_rock.htmlr

r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r El Capitan Moraine and Ancient Lake Yosemite >r

r r

r

r r r

r **Next: Moraine Dome •r Contentsr • Previous: Striped Rock Floorr** r

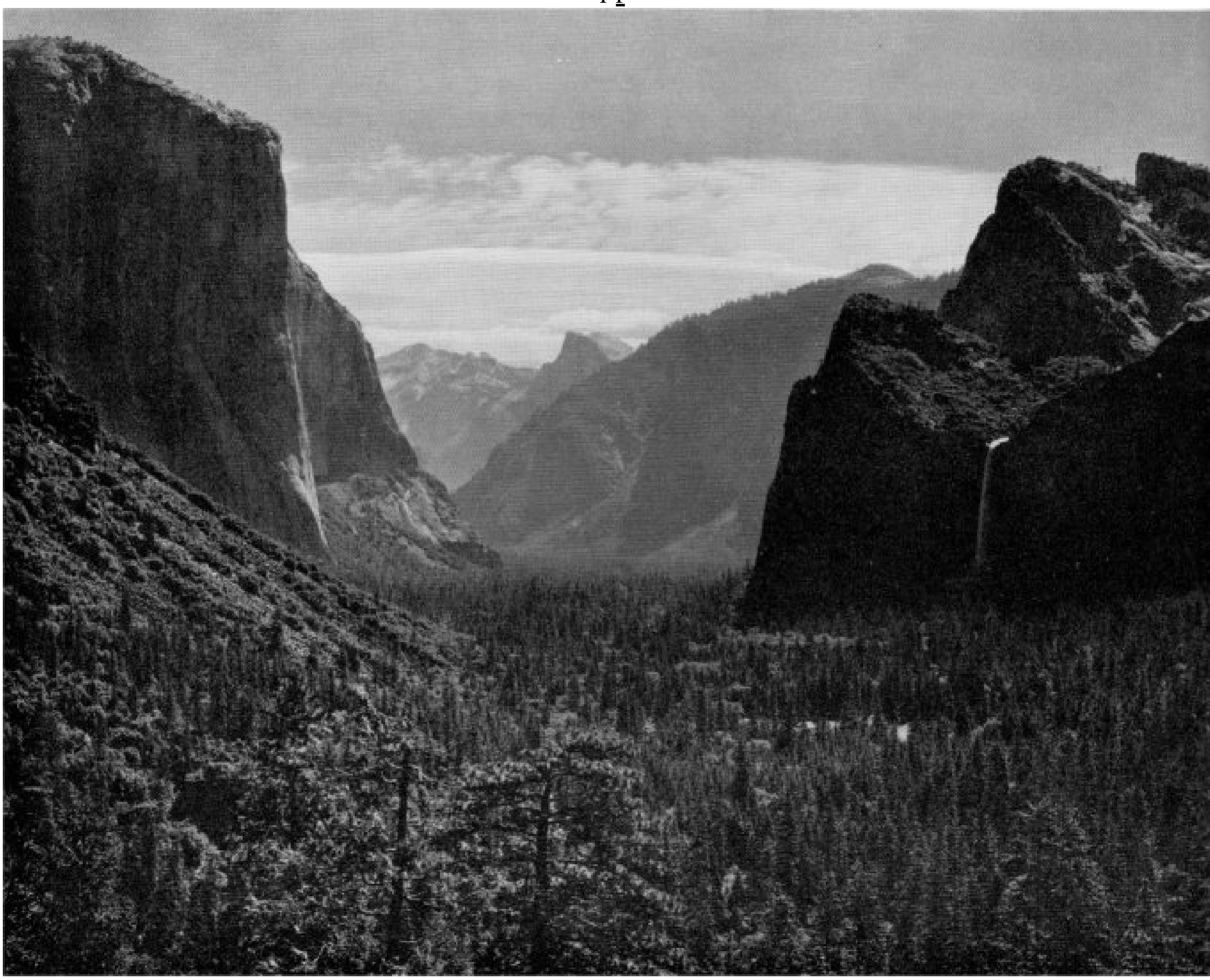
r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

r r r r

r r



r

r r r

r r Distant Storm Front, Yosemite Valley, California. By Ansel Adamsr

r

r r r r

EL CAPITAN MORAINE AND ANCIENT LAKE YOSEMITE

r r r

r r It seemsr r well nigh unbelievable in these days of enlightenment that sor eminent a scientist as the late Professor J. D. Whitney should have seen fit tor deny the former existence of glaciers in the Yosemite Valley.

Said he in hisr famous oldr Guide Book:r “A more absurd theory was never advanced than thatr by which it was sought to ascribe to glaciers the sawing out of these verticalr walls and the rounding of the domes. Nothing more unlike the real work of ice,r as exhibited in the Alps, could be found. Besides, there is no reason to suppose,r or at least no proof, that glaciers have ever occupied the valley or any portionr of it . . .”r

r r

r As a matter of fact, there are excellent reasons for believing that ther Yosemite Valley was once invaded by ice, and the proofs of its glacial occupancyr are abundant and indubitable. The wonder is that Whitney could have overlooked them.r The very shape of the valley, trough-like, steep-sided, clean-cut; the greatr height of the hanging valleys from whose lips the thundering waterfalls pour;r the giant stairway down which the Merced River tumbles in its descent fromr the Little Yosemite; these features are, on the face of them characteristicallyr glacial, and impressively attest the great magnitude of the erosional work doner by the ice.r But perhaps the skeptical reader would prefer evidences of a more tangibler sort, more immediately linkable with the intimate form and habits of glaciers,r and demanding less from the imagination in the way of appraisal of the capacityr of glaciers to erode, a subject on which even those best qualified to judge are byr no means united.r

r r r r

r Allow me to invite him to the floor of the Yosemite Valley, and, with ourr backs turned to the lofty hanging valleys and their eloquent cataracts, let usr search for the less spectacular but more direct, and perhaps more convincing,r proofs of ice work which there exist.r

r r

r If we should set up a surveyor’s level in the meadows opposite the Sentinelr Hotel and thence run down the valley, taking careful elevations on the way, wer would find the altitude to remain essentially unchanged for miles. Indeed, asr far as the El Capitan bridge there is no appreciable fall to the valley floor, andr the Merced River meanders dreamily, in lazily swinging, sandy loops and curves.r At the El Capitan bridge, however, there is an abrupt change. The streamr awakens, as if refreshed from its nap in the valley, and with quickened pace,r dashes over riffles and churns among boulders, tumbling lustily like a youthfulr mountain torrent. Its fall becomes rapid, fifty to one hundred feet per mile,r whereas above the bridge, in a distance of six miles, it descends only aboutr six feet.r

r r

r Evidently, the El Capitan bridge marks a critical point in the course of ther river and a dividing line in the valley itself. Broad and level above the bridge,r below it the valley can scarcely be said to have any floor at all. Even the Bridalveil Meadows, which occupy the widest place, slant strongly toward the river,r being a debris fan built by Bridalveil Creek. Farther down, the valley sidesr close in from either side and the river lies constrained in the bottom of ar narrow V.r

r r

r What may be the cause of this abrupt change of scene at the El Capitanr bridge? No doubt many of the readers of the Bulletin have passed back andr forth over that bridge, but probably few have taken careful notice of its peculiarr location. The writer himself did not become aware of the significance of the siter until after a sojourn of several months.r

r r

r It was no mere whim that led Galen Clark to select that spot for a bridge.r A strong ridge of boulders here lies athwart the floor of the valley, and it is acrossr the gap in that ridge, worn through by the stream, that the bridge has beenr thrown.r

r r

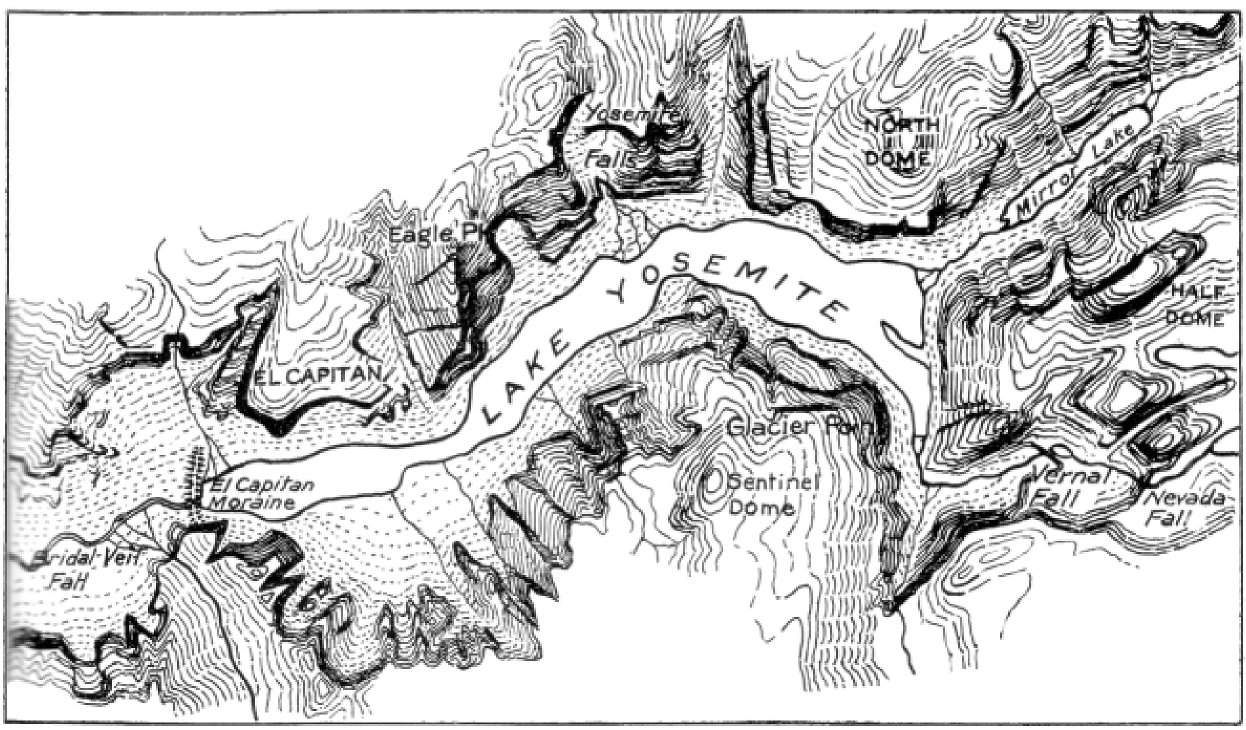
r South of the El Capitan bridge the grading of the wagon road has necessitatedr cutting away part of the ridge, but the huge boulders, of which it is largely composed, may be seen in the side of the cut. Climbing out of the road, one mayr follow the curving crest for a few hundred feet until it becomes lost in the coarser debris at the base of the Cathedral Rocks.r

r r r r

r North of the river, the ridge runs west of the road, stretching across ther valley for half a mile like a steep-sided, narrow-crested embankment. At firstr fully fifteen feet high, it gradually loses in height and prominence, and finally,r toward the road forks, appears to die out altogether. However, it does not endr here, but merely becomes buried under the toe of the huge debris slopes descending from the cliffs about Ribbon Fall.r

r r r

r r



r

r r r

r r Sketch-map of Yosemite Valley. showing the extent of ancient Lake Yosemiter

r r r r

r Were this peculiar ridge, unique in the configuration of the valley floor,r situated in the open so that its form stood out conspicuously above the surrounding flat, no doubt from the first it would have attracted attention; its significancer would have been looked into and now would be common knowledge. As it is,r dense thickets of pine and cedar effectually mask the ridge; most passers-by arer not aware of its existence, and even some of the scientists who have studied ther valley in detail have missed the feature and thereby the key to the recentr geological history of the entire valley floor.r

r r r r

r The boulder ridge in question is a typical glacial moraine; no experiencedr glacialist would for a moment hesitate in identifying it as such. It is a terminalr moraine, properly speaking,—that is, a debris ridge of the sort which glaciersr commonly build up at their fronts. All glaciers, as is well known, carry a considerable amount of rock debris derived from the floor and sides of the valleysr through which they advance, and this material, as the ice melts away, is releasedr at the lower end. While the front of a glacier is inherently subject to frequentr oscillations, some years melting back, at other times advancing, there are nevertheless occasional periods of relative constancy during which the front remainsr stationary, or very nearly so. It is then that this ice-freed debris accumulates inr the form of an embankment or morainic ridge, as it is technically termed. When,r moreover, the period of quiescence follows immediately upon one of advancer and pronounced erosional activity, during which the glacier heavily loaded itselfr with debris, the moraine is likely to assume proportions that will enable it tor endure as a topographic feature of some permanence.r

r r

r This, in fact, is what occurred in the Yosemite Valley. When the ice frontr receded for the last time—there were several separate glacial epochs—it mader a number of minor readvances, following one upon the other like so many gradually dying pulsations. Each of these readvances left a separate moraine, andr accordingly a number of such ridges are found spaced at intervals across ther valley floor. All of them are situated in the lower half of the valley, and ther moraine at the El Capitan bridge, which may appropriately be called the Elr Capitan moraine, is the uppermost, the youngest of the series.r

r r

r It is also the strongest, the most perfectly preserved of all. The otherr moraines today are represented only by truncated fragments, their majorr portions having been broken down and swept away by the swollen river. Aroundr the broken end of one of these ridges, projecting from the extreme northwestr corner of the Cathedral Rocks, the wagon road swings as it bends southward tor the Bridalveil Fall.r

r r

r The El Capitan moraine, it appears, not only escaped the partial demolishment that overtook its brethren, but, by virtue of its strength and peculiar situation, became a factor of importance in the post-glacial remodeling of the valleyr bottom. Stretching across the valley from wall to wall, like an unbroken dam,r it ponded the waters behind it, and, as the ice melted back, transformed ther upper Yosemite Valley into a lake.r

r r

r This sheet of water—Lake Yosemite, it may aptly be called—like mostr r r lakes of a similar origin, was not destined to endure. No sooner had it comer into existence than the Merced River, turbid with debris from the glaciersr farther up, proceeded to build a delta at the upper end, and this delta, slowlyr but inexorably advancing, in time wholly extinguished the lake.r

r r

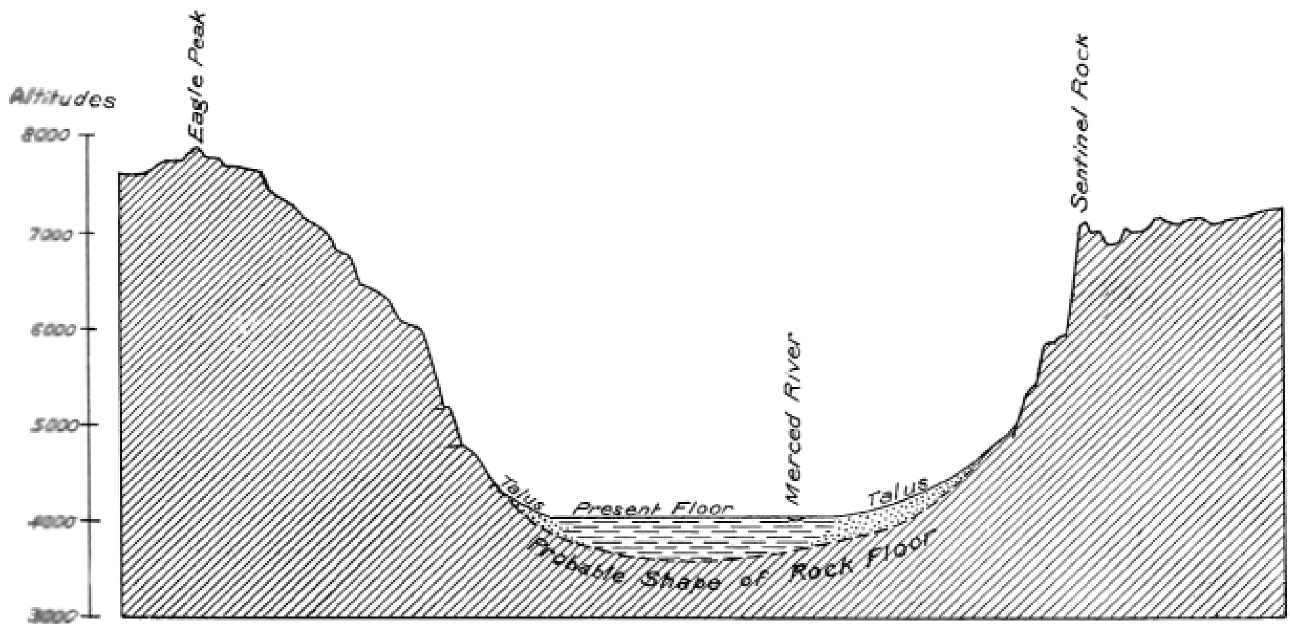
r The manner in which the filling was accomplished one may today watch inr Mirror Lake. Already reduced from a sheet of water more than a mile long, thisr little lake, famous for its reflections, is annually being diminished in area by anr appreciable amount through the rapid forward growth of the delta of Tenayar Creek. Measurements of the delta front for a few consecutive years would affordr a basis for an estimate of the length of time that the lake is likely to continue tor delight the visitor with its beautiful reflections.r

r r

r Although nothing now remains of ancient Lake Yosemite, its extent, nevertheless, is still easily ascertained. One need but follow the edge of the levelr meadows that now form the valley floor, in order to trace the former shore line.r Evidently the lake occupied the entire extent of the valley, up to the cliffs thatr enclose its head; its length, therefore, must have been close to six miles.r

r r r

r r



r
r r r

r

r r Section of Yosemite Valley from Eagle Peak to Sentinel Rock, showing 1913 estimate ofr r probable depth of river sediment filling the basin of ancient Lake Yosemite. Seismic soundingsr r have subsequently indicated a much deeper excavationr r (see page 62).r

r
r r r r r

r Nor was it a mere shallow pool. Its depth, there are reasons for believing,r may have exceeded 500 feet. No actual measurements, such as might be obtainedr by borings, for instance, are available, it is true, and the figure mentioned cannotr claim to be any more than a mere estimate. Yet it is not wholly without foundation, as a glance at the accompanying diagram has shown. That diagram represents one of a number of cross-sections of the valley, constructed by the writerr with the accurate and abundant trigonometric data on which the detail map ofr the Yosemite Valley is based. Being free from vertical exaggeration, it affords ar fair means for judging the probable depth of sediment now filling the valley. Itr is reasonable to assume that the Yosemite Valley, having been vigorouslyr glaciated, possesses a somewhat concave rock floor, shaped like the bottom partr of a U. Completing, tentatively, the missing part of the curve, therefore, oner obtains an approximate measure of the depth of the extinct lake. In the cross-section published herewith, the curve has purposely been drawn quite flat, inr order that the estimate of depth may not be accused of undue liberality. Yet,r the depth indicated by the diagram is not far from 500 feet. Other cross-sectionsr give closely accordant figures, those toward the head of the valley indicatingr still greater depths.r

r r

r Is it to be inferred also, the question may here be asked, that the El Capitanr moraine has a height of 500 feet? No, that ridge, in all probability, does notr stand a hundred feet high above its base. A direct measurement of its height,r unfortunately, cannot be had. The river has not yet cut the notch down to bedr rock. At least so Galen Clark informed the writer. While still in charge of ther valley, he had undertaken to enlarge the notch in order to lessen the dangerr from floods during the spring freshets. He had found only loose boulders, whichr he had removed with the aid of dynamite.r

r r

r On its up-stream side the ridge is buried under lake deposits, and only ther upper fifteen feet emerge. On its down-stream side it slopes down twenty-five tor thirty feet, but there, too, its foot is covered by river gravels of unknown depth.r Examination of other moraines in the Yosemite region, more especially those ofr the later ice invasions, to which the El Capitan moraine itself belongs, seems tor indicate, however, that a height of one hundred feet is the maximum assignable.r The majority of these ridges scarcely exceed fifty or sixty feet in height. Five-hundred-foot moraines are foreign to the region.r

r r

r If the El Capitan moraine is not over one hundred feet high, how, then, shallr we account for the great depth of Lake Yosemite, as indicated by the diagram?r r r The answer is, by assuming the existence of a deep basin eroded in the rock floorr of the valley by the ice. There is nothing violent in that assumption. Glaciersr normally excavate extensive rock basins in the bottom of their valleys. The well-attested instances of such action are literally numberless. Lake basins are ar familiar feature of all glaciated mountain regions, and in some cases—such asr that of Lake Chelan—they occur on a truly stupendous scale, dwarfing Laker Yosemite into insignificance.[1]r

r r

r Nor need one go outside the Yosemite region for examples. There is evidencer of a lake basin on every tread of the stairwise descending branch canyons. Ther stair-like character of the floors of these canyons, it may be pointed out inr passing, is a distinctly glacial trait, and the presence of lake basins hollowed outr in the treads is only one of the concomitant features.r

r r

r Thus the entire Little Yosemite Valley was once occupied by a lake. Filledr with river gravels, like the main valley itself, it now presents the appearance ofr a gradeless flat of some three miles, above which only the crests of several curving terminal moraines emerge.r

r r

r On the tread immediately above the Vernal Fall, again, is Emerald Pool,r diminutive, yet as typical a glacial rock basin as one can find anywhere. Tenayar Canyon, it appears, once possessed four glacial lakes, situated at successivelyr higher levels. All but the lowest, however, are now filled with sediment; Mirrorr Lake alone survives as a remnant of the largest lake.r

r r

r After one has become familiar with all these lake basins in the branch canyons of the Yosemite Valley, and one has, moreover, gained an insight into theirr mode of origin, one can scarcely avoid reaching the conclusion that in the mainr valley, too, there is a deeply eroded rock basin, now covered by the silts of Laker Yosemite. The combined mass of the Tenaya and Merced glaciers here mustr have eroded with particular vigor. The very fact that each of these ice streams,r by itself, was able to excavate rock basins of considerable extent and depth,r leaves little doubt that united they achieved still larger erosional results. Besides,r it has been noted that it is immediately below the confluence of glaciers that ther ice usually attains the greatest power to excavate.r

r r r r r

r The El Capitan moraine, then, is not to be given sole credit for the creationr of Lake Yosemite. That lake in all probability lay in a rock basin eroded by ther ice, and the only function of the moraine dam was to raise the level of the waters,r thus increasing their depth and extent.r

r r

r In the meanwhile it should not be forgotten that the existence of the rockr basin is purely inferential and is to be considered unproven until a series ofr borings along the whole length of the valley shall afford the necessary facts. It isr to be hoped that some day such borings may be undertaken; they would notr merely serve to solve a problem of great local interest, but would contributer much-desired data regarding the still challenged eroding efficiency of glaciers.r

r r

r That the Yosemite Valley has actually been occupied by glacial ice no oner will venture to dispute; were all other ice signs in the valley rejected as untrustworthy, the El Capitan moraine alone would afford evidence sufficient and irrefutable. As to the extent to which the ancient glaciers have remodeled and excavated the valley, nothing, perhaps, would go further toward settling this vexedr question than a series of direct measurements establishing beyond doubt ther depth of former Lake Yosemite.[2]r

r r

r *Reprinted from* Sierra Club Bulletin, *January, 1913, pages 7-15.*r

r r r

r [1]The writer’s attention has been called to what appears to be rock-in-place visible in the bed ofr the Merced in the upper part of the valley. The supposed great depth of sedimentary filling in ther valley would thereby seem to be discredited. A visit to the spot in the fall of 1910, however, enabledr the writer to satisfy himself that the outcrop of rock reported is in reality only an indurated bed ofr coarse river sand, irregularly gullied out by the current, and closely resembling solid granite. It isr friable in the hand and is underlain by unconsolidated layers of sand and silt.r

r r

r [2]The borings which Matthes hoped might eventually give conclusive answers to questions concerning the depth of Lake Yosemite, the fill of sediments in Yosemite Valley, and the depth andr configuration of the bedrock floor beneath, have yet to be made. However, from another quarter,r undreamed of in 1913 when Matthes published this essay, have come significant data relating to theser questions, namely seismic soundings at many points on the valley floor. These soundings were mader in 1935 and 1937, and the resultant technical report ("Seismic Explorations on the Floor of Yosemiter Valley, California," by Beno Gutenberg, John P. Buwalda, and Robert P. Sharp.r *Bulletin of the Geological Society of America*, Volume 67 [August, 1956], pages 1051–1078)r may be consulted byr readers interested in the detailed interpretations drawn from the seismic data. The introduction says:r

r r

r "For fully 50 years earth scientists have differed strongly as to the efficacy of glacial erosion. Oner discussion of considerable warmth centered on Yosemite Valley, which Muir stoutly maintained wasr largely the product of glacial sculpturing and which Whitney contended was a product of tectonicr subsidence. Other workers thought that erosion by running water and moving ice had done the job,r but it remained for Matthes to show that these two agents played essentially equal parts in creatingr Yosemite Valley. Matthes' work is an outstanding attempt at a quantitative estimate of the magnituder of glacier excavation based on geological evidence.r

r r

r "The seismograph shows that even Matthes, an enthusiastic glacial sculpturist, underestimatedr by a full order of magnitude the amount of glacial excavation on the bedrock floor of Yosemiter Valley. Where he estimated 450 m of deepening by glaciers, at least another 550 m must be added.r Where Matthes estimated the unconsolidated valley fill to be 90 m it is closer to 600 m. Thus, ther steep granitic walls rising 900 m above the present valley bottom are more than 1500 m above ther bedrock floor. The visitor sees but three-fifths the splendor and magnitude. . . .r

r r

r "Yosemite Valley is thus an outstanding example of the efficacy of glacial excavation in over-deepening valleys and in creating large closed depressions. It is comparable in this respect to Laker Chelan, the Great Lakes, the Finger Lakes, and many fiords." (References omitted from quotation.)r

r r r
r r

---

r r

r **Next: Moraine Dome •r Contentsr • Previous: Striped Rock Floorr** r

r r r

r

r r

r

r r

r http://www.yosemite.ca.us/library/matthes/lake_yosemite.htmlr

r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r The Story of Moraine Dome >r

r r

r

r r r

r **r Next: Cockscomb Crest •r Contentsr • Previous: El Capitan Moraine and Lake Yosemiter** r

r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

r r r

THE STORY OF MORAINE DOME

r r r

r r Surmountingr r the north wall of the Little Yosemite Valley—the “ante-chambre” through which the Merced River approaches the Yosemite Valleyr proper—is a rounded eminence of bare granite, a typical dome of the kind sor common in the central Sierra Nevada. Fully 2000 feet high above the floor ofr the Little Yosemite, it rises to an elevation of 8012 feet, to within a hundred feet,r in other words, of the level of Sentinel Dome, the favorite panoramic view pointr of the tourist; yet it is an inconspicuous feature in the landscape, a mere waver in the billowy highland that stretches on either side of the valley trough. Ther towering bulk of the Clouds Rest massif, about a mile to the northward, furtherr dwarfs it into insignificance; and thus, being remarkable neither for height norr for scenic assets, this unobtrusive little dome has remained generally unnoticedr and unknown. Indeed, until quite recently, it did not even possess a name. Yet,r to him who sees and knows, it is a place of peculiar if not unique interest, wellr worthy of a pilgrimage. There are other qualities besides spectacular heightr and scenic charm that attract one to some spots.r

r r

r It was in 1906, at the time when the topographic survey of the Yosemiter Valley was in full swing, that a party of surveyors one hot summer day approached this height, intending to make an instrument station on the summit.r Keen to select an easy route for the ascent with their heavy plane-table outfit,r they resolved to take advantage of what appeared to be a massive, tree-grownr embankment that wound in a long smooth curve up the bulging south side of ther dome (see photos on pages 66 and 67). Some 40 feet high, it rose with steady,r uninterrupted grade, as if laid by a careful engineer, carrying its strip of forestr with it across the bare, sun-baked granite slope; and thus, by easy stages andr under genial shade, the party reached a point less than a hundred and fifty feetr below the summit. There the ridge came abruptly to an end, cut off by a precipicer that fell off sheer almost 2000 feet to the valley floor below.r r

---

r r r

r Prof. A. C. Lawson[1]r
r University of Californiar
r Berkeley, Calif.r

r Washington, D. C.r
r Jan. 24, 1915r

r r

r My dear Prof. Lawson:r

r r

r I am sending you by registered mail the manuscript of a paper on Moraine Domer which I had prepared for the *Sierra Club Bulletin*. (Through various delays it couldr not be finished in time to be included in the January issue, but I shall reserve it forr the next one).r

r r

r I believe you may like to read it over, as it deals with the question of multiple glaciations in the Sierra Nevada. The Moraine Dome locality is of special interest in that itr shows with considerable clearness the contrast in the age of the older and youngerr moraines. In fact, it was on Moraine Dome that the conviction first grew upon me thatr there are two distinct moraine series in the Sierra Nevada, recording two glacial episodesr separated from each other by a long interval of time. The story of Moraine Dome, asr told, is not really complete, as I intended it to be "popular" and as nearly free fromr complications as possible. It does not, however, omit any important facts. Referencer might have been made to the older moraines shown on the map, which are so dim as tor be unrecognizable as topographic features and can be traced only as belts containingr Cathedral granite and other rock material foreign to the Yosemite neighborhood. Perchedr erratics occur on the Quarter Domes which lie just under the upper limit reached by ther earlier ice. These domes show residual masses of granite decaying in place some fiver feet high.r

r r

r Dr. [Grove Karl] Gilbert is familiar With Moraine Dome and has visited it twice.r The photo of the aplite wall was taken by him. Evidently his conclusions agree withr mine, to judge from the notes appended to his photos in the Survey collection. Neitherr of us, however, knew that the other had visited Moraine Dome until I showed him myr views (in 1906 it was, I believe).r

r r

r I should greatly appreciate criticism from you.r

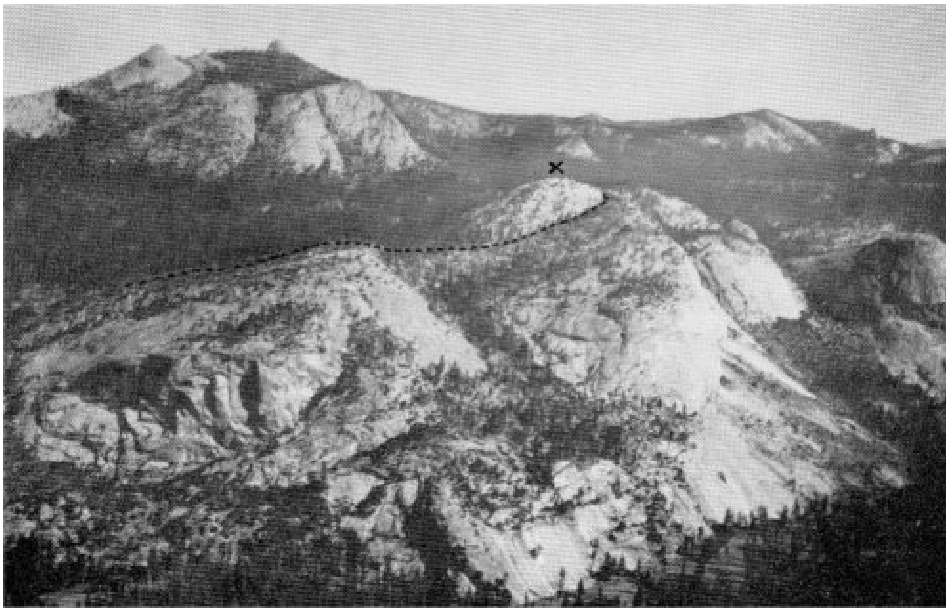
r r

r [Unsigned]r

r r

---

r r r

r As to the real nature of the embankment, there never was a moment's doubt;r it was manifestly a "moraine" of the ancient Merced Glacier, a ridge of ice-transported rock debris, deposited along the margin of the "mer-de-glace" thatr once filled the Little Yosemite. Its very shape, together with the character ofr r r r r  r

r r r

r r General view of north side of Little Yosemite Valley. Moraine Dome in the center, marked byr r a cross. The great morainal embankment is accentuated by a row of dots. In the backgroundr r is Clouds Rest. The faint, white horizontal line to the right of Moraine Dome is the boulder-r r studdedr crest of the highest moraine of the later ice flood. The earlier ice flood overtoppedr r most of the low mountains along the sky line.r r

r r r r the boulders and cobbles protruding from its surface, many of them rounded andr polished, and some representing rock types foreign to the Yosemite neighborhood, at once established its identity.rr r

r Moraines are plentiful about the Yosemite Valley and its branches, but noner had been observed so remarkably clean cut and perfect, nor had any been foundr in so striking a position, wreathed, as it were, about a dome. And so, quiter naturally, the appropriateness suggested itself of naming the eminence for ther embankment—and then and there the height was christened Moraine Dome.r

r r

r A full appreciation of the significance of the embankment, however, was notr r r gained until afterwards. As the locality became better known in the course ofr the survey, the fact developed that the embankment on the side of the dome isr the highest and largest of a series of parallel moraines. Spaced at intervals ofr a few hundred feet across the rounding granite slope below the great embankment are a number of such glacial deposits, all describing sympathetic arcs, allr slanting westward at approximately the same rate. Each evidently records ar halt in the subsidence of the ice flood, or a transitory rise of its lowering surface;r together they tell the story of the progressively diminishing pulsations of ther glacier during its decline. Some consist of little more than a mere row of bouldersr from among which the finer material has washed away; they bespeak fluctuations of ephemeral briefness. Others have the form of massive ridges, ten tor fifteen feet high and supporting dense growths of manzanita and occasionalr pines; these attest rises of relatively long duration.r

r r

r However, one must guard against interpreting these features with too muchr confidence; moraines are inherently tricky in their nature, changing deceptivelyr in aspect from place to place. Thus, the great upper embankment on Morainer Dome, by its superior size and bulk, might readily lead one to infer that ther

maximum stage of the ice flood was an unusually protracted one; but, whenr r
r
r r

r r Looking up the crest of the winding embankment. The summit of Moraine Dome lies to the left.r
r r r

r r  r

r r r r this embankment is followed westward to the base of the dome, it is found tor divide into two discrete moraine bodies which thence accompany each other asr sister ridges 200 to 300 feet apart. Still farther west, upon entering the greatr embayment in the north side of the Little Yosemite Valley, each of these twor ridges again is found to split into three separate sharp crests. What on the dome,r therefore, would be taken for a single, compact, heavy moraine, proves inr reality to be a composite mass, containing the proceeds of six separate glacierr fluctuations.rr r

r The cause of this mysterious behavior of the moraines is to be sought in ther influence exerted on the shape of the ice stream by the variations in the width ofr the valley trough. Opposite Moraine Dome there is a marked narrowing betweenr promontories of sharp declivity. There the lesser fluctuations in the glacier'sr volume found expression in only insignificant lateral oscillations of its borders,r and the moraines, in consequence, lie plastered against and upon each other, inr places indistinguishably merged together. But farther west there is a pronouncedr widening of the valley trough, accompanied by gentler side slopes, and there,r naturally, the borders of the ice stream expanded and contracted in obediencer to volume changes on a relatively generous scale, placing each moraine anr r
r
r r

r r The great morainal embankment viewed from the bare granite slope of Moraine Dome abover
r r r

r r  r

r r r r appreciable distance from its fellows. Particularly complete and detailed, forr this reason, is the morainal record in the great embayment on the north side, asr the traveler on the Sunrise Trail may conveniently observe. That route, in ther first 1000 feet of its ascent from the floor of the Little Yosemite Valley, traversesr 30 moraines in succession.rr r

r Let us now see whether it is possible to trace the course of the upper embankment eastward from the dome. As was stated, the embankment terminates at ar point about 150 feet below the summit. It stops there, however, not because ther glacier was deficient in rock debris east of this point, but because the precipitousr character of the cliffs here does not permit the lodgment of loose debris. It mayr reasonably be anticipated, therefore, that farther east, on more favorable ground,r the moraine will be found to resume its course. And, so, indeed, it does; only,r one must not look for any plain sailing in a search of this kind. The windings ofr a moraine are in considerable measure conditioned by the features of the landscape, and, in a locality of peculiar configuration such as this, are likely to ber devious and elusive, like the turns and twists in a rabbit's track.r

r r

r Moraine Dome, it will be observed on the map, does not curve down symmetrically in all directions. Northeastward it is prolonged in a nearly level,r round-backed ridge, half a mile long and only some 60 feet lower than ther summit. At its farther extremity this ridge carries a knoll of about the samer height as the dome. Somewhere on this ridge, to judge from the slant of ther embankment on the dome, the upper moraines may be expected to be foundr again. Starting out in search along the back bone, however, one is disappointedr to find it bare and smooth like the dome itself. Even the lowest sag, which wouldr naturally seem to hold most promise, is utterly devoid of debris. But on ther terminal knoll, in the place where one would least expect to find them, there ther moraines turn up again. At first they impress one as a confused jumble of boulderr heaps, partly overgrown with brush; but a little study shows them to consist ofr several distinct bands, looped over the summit at intervals and trailing down tor the southwest and to the northwest at a strong angle with the slope.r

r r

r On the south side of the knoll the loops are cut off short by the same greatr cliff that interrupts the embankment on the dome, but on the north side they canr be traced down all the way to Sunrise Creek, across the Sunrise Trail and upr again through a long arc to the south base of Clouds Rest.r

r r

r On the ground the significance of this arc is not readily apparent, as ther forest growth precludes a comprehensive view; but when seen in its entiretyr r r on the map the arc is at once recognized as the outline of a short lobe of ther Merced Glacier. That ice stream, it would appear, split upon the knoll and sentr a small portion of its mass through the saddle to the north. How near the glacierr came to overtopping the height is attested by the looped position of the moraines.r The most advanced of the series even lies a little west of the highest point of ther knoll. One wonders that the ice, having come this far, did not engulf the lowr ridge before it and advance to Moraine Dome; but its viscosity evidently didr not permit this.r

r r

r Moraine Dome, together with the ridge extending northeastward from it,r is, then, of special interest as a landmark demarcating what appears to ber the highest level reached by the ice in the Little Yosemite Valley. Should anyone doubt the correctness of this interpretation, let him pursue the morainesr described farther east. He will find them running along the north side of ther valley as far as Sunrise Mountain, in the form of a great series of massive,r parallel embankments. The Sunrise Trail for a considerable distance takesr advantage of the mile-long, uninterrupted stretches of good going which theser embankments afford and at last surmounts the highest of the series.r

r r

r No one, not even the most casual of observers can help noticing the uppermost moraine as he crosses it. Like an artificial battlement it looms, crownedr with gigantic granite boulders that produce a white line through the forest visibler from afarr (photo, page 65).r Below it are tiers of successively lower crests, allr rock studded, and imparting to the mountain side a chaotic, wild appearance.r Above, on the other hand, the slope is relatively smooth and featureless, smothered for the most part under a heavy mantle of disintegrated granite sand. Sor striking is the contrast, indeed, so conspicuous is the boundary between ther moraine littered slope below and the smooth slope above that no one fully cognizant of its significance but will unhesitatingly declare: This line marks ther highest level of the ice flood. Above it the glacier never rose.r

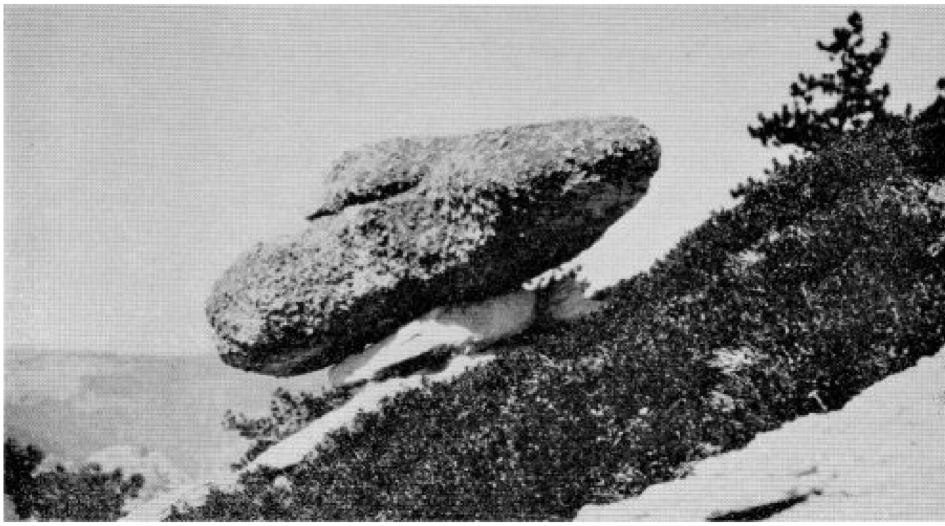
r r

r And yet again, it is well not to be too positive about these matters.r

r r

r On continuing the ascent of Moraine Dome from the upper end of the embankment, what does one find? About 30 feet below the summit, on the southr side, is an elongated boulder measuring 12 by 6 by 5 feet, perched on a pedestalr some three feet highr (photo, page 70).r The pedestal is made up of remnants ofr inclined shells clearly belonging to the dome (surface shells of this kind, it mayr be explained in passing, are now recognized to be a normal feature of the Sierrar domes), but the great capping boulder consists of a material differing conspicuouslyr r r from the local rock. Moraine Dome is composed of a fairly even-texturedr granite of creamy color speckled with dark mineral (Half Dome granite it isr called by geologists, as Half Dome consists of this rock), while the perchedr boulder is of a pinkish granite with swarms of large, square-cornered feldsparr crystals of a paler hue. More resistant to weathering than the matrix betweenr them, these crystals stand out on the surface in high relief, like so many dominor blocks, two to three inches long, lending the rock a perculiar, lumpy aspect.r

r r r

r r  r

r r r

r r The “erratic” boulder of Cathedral granite on its pedestal. The rock is 12 feet long and 5 feetr r high. It attests a much earlier and higher ice flood than the morainal embankments fartherr r down.r r

r r r

r Nowhere in the Yosemite region is this type of granite found “in place”; butr higher up in the Sierra Nevada it constitutes the prevailing country rock overr large areas, notably in the upper Tuolumne basin. The rugged chain which terminates in Cathedral Peak is largely composed of it, and, accordingly, the rockr has been named Cathedral granite.r

r r

r The nearest locality from which the boulder could have been derived isr Long Meadow, which lies back of Sunrise Mountain, some five miles to ther northeast. Clearly there is but one agent that could have brought it from thatr place, and that is a glacier. The very size of the boulder precludes the possibilityr of its having been transported by another agent. Besides, it is known that ther r r Merced Glacier carried considerable of this material, fragments being plentifulr in all of the moraines described.r

r r

r The glacial origin of the boulder being admitted, the conclusion previouslyr reached that the great embankment on the flank of the dome marks the highest level reached by the ice, must be revised. Evidently the glacier did riser higher once.r

r r

r But, it may be objected, is this one boulder the sole evidence available ofr a higher ice stage? Granted that it is a sure-enough “erratic,” one would feelr better satisfied, were there additional testimony of some sort. Such testimonyr indeed is found in the presence of another boulder of Cathedral granite, locatedr on the very summit of the dome. Its position is such as to suggest that the entirer dome may once have been overridden by the ice, and that, in order to determiner the highest level attained by the glacier, the search may have to be carried tor higher ground. This, it should be said, has actually been done, with the resultr that the ice is now definitely known to have overtopped the dome by five hundredr feet at least.r

r r

r In the meanwhile the entire story of Moraine Dome is not told. In the firstr place, there is a certain significance in the almost complete isolation of the twor erratics mentioned. Search as one may, there is not another rock of extraneousr origin to be found on the dome. Yet the summit is broad and level, affordingr ample space for a heavy glacial deposit. If moraines are able to maintain themselves in the form of strong embankments on the steeply inclined flanks of ther dome, why should there be such a paucity of glacial material on the much morer favorable, level summit?r

r r

r The suspicion here insinuates itself that possibly one has to do here withr the vestiges of what may once have been a moraine of considerable volume,—r a moraine, however, of a very much earlier ice flood than the one whose historyr is so fully recorded in the heavy embankments lower down, a moraine so ancient,r indeed, that all of its material has by this time disintegrated and washed away,r save for these two solitary erratics. Several things seem to strengthen thisr suspicion. For one thing, both rocks have long since lost their ice-smoothed,r rounded contour, and have weathered down to irregular, lumpy forms. Again,r both rocks have pedestals. That the smaller one on the summit possesses such ar support, has not been mentioned. The fact is that it no longer occupies its pedestal, but leans against the base, having slipped down apparently not long ago.r That the little pile, which stands about twelve inches high, really once did server r r as a support for the erratic, however, is beyond question; the badly decomposedr granite of the pedestal clearly could not have survived above the general surface of the dome, save through the presence of a protecting cover of some sort.r Indeed, there is no doubt but what the pedestals of both boulders owe theirr preservation to the protective influence of the resistant cap rocks. They haver remained standing while the surrounding parts of the dome have graduallyr wasted away under the attacks of the elements. They point, therefore, to ar general denudation of the dome that has been in progress for a considerable lapser of time. The exact rate at which the surface of a granite dome is annuallyr lowered is, of course, not definitely known, but it is safe to say that the periodr involved was a lengthy one, to be reckoned in thousands of years.r

r r

r Perched erratics, it is to be noted, are by no means a common feature of ther Yosemite region. Below the great morainal embankment that was thought tor mark the culmination of the ice tide, perched boulders are signally absent.r Detached erratics abound between the moraine ridges, it is true, but invariablyr they are found resting on the hard, smooth surface of the granite, which, evenr as the boulders themselves, appears to have undergone little or no change sincer the withdrawal of the ice, and in many places still retains the polish and scourings, imparted to it by the grinding glacier. Similarly among the thousands andr thousands of glacial boulders scattered over those wonderful expanses of ice-smoothed, bare granite which one traverses on the way to Merced Lake, therer is not one to be found supported by a residual pedestal. So striking is this factr after one has become acquainted with the conditions on the summit of Morainer Dome, that one cannot escape concluding that the contrast betokens a greatr difference in age between the glacial material lying respectively above and belowr the line of the great embankment. That embankment accordingly assumes a newr and more definite significance; it appears to mark the culminating stage of ar relatively recent ice flood, whereas the ancient-looking perched erratics on ther dome attest a glacial epoch of a relatively remote date.r

r r

r It may have been remarked that the pedestals of the two erratics on Morainer Dome do not accord in height. That of the large lower boulder is three feet tall,r while that of the smaller rock on the summit measures only about one foot. Toor much significance should not be attached to this disparity, for there is goodr reason to believe that neither boulder has retained its exact position throughoutr the entire period of its lodgment on the dome. The lower one, being situated onr a steep incline, no doubt has crept down hill from time to time, as its disintegratingr r r support crumbled under the load, or as its equilibrium shifted through ther flaking off of portions of its own mass. Indeed the aspect of the pedestal is suchr as to warrant the inference that the great erratic has not lain long in its presentr position.r

r r

r As for the boulder on the summit, the chances are that in slipping from itsr support, it has merely repeated an act it has performed before. A rock of suchr moderate dimensions (it measures but little over three feet across) is not likelyr to generate a pedestal of any considerable height. The supporting column,r r r

r r  r

r r r

r r The little "aplite" wall near the umbrella tree on the summit of Moraine Dome. Its height, 7r r feet, affords a rough measure of the depth to which the dome has been denuded since the passager r of the earlier ice flood.r r

r

r r because of its small diameter, would soon be weathered through and through,r and would either crumble down or shed the cap rock. The latter, in its newr position on the surface of the dome, would then through its protective influence,r proceed to generate another pedestal, and this column, in time, would probablyr fare like the first. Thus, it will be seen, the erratic may have occupied severalr low pedestals in succession.rr r

r These conjectures may seem far fetched perhaps, nevertheless they possessr strong elements of probability, as is indicated by certain other residual featuresr on Moraine Dome. Scarcely 50 feet to the northeast of the small erratic on ther summit, close to a dead umbrella tree that marks the highest point, is whatr might be taken for a dilapidated garden wall, built of dry slabs, with manyr chinks that let through the daylight. It is 7 feet high and 4 feet thick (see above),r r r and over a length of about 12 feet seems entire, but the southern end appears tor have tumbled down in part, and terminates in shapeless piles of slabs.r

r r

r The interpretation of this odd feature is not difficult. It is a portion of a thickr vein or "dike" of a yellow, fine-grained igneous rock, known as aplite, that cutsr vertically through the body of the dome. Aplite, it should be explained, weathersr much more slowly than does granite. As the surface of the dome, therefore, wasr being lowered by the gradual wasting away of the granite, the dike came tor stand out more and more, attaining at last its present wall-like aspect. Ther surrounding granite is still disintegrating and wasting away, and as a consequence the wall is even now growing imperceptibly in height.r

r r

r The weather, however, has also told on the aplite, and has greatly weakenedr the little structure. It has caused the slabs (which are remnants of surface shellsr that once extended over the entire crown of the dome) to crack in places, andr has enlarged the partings between them to gaping holes and chinks. In fact, ther greater part of the wall, as stated, has already broken down, probably under ther stress of the heavy winter snows.r

r r

r Special interest attaches to the best preserved and highest portion of ther wall, as its height affords perhaps the most trustworthy index available of ther depth to which Moraine Dome has been stripped since the passage of the earlierr ice flood.r

r r

r In the first place there is no possibility that the wall might in part haver been inherited from a time antedating the earlier ice flood. An obstacle so feeble,r standing at right angles to the current of the ice stream, would inevitably haver been completely razed. Whoever has traveled through the High Sierra may haver noted that on the great expanses of ice-polished granite characteristic of thatr region, all aplite dikes, the largest as well as the smallest, are shorn level withr the surrounding granite. There is thus every reason to believe that the apliter dike on Moraine Dome was similarly smoothed off by the overriding glacier, andr did not begin to weather out until after the culmination of the earlier ice flood.r

r r

r No trace of glacier polish remains on the top of the wall today (which is notr surprising, as all polish of the earlier ice flood has long since vanished throughout the Yosemite region, except in those rare localities where it was fortuitouslyr preserved under debris that has remained undisturbed by the later ice), andr thus there is no guarantee that the top coincides even roughly with the originalr glaciated surface. Nevertheless, it seems safe to say that the wall has not beenr reduced much below the initial level—not as much as a foot, perhaps,—for itsr r r top is broad and flat so that superincumbent slabs (if ever there were any)r could not readily have fallen from it without leaving behind a fragment. Norr are there any broken slabs about the base of the wall that appear to have beenr derived from the top.r

r r

r Again, there is a remarkable accordance in height between this aplite wallr and two other walls of a similar kind, located near the southwestern end of ther summit of the dome. These walls also owe their existence to the superior resisting power of aplite, but they differ from the little wall described in that ther aplite veins in them are steeply inclined instead of vertical, and form slantingr roofs under which masses of granite have remained preserved. They are therefore composite bodies, containing both granite and aplite, and are rather massiver and irregular in shape. The upper wall is 8 feet high, about the same as ther wall near the umbrella tree; the lower is almost 11 feet high, but, as it isr situated on a steep south-facing slope where denudation is bound to progressr more rapidly than on a level tract, one should properly expect it to be taller thanr either of the walls standing on the summit platform. There is thus substantialr agreement in the height of the three walls on Moraine Dome, although they arer somewhat dissimilar in make-up and of unequal thickness, and accordingly oner feels justified in accepting 8 feet as a minimum measure of the thickness ofr granite that has been stripped from the summit of the dome since the culmination of the earlier ice flood. Small wonder that the morainal material attestingr that ice flood is so scarce on Moraine Dome! Indeed, one marvels, in ther light of these evidences of wholesale weathering, that even the two erratics ofr Cathedral granite have remained to tell the tale.r

r r

r The story that Moraine Dome tells is then, briefly, a story of two glacialr epochs, separated by a lengthy interval of time.[2] The earlier ice flood was byr far the mightier and rose to considerably higher levels than the later one, butr so remote was the date of its occurrence that since then Moraine Dome andr probably all similar granite heights in the Yosemite region have lost at least 8r feet in height, and the morainal material that was deposited on them has all butr disappeared. On the other hand, the later ice flood culminated so recently, relatively speaking, that the scoured granite surfaces left by it appear even nowr essentially unchanged, and retain their polish over large areas, while the fluctuations of the declining glacier are still fully recorded in great series of moraines,r many of which are strong even on exposed places such as the slopes of domes.r r r Time was when the question at issue was whether the Yosemite had everr been visited by ice or not. Now that question is not only definitely settled, butr one can speak with confidence of two separate glacial episodes. And, in view ofr the strong denudation that appears to have taken place since the earlier of theser epochs, and has so greatly dimmed its record, one feels justified in going oner step further and in asking whether there may not have been other, still earlierr ice floods whose traces by now are completely effaced?r

r r

> r *r It is not known with certainty why this manuscript remained unpublished, though probably itr was because of the many urgent duties which Matthes as a member of the Geological Survey had tor assume in the critical world situation prior to World War I. However, a technical abstract, "Morainer Dome and the Moraines of the Little Yosemite Valley," was published in the Journal of the Washington Academy of Sciences, volume 4 (1914), pages 295-296. Also, Matthes' interpretations were setr forth inr r Professional Paper 160 (1930), though differently stated in that volume*.—Ed.r

r r r

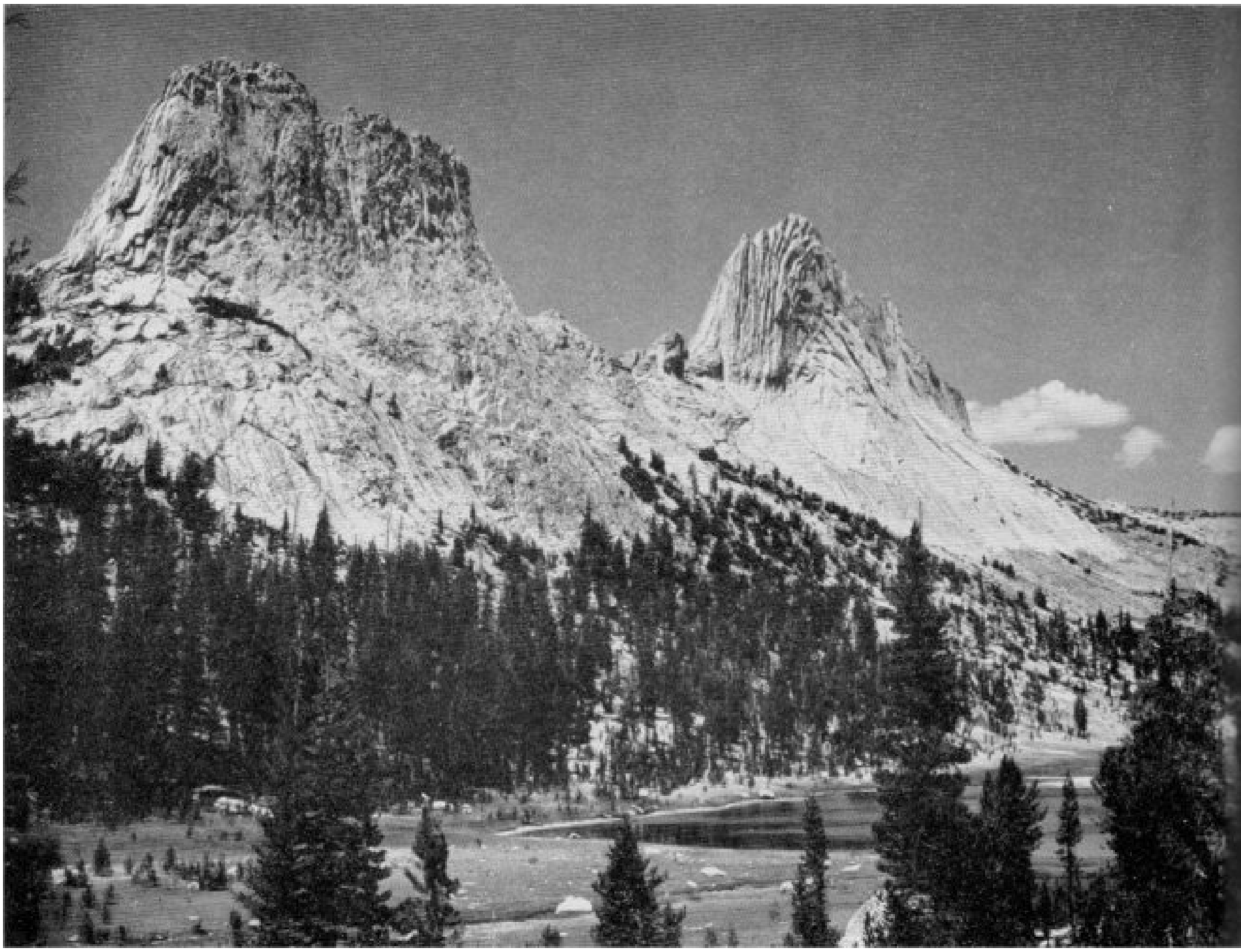
r [1]Draft of a letter presumably sent to A. C. Lawson, and attached to the unpublished manuscriptr entitled "Little Studies in the Yosemite Region, V. The Story of Moraine Dome."r

r r

r [2]Later, at least three and possibly four epochs were recognized. See pp. 114, 156.—Ed.r

r r r r

r r



r r r
r r Matthes Crest, Yosemite National Park. By Reid Moranr

r r r r
r r

---

r r

r **r Next: Cockscomb Crest •r Contentsr • Previous: El Capitan Moraine and Lake Yosemiter** r

r r r

r

r r

r

r r

r r r r r r r r r r r r r

r

r r

r r

r

r r r

r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

---

r r r

COCKSCOMB CREST

r r r

r r Familiarr r to all who have visited the Tuolumne Meadows, and transcendingr perhaps all other mountain groups overlooking that campers' paradise in spectacular beauty and monumental dignity, are the pinnacled and spired peaks ofr Unicorn, Echo, and Cathedral. Each has its own individuality, striking andr unforgettable, each is wholly different from the others, yet all are notably aliker in one respect: their frail minarets and splintered crests stand planted upon full-bodied mountains of great bulk, all rising to approximately the same height;r they seem like delicate super-structures, specially added for the sake of ornamentation. Indeed, they recall the slender turrets and spires on certain ponderousr cathedrals of Old Europe.r

r r

r The significance of this peculiar style of mountain architecture, which is notr prevalent in the Sierra Nevada, has been hinted at by more than one writer.r Muir and Chase both have suggested that the sharp pinnacles and crests mayr be summits that were never overridden by the ice of the Glacial Epoch; thatr stood out above even the highest ice-floods and escaped being planed down andr rounded off as were the massive shoulders of the mountain pedestals underr them. This explanation, though only conjectural, was eminently reasonable, andr it is a genuine satisfaction, now that the region has been submitted to a systematic and detailed study, to be able to confirm its correctness and to corroborater with positive and abundant evidence the surmise of these two keen and perceptive observers.r

r r

r However, the matter is not so simple as it at first may seem. In Muir's dayr glacial science was in its infancy, and no man had as yet that perspective of ther succession of ice-ages and intervening epochs of milder climate which the world-wide research of the last two decades has made known to us. To Muir and hisr r r contemporaries the Glacial Epoch still seemed a single, uninterrupted cycle ofr glacial conditions that slowly reached a climax, like an oncoming tide, and thenr slowly waned, the glaciers making many repeated but progressively feeblerr re-advances, like the waves of an out-going tide. Today we know that the Glacialr Epoch, so-called, really consisted of several prolonged ice-tides separated byr equally prolonged intervals, during each of which the continental ice-sheet andr the lesser ice-bodies on our western mountain ranges shrank back to their sourcesr and perhaps vanished altogether.r

r r

r In the Sierra Nevada indications of at least two great ice-floods have beenr clearly recognized by several observers—two ice-floods that occurred manifestlyr at widely different times, the later culminating probably only twenty thousandr years ago, the earlier, perhaps as much as several hundred thousand years ago.[1]r The evidence is the more readily established as the later ice-flood was the smallerr and less extensive of the two and left undisturbed the moraines—that is, ther ridges of ice-carried rock debris—that mark the limits of the earlier ice-flood.r In no part of the Sierra Nevada have these facts been ascertained with morer precision than in the Yosemite region and the High Sierra immediately abover it. Thus it is now definitely known that the later ice-flood invaded the Yosemiter Valley only as far as the Bridalveil Meadows, whereas the earlier ice-floodr advanced eleven miles farther down the Merced Canyon, coming to a halt ar short distance beyond El Portal.r

r r

r It will be clear from this that there must be from the Bridalveil Meadowsr upward throughout the Yosemite region and adjoining the High Sierra not oner but two “ice-lines,” each marking the culmination of an ice-flood. The pursuitr of these two ice-lines up towards the crest of the range was, indeed, for ther better part of two seasons the writer’s most engrossing occupation. He tracedr them in detail and mapped them along the length of the Yosemite, up throughr the Little Yosemite and the upper Merced Basin and all its tributary canyons,r and also up through Tenaya Canyon and the great Tuolumne Basin and itsr tributary canyons. The result, it may be said, was to him, as glacialist, a genuiner surprise. The two ice-lines, which in the lower Yosemite lie several thousandr feet apart in altitude, were found to approach each other as they ascend ther range and ultimately to coalesce at its crest. One might reasonably have expectedr the extensive and deep ice-fields and glaciers of the earlier epoch to have comer from a Sierra crest completely domed over with smoothly sloping, unbrokenr

r r r r r snow-fields, and the relatively modest ice-stream of the later epoch to haver flowed forth from cirques filled only to moderate depth, and partitioned fromr one another by bare rock crests and “arêtes” rising high above the ice; but,r curiously, it appears that the snow conditions along the Sierra crest were substantially the same in both epochs.r *The snows that fed the vast glaciers of ther earlier epoch filled the summit cirques to no greater depth than did the snowsr that formed the smaller glaciers of the later epoch.*r The significance of thisr remarkable coincidence need not be here discussed—it would lead too far afield;r suffice it for our purpose that the fact has been established.rr r

r A few figures will help to give more definiteness to one’s conception of ther relation of the two ice-lines. The later Yosemite Glacier ended at the Bridalveil Meadows at an altitude of 3900 feet, but the lateral moraines left by ther earlier ice-stream on either side of the Yosemite chasm lie 2700 feet above thisr spot. At the head of the valley the later glacier attained a depth of about 1500r feet, but the lateral moraines of the earlier glacier still lie 2400 feet higher.r Within the next few miles the two ice-lines converge with remarkable rapidity.r In the Little Yosemite, for instance, they are only 600 feet apart. There the laterr ice rose within 100 feet of the top of Moraine Dome, but the earlier ice passedr over it with a depth of over 500 feet. Opposite Lake Merced the difference inr altitude between the two ice-lines dwindles to 400 feet, and thence upward, tor the ultimate source of the glacier under Mount Lyell, the difference steadilyr decreases until it becomes a vanishing quantity.r

r r

r Following the ice-lines up through Tenaya Canyon, they are found to ber 2100 feet apart in altitude opposite Half Dome. That rock monument wasr engulfed by the earlier ice up to within 700 feet of its summit, but even the footr of its great cliff rose 800 feet above the surface of the later glacier. At the headr of Tenaya Canyon the earlier ice rose only 900 feet higher than the later ice, andr still farther up, on the divide between the Tenaya and Tuolumne basins, ther two ice-lines are only 400 feet apart. In the great upper Tuolumne Basin, whichr held an ice-field embracing 140 square miles, the earlier and later ice-floodsr differed only 200 feet in level, as is to be inferred from the two ice-lines onr Ragged Peak. And on the Cathedral Range, which was in large measure ther generator of this immense ice-field, being the great hedge behind which the wind-blown snows accumulated, the difference was least of all. From Cathedral Peakr eastward to Mount Lyell it lessened by degrees until at length it becamer insignificant.r

r r r r

r The figures are but a very few out of many scores determined by the writerr on both ice-lines. Indeed, the total number of determinations made was larger enough to enable him to construct a contour map of each ice surface. Theser contour maps, he is happy to say, have furnished excellent proof of the mutualr concordance and consistency of the data.r

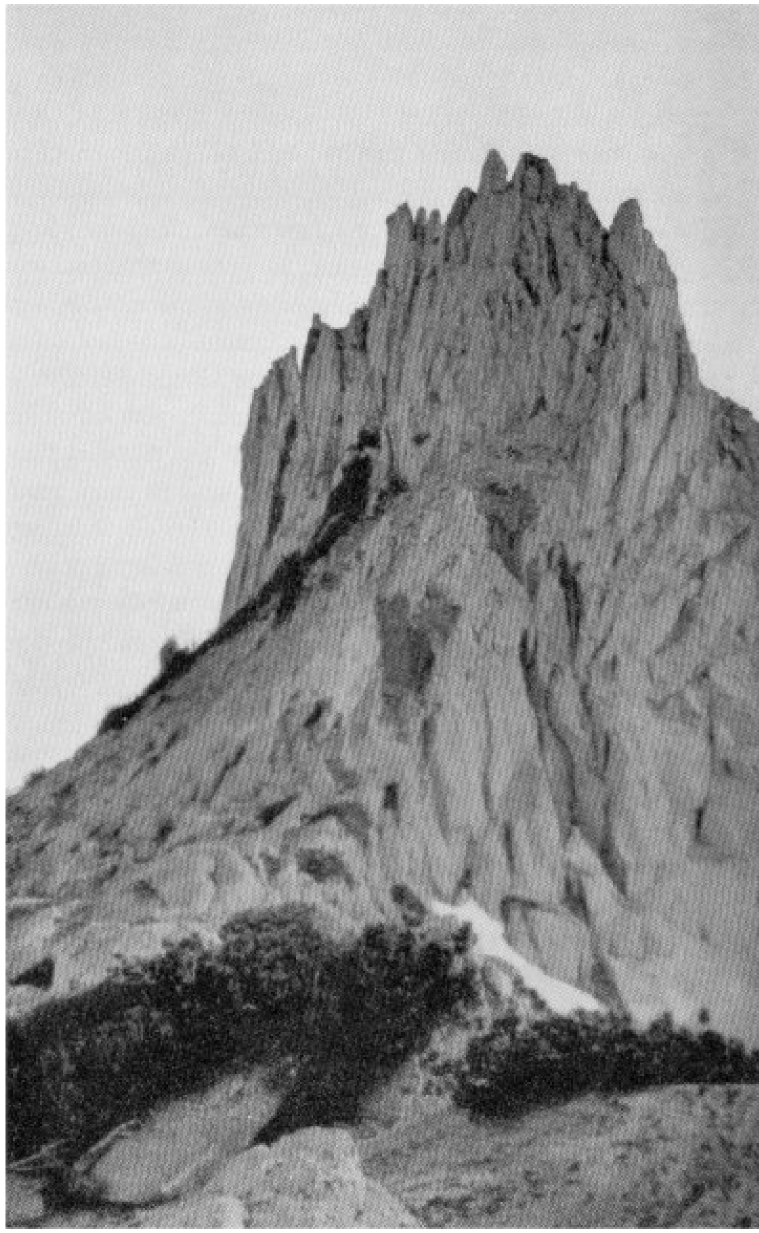
r r

r The group of pinnacled mountains, it will be clear from the foregoing, standsr in a region where the two ice-floods reached substantially the same height. Mostr of the work of paring away the sides of the pinnacles and crests was done byr the earlier ice-flood, which was the one of greater duration, but the later ice-flood undoubtedly did much to accentuate the effect produced by the first. It isr a significant fact that farther down on the Sierra flank, where the ice-linesr diverge widely in altitude, and where the fluctuations in level of each of ther floods no doubt were of considerable amplitude, no attenuated pinnacles orr crests rising abruptly from ice-rounded mountains are to be found.r

r r

r In Greenland, which is one of the few parts of the earth even now under ther dominion of the ice, an Ekimo word is commonly used to designate those barrenr rocky summits that protrude here and there above the rapidly descendingr glaciers forming the fringes of the vast and otherwise continual glacial mantle.r That word is *nunatak*. Physiographers throughout the world have adopted it asr a technical term for rocky summits rising above surrounding ice-sheets andr glaciers. The pinnacles and crests of the Cathedral Range might, therefore, ber referred to as *former nunataks*. But the appropriateness and desirability of sor styling them are, in the writer’s opinion, open to question.r

r r

r For one thing, it must be borne in mind that the pinnacles and crest were notr the only summits of the Cathedral Range, nor of the entire High Sierra, thatr remained uncovered by the ice. There were many larger and more massive summits of varying shapes and designs, and even occasional plateau-like tracts.r Only half a mile to the southwest of Unicorn Peak, for instance, stands ar massive peak of blunted, pyramidal form (still unnamed, although higherr than Unicorn) that rose several hundred feet above the ice. Parsons Peakr and the broad-topped mountain (still unnamed) northeast of Vogelsang Passr are examples of elevated plateaus that remained emergent. Surely no one wouldr think of placing these in the same class with the attenuated crest of Unicornr Peak, the triangular teeth of Echo Peak, or the ethereal spires of the Cathedral.r “Former nunatak” might do in a generic and vague sense for all of them, butr there is clearly need of a distinctive term for the more fragile, evanescent forms.r r r r r  r

r r r

r r Cockscomb Crest, the most magnificent of all the sharply attenuated crestsr
r that indicate the highest level reached by the ice in the High Sierra. Byr
r François Matthesr r

r

r r r What is more, there is need, it seems to the writer, of a term from the Sierrar Nevada itself, if possible from the locality where the type is found in itsr purest form.rr r

r Now, as a matter of fact, neither Unicorn, Echo, nor Cathedral represents ar "pure type" of mountain sculpture. In each the paring effect of the ice is somewhat obscured or even outweighed by other influences, either by the headwardr gnawing of local cirque glaciers or by peculiarities of the structure of the rock.r When closely analyzed each is found to present a rather complex case. Butr fortunately there are in the same neighborhood three other peaks or crests eachr of which might well be taken as a type example.r

r r

r The first of these is that narrow, linear, bladelike crest southwest of ther Cathedral Pass and overlooking Long Meadow, which has been aptly namedr Columbia’s Finger. On the topographic map the name is misplaced, and as ar consequence there has arisen some confusion as to the identity of the featurer to which it is supposed to refer. The writer himself is willing to admit somer uncertainty on his own part, but, if form be the main criterion—and it certainlyr should be in a case of this sort—then the name surely belongs to the crest justr mentioned. For that crest terminates southward in a tall, columnar rock pinnacle that seems to point heavenward like a slender, tapering finger. It is especially impressive when viewed endwise, from the direction of Long Meadow,r and doubtless it was named by someone who traveled through that flat on hisr way to Soda Springs. The case is parallel to that of Unicorn Peak, which wasr named unquestionably by someone in the Tuolumne Meadows, and whose crestr does not resemble a pointing horn except when viewed endwise, from one particular direction.r

r r

r The second crest in question rises a scant mile to the north of Columbia’sr Finger, and is of exactly the same narrow, linear type. It even duplicates ther latter’s terminal pinnacle, but only in what, by contrast, might be called ar “stubby thumb.” More perfectly modeled even than Columbia’s Finger, thisr crest eloquently tells its story—one wonders that it should still be withoutr a name.r

r r

r The third crest is a much more imposing feature than either of the foregoing.r Rising abruptly from a long-drawn ridge as even-topped as the roof of a house,r about a mile south of the Unicorn, it attracts the eye at once by its wonderfulr symmetry and the supreme boldness of its design. Seen endwise it seems but ar narrow blade, springing almost without transition from the broad mountainr r r r under it. From certain directions it is suggestive of the upper half of an ornamental “fleur-de-lis,” but from most view points it resembles nothing so muchr as a splendidly sculptured, gigantic cockscomb. Indeed, it stands planted uponr the ice-smoothed ridge as a cockscomb surmounts the proud head of a cock.r

r r

r The appropriateness of the name Cockscomb may be judged from the photograph onr page 81.r The writer does not claim to be a connoisseur in poultry;r nevertheless, he believes that the likeness to a lobate cockscomb is fairly close—r as close as one might expect to find in a piece of mountain sculpture.r

r r

r Last summer it was the writer’s pleasure to accompany a party from ther Sierra Club under the leadership of Mr. Colby across the Cathedral Range byr the natural pass above Elizabeth Lake, and into the country at the headwatersr of Echo Creek, where the Cockscomb stands. He took that occasion tentativelyr to submit to those present the name Cockscomb, and was gratified to find it meetr with general approval. And so, with additional confidence, he now submits it tor the entire membership.[2]r

r r

r There is a special advantage in the adoption of the name that is worthr pointing out. Not only is the appelation Cockscomb apt because it is descriptiver of the form of this crest, but it would also be an extremely convenient genericr term for the designation of all similarly sculptured crests—of all crests suchr as those previously described, which owe their attentuated linear forms to ther paring action of the ice that split upon them and passed on either side withoutr overwhelming them. It would admirably serve the physiographer’s needs asr standing for the type of mountain sculpture of which the beautiful crest underr discussion is the finest example known.r

r r

r In conclusion, a word anent the desirability, the urgency even, of the members of the Sierra Club giving serious thought to the bestowal of appropriater names upon those peaks, lakes, and other prominent landmarks within ther Yosemite National Park which are as yet unnamed. The next few years doubtless will see a tremendous influx of tourists and pleasure-seekers into the higherr portions of the park, more especially into the Tuolumne Meadows and the Laker Merced neighborhood. That influx, indeed, has already set in, as all those ofr us who camped with the Sierra Club at Soda Springs last summer have had ampler opportunity to see for ourselves. One inevitable result will be the proposal ofr names for all such features of the landscape as are of especial popular interestr r r r and still without names on the map. That this naming is likely to be mostlyr haphazard and ill-considered is almost a foregone conclusion—one need butr visit a tourist resort where the naming has been left largely to the public andr the guides. We of the Sierra Club, it seems to the writer, owe it to the gloriousr mountain country that is so dear to us to forestall such a fate for its landmarks.r As it is, some of them already bear names that are distinctly inappropriate orr even objectionable.r

r r

r The writer ventures to make this suggestion, although he is by no meansr certain that Cockscomb Crest, the name proposed by him, will stand. It is stillr to be acted upon, first by the Sierra Club as a whole, and second by the Unitedr States Geographic Board. But he cherishes the hope that in any event his proposal will stimulate interest in the duty before us—and it is plainly a duty—ofr finding suitable names for the features of the High Sierra.r

r r r

r *Reprinted from* Sierra Club Bulletin, *January, 1920, pages 21-28.r* r

r r

r [1]See footnotes on pagesr 114 andr 156.—Ed.r

r r

r [2]The name "Cockscomb Crest" now appears on the topographic map of Yosemite Nationalr Park.—Ed.r

r r
r r

---

r r

r **r Next: Kings River Canyon •r Contentsr • Previous: Moraine Domer** r

r r r

r

r r

r

r r

r http://www.yosemite.ca.us/library/matthes/cockscomb_crest.htmlr

r r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r Kings River Canyon and Yosemite Valley >r

r r

r

r r r

r **Next: Devil's Postpile •r Contentsr • Previous: Cockscomb Crestr** r

r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

r r r

KINGS RIVER CANYON AND YOSEMITE VALLEY

r r r

r r It is notr r without some hesitation that the writer ventures upon this theme.r For he is mindful of the truth there is in that well-known saying about comparisons. Nor would he essay any comparison of the Kings River Canyon and ther Yosemite Valley as two masterpieces of nature's handiwork. That is a task forr a more gifted pen than his. Besides, there is no need for it has been done, andr well done, by acknowledged masters. What he proposes to give in these pages isr a comparison of the outstanding features and characteristics of the two chasmsr as a geologist understands them.r

r r

r Perhaps it should be added, as a geologist *of the present day* understandsr them, for we have now at our disposal a wholly new branch of earth science, ar branch that has developed almost entirely since the eighties of the last centuryr —geomorphology, the science of the evolution of mountains and valleys and ther surface features of the earth in general. Its application to the Sierra Nevadar already has yielded a veritable harvest of new knowledge; it has given us anr insight such as was impossible heretofore of that range—not only during the Icer Age and since its close, but also during the long stretches of time that wentr before. The Yosemite Valley has been studied in particularly close detail, andr as a result we can now trace its evolution back through successive stages allr the way to its beginning in a remote geologic period. The Kings River Canyon,r it is true, has been accorded thus far little more than a reconnaissance, yet ther salient facts of its history now also stand revealed, the key to them being furnished by the research that has been done in the Yosemite region and in otherr parts of the Sierra Nevada. What is to follow here, then, is an interpretation ofr the resemblances and differences between the two chasms in the light of thisr new knowledge.r

r r r r

r First, let us see what the main points of resemblance and difference are. Asr is generally agreed by those familiar with both chasms, the Yosemite Valleyr and the Kings River Canyon[1]r are most closely similar in their larger modeling,r less so in their detail sculpture, and least in their environmental setting. Both arer hewn like gigantic troughs, steep-sided, level-floored, and remarkably constantr in width throughout, although more or less sinuous in course. In cross-sectionsr they are broadly U-shaped, in contrast to the other great canyons of the lowerr Sierra, which are prevailingly V-shaped. They are even more broadly U-shapedr than the typical glacier troughs of the High Sierra, which are among the mostr perfectly modeled of their kind.r

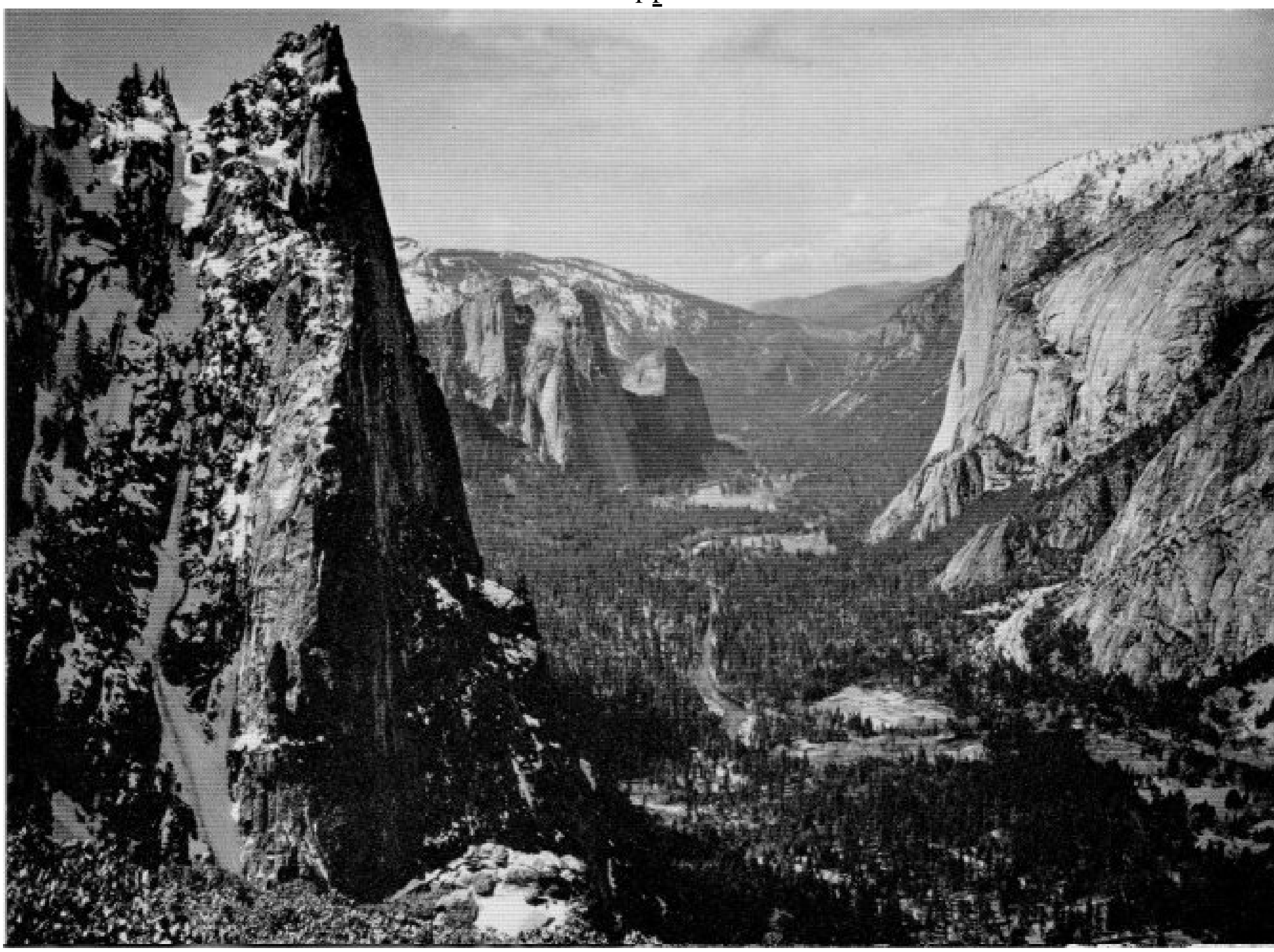
r r

r Indeed, it may well be said that their broad, level floors, which beckon tor us with their charming sunlit groves and the sublime vistas of cliff and peakr r
r

r r

r r A view down Yosemite Valley from the trail above Union Point showing the broad U-shape ofr r the chasm. Sentinel Rock. Cathedral Rocks, and El Capitan. By Ansel Adamsr

r r r
r r



r r r r r r which they afford, largely make these yosemites what they are to us and whatr no narrow-bottomed gorge, however profound, can be.rr r

r Both the Yosemite Valley and Kings River Canyon, be it observed further,r are limited in extent strictly by their floors. At the lower end each narrows downr to an essentially V-shaped canyon, no wider at the bottom than the channel ofr the river (Fig. 3). And at the head each branches abruptly into two lesserr canyons—or, to put it differently, each chasm commences abruptly on a grandr scale of its own, the branch canyons opening into it by separate portals and atr different levels. And so the Yosemite and the Kings River canyons both haver the appearance of being complete in themselves, set off from the canyons abover and below, although in reality they are but short links in extensive canyonr systems.r

r r

r Upon closer inspection, nevertheless, the Yosemite Valley and the Kingsr River Canyon are found to differ appreciably in their proportions—their ratiosr of length, width, and depth. The Yosemite Valley is seven miles long, on anr r
r
r r

r r A similar view down the Kings River Canyon showing its pronouncedr r Yosemite-like character. By J. N. LeConter
r r r
r r

r
r r r r average three-fourths of a mile wide from cliff base to cliff base, and two milesr wide from brink to brink; and it has a depth of 3000 to 3500 feet from brink tor floor. The Kings River Canyon, on the other hand, is nine miles long, on anr average only about three-eighths of a mile wide from cliff base to cliff base, andr but slightly over one mile wide from brink to brink, in so far as it can be said tor have any brinks. Its depth below the same ill-defined brinks ranges from 2000r to 2500 feet. The Kings River Canyon, therefore, though two miles longer thanr the Yosemite, is only one-half as wide and two-thirds as deep.rr r

r The cliffs in both chasms are distinguished in general by the same massive,r monumental style of sculpture; but a comparison of individual rock-forms mustr naturally result in favor of the Yosemite. Nor is this because of any real deficiency in such forms in the Kings River Canyon, but rather because of ther matchless wealth and variety with which the Yosemite is endowed. No otherr chasm on this continent, nor perhaps on any continent, possesses within sor small a compass so remarkable an assemblage of uniquely sculptured cliffs andr monuments.r

r r

r The upper part of the Kings River Canyon, however, is no distant rival; itsr Grand Sentinel and North Dome, though not quite so clean-cut as comparabler forms in the Yosemite, are fully as majestic and impressive; and the Sphinx,r were it situated in the tourist-thronged and well-advertised Yosemite region, nor doubt would have long since become known the world over as one of its strikingr landmarks. But the lower part of the canyon possesses few sculptures of equalr distinction. Some of its cliffs are of noble proportions, but they are not of ther kind that stand out in the memory forever.r

r r

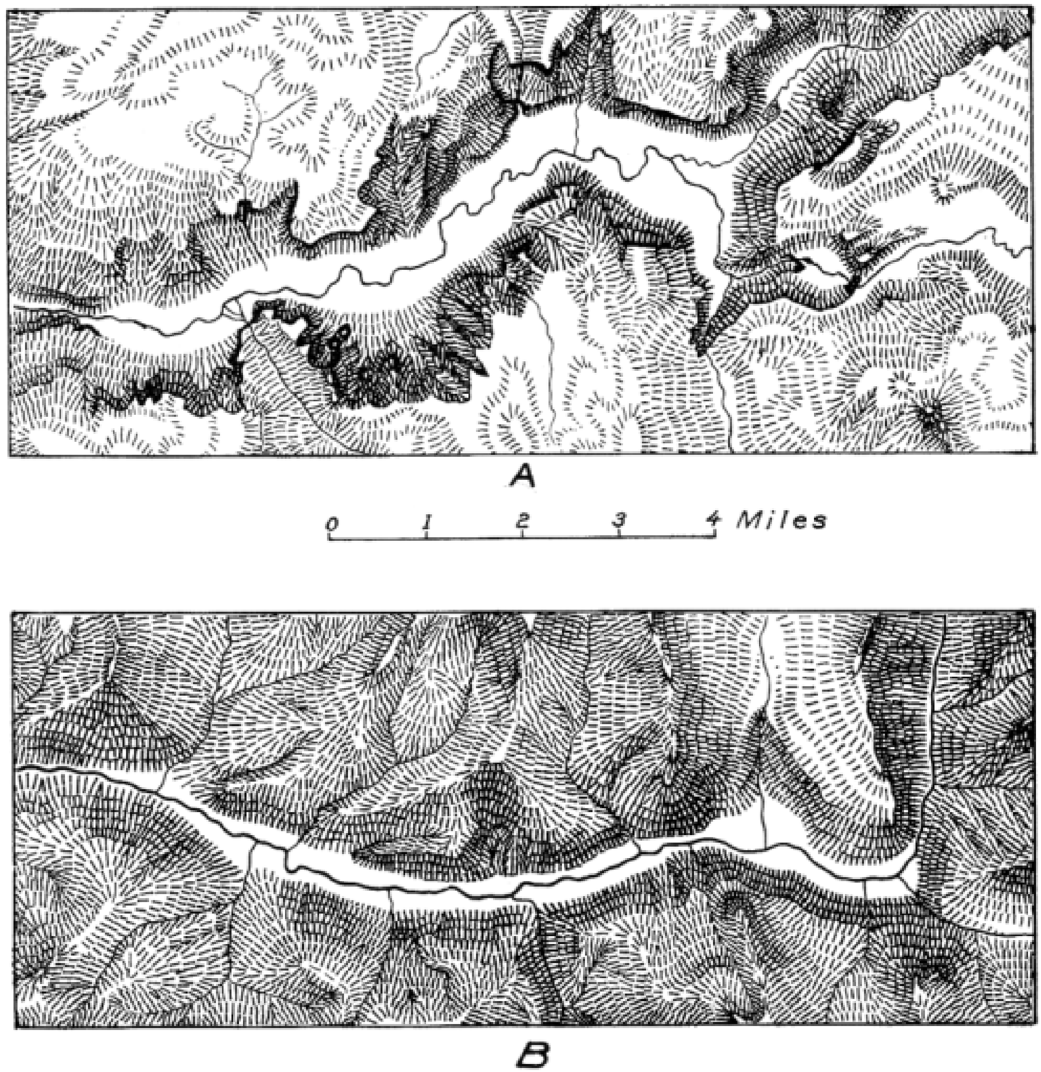
r In another respect also, it must be admitted, the Kings River Canyon cannotr compete with the Yosemite—namely, in wealth of waterfalls. It possesses reallyr but one cataract of note, that of Roaring River; and that cataract is to be measured only in tens of feet, whereas the falls in the Yosemite Valley are measuredr in hundreds of feet.r

r r

r This lack of falling waters in the Kings River Canyon is of peculiar interest,r in that it is due in large part to the scarcity of typical “hanging valleys”—that is,r tributary valleys opening abruptly at a considerable height above the floor ofr the main chasm. In the Yosemite region “hanging valleys” notably abound.r Typical examples are the valley of Yosemite Creek, which opens at a height ofr 2565 feet; the valley of Ribbon Creek, which opens at a height of over 3000r feet; and the valley of Illilouette Creek, which opens at a height of about 1800r r r feet. From their mouths leap the glorious waterfalls for which the Yosemite isr famed. The streams tributary to the Kings River Canyon, on the contrary, haver nearly all cut their valleys down to so great depth that they debouch at or butr slightly above the level of its floor.r

r r

r True hanging valleys, nevertheless, are not wholly wanting in the Kingsr River region: the valley of Bubbs Creek, for instance, opens at a height of fullyr r r r



r r r

r r r

r r Figure 3.—Hachure maps of Yosemite Valley (A) and Kings River Canyonr r (B), permitting a direct comparison of their main features (same scale).r r

r

r r 1400 feet; the valley of Copper Creek, at a height of 2000 feet; and the valleyr of Granite Creek, at a height of at least 1200 feet. But their streams, insteadr of leaping down in spectacular falls, descend in broken cascades ensconced inr narrow slot-like gorges.rr r

r The prevailing depth of the Kings River's tributary valleys, again, is intimately linked with the extreme ruggedness of its flanking heights. These contrastr r r with those of the Yosemite Valley as mountain peaks contrast with foothills.r The Yosemite lies between unimpressive, billowy uplands, the individual swellsr on which are only 1000 to 1.500 feet high—only one-third to one-half as high asr the chasm itself is deep. The Yosemite is therefore easily the dominant featurer of its district; there is little in its environment to distract the eye from it. Ther Kings River Canyon, on the other hand, is surrounded by a galaxy of peaks andr crests many of which tower 4000 and even 5000 feet above its brinks—to twicer the height of the chasm's own walls. To one who surveys the landscape fromr Lookout Point the disproportion is at once apparent, and yet, *mirabile dictu,* ther chasm does not seem dwarfed, it loses not one jot in majesty, but rather gainsr by reason of its stupendous setting. And does not therein lie the real test of itsr inherent scenic grandeur? A chasm less sublime would sink into insignificancer amid such titanic surroundings.r

r r

r And now let us see how these various facts are to be explained. Throughr what circumstances is it that the Kings River Canyon and the Yosemite Valleyr have come to be so closely alike in some respects, though so unlike in others?r

r r

r To begin with the most obvious: Both chasms unquestionably owe theirr broad trough form to repeated and intense glaciation. Their almost uniformr U-shape and their sheer, spurless, parallel sides are characteristic features ofr glacier channels. But this does not necessarily imply that the chasms are productsr of glacier action alone or even mainly; it is clear from the positions of ther moraines, as well as from many other things, that the chasms are stream-wornr canyons that have been remodeled and enlarged by the ice, the transformationr from the original V-shape to the final U-shape having been brought about byr widening fully as much as by deepening.r

r r

r Just what proportion of the total work of excavation in either chasm is tor be attributed to glacier action and what proportion to preglacial stream actionr has long been a moot question, but today we are for the first time in a positionr to give the answer, for the Yosemite at least, in rather definite quantitative terms.r For it has been found possible to determine the preglacial depth of that chasmr within narrow limits, and consequently it is also possible now to compute ther amount of rock that was excavated by stream and glacier respectively.r

r r

r Indeed, the Yosemite is probably the first glaciated canyon whose preglacialr dimensions and configuration have been ascertained in some detail.[2] Three favoringr r r r circumstances have rendered this possible: the presence of certain featuresr in the Yosemite Valley that are fairly reliable indices of its preglacial depth;r the availability of a topographic base of adequate accuracy for necessary measurementsr of height and distance (the map which the writer prepared in 1905–06);r and the granting by the U. S. Geological Survey of sufficient time andr funds for an intensive study of the problem.r

r r

r As a result it can now be stated with some confidence that the Yosemite,r prior to the advent of the glaciers, was fully 2400 feet deep, measured from ther brow of El Capitan, and 2000 feet deep opposite Glacier Point. The additionalr deepening effected by the ice, therefore, ranges from 600 feet at the lower endr to more than 1200 feet at the upper end of the chasm.[3]r

r r

r For the Kings River Canyon no such definite figures can be given; indeed,r it is doubtful whether any can ever be determined. But from the preliminaryr studies it seems reasonably certain that the depth of glacial cutting in the canyonr was less, on the whole, than in the Yosemite, save at the extreme head, where itr was about the same in both.r

r r

r A word, next, about the broad, level floors that distinguish the Yosemite Valley and the Kings River Canyon from the typical U-troughs of the High Sierra.r These floors are not products of glacial excavating, but due in each case to ar filling of loose debris that conceals the bottom contours of the U-trough. In ther Yosemite the rock floor was scooped out by the ice in the form of an elongatedr basin—the basin of ancient Lake Yosemite—and this basin was filled with sandr and gravel deposited by the Merced River. In the Kings River Canyon probablyr no basin was excavated (there may possibly have been a shallow one near ther upper end), but during the final recession of the glacier the floor was left deeplyr encumbered with ice-borne debris. The Kings River Glacier evidently was muchr more heavily loaded with rock-waste than the Yosemite Glacier, and not only leftr one moraine loop after another, but between moraines liberated immense quantities of gravel and boulders that were spread out in thick sheets by the torrentsr flowing from the melting ice. This outwash material now forms the greater partr of the floor upon which one travels and camps; only the crests of the recessionalr moraines emerge here and there above it.r

r r

r The difference in the nature of the filling in the two chasms accounts forr the contrast in degree of flatness of their respective floors. The floor of ther Yosemite is so nearly level that the eye can not detect its slope—it descendsr r r r only twenty feet in a distance of five miles; whereas the floor of the Kings Riverr Canyon descends 600 feet in a distance of nine miles, or at an average of sixty-six feet to the mile.r

r r

r The great width of both chasms is due largely to the fact that the glaciersr were able to “quarry” laterally to far better advantage in them than in ther canyons above or below. This glacial quarrying was facilitated by the prevalencer of “joints” in the rock—more or less regularly spaced fractures—whereby blocksr of convenient size were made available for plucking and transportation. Ther canyons above and below, on the contrary, are narrow, because the rock in themr was less generally fractured—in fact, for considerable distances it was whollyr undivided—and as a consequence the glaciers could only grind and polish.r And in the hard Sierra granites these abrasive processes work with exceedingr slowness.r

r r

r Another circumstance that doubtless contributed toward the production ofr the great width of the two chasms was the confluence at their heads of twor powerful tributary glaciers. For it can be shown analytically that the consolidation of two or more glaciers into one is bound to result in a decided increase inr economy of movement and a corresponding increase in kinetic energy (energy ofr mass movement due to gravitation) available for erosive action. But the importance of this factor should not be overrated, for there is ample evidence that ar confluence of glaciers was not indispensable in every case in the Sierra Nevadar for the production of a typical Yosemite. Instances are not wanting of suchr valleys whose heads are not marked by any junction of tributary glacier troughs.r The Little Yosemite is a good example. In its case, certainly, the predominancer of well-jointed and readily quarried rock is the prime factor that determined itsr great width.r

r r

r Withal there are few places in the Sierra Nevada where the relative impotencer of the ice when dealing with massive, undivided granite is more strikinglyr exemplified than in some parts of the Little Yosemite. Liberty Cap and Mountr Broderick, the two great bosses that obstruct its mouth, stood directly in ther path of the glacier, yet they have survived as gigantic *roches moutonneés*, eachr being essentially an unquarriable monolith.r

r r

r There is, then, little doubt that both the Kings River Canyon and ther Yosemite Valley have been developed in places where the joints in the rock permitted glacial quarrying on an extraordinary scale. Their broad trough form,r accordingly, is a “function,” as mathematicians would say, of their rock structure.r r Of course, it is a function also of the quarrying power of the glacier. Thatr the Kings River Canyon is only one-half as wide and two-thirds as deep as ther Yosemite is due in part to the inferior quarrying power of the Kings Riverr Glacier and only in part to the less quarriable nature of its rocks. Space does notr permit here for the giving of a comparison of the Kings River and Yosemiter glaciers. Suffice it to say that their relative magnitudes and quarrying powersr are readily inferred from their respective moraine systems, of which the writerr was able to make a comparative study in the summer of 1925.r

r r

r The detail sculpture of the cliffs of both chasms also is intimately associatedr with the varying structure of the rock. Indeed, each type of sculpture is ther expression of a definite type of structure, and because of the delicacy of touchr of the postglacial sculpturing agents—frost, temperature changes, running water,r snow-slides, ground water, and so forth—every local change and vagary in ther structure has been brought out in *bas-relief*.r

r r

r The massive, undivided granite in general gives rise to rounded domes andr curving walls—it tends to assume simple flowing outlines, because it “exfoliates”r at the surface in smoothly curving concentric shells. The jointed rocks, on ther other hand, are carved into prevailingly angular, faceted forms. And where theser two types of structure intermingle in capricious fashion, there arise forms ofr unusual, striking individuality, monuments of unique design, such as Half Dome,r Cathedral Rocks, the Grand Sentinel, and the Sphinx.r

r r

r Two things account for the phenomenal array of bold and contrasting sculptural forms in the Yosemite Valley: the rather fortuitous assemblage within itsr compass of a number of differing types of rock, and the frequent occurrence ofr extreme types of structure in immediate juxtaposition. The upper Kings Riverr Canyon owes its pronounced Yosemite-like sculpture likewise to the presence ofr granite of highly irregular structure; the lower part of the canyon, on the contrary, is cut in more evenly jointed rocks, and therefore is scenically lessr impressive.r

r r

r What now may be the reason for the marked disparity between the twor chasms in the matter of hanging valleys and waterfalls? In the last analysis it,r too, is traceable to structural influences. The elevated hanging valleys of ther Yosemite region are held up by massive granite exceedingly resistant to bothr stream and glacier erosion. One need but view the grand cliff under the upperr Yosemite Falls to be convinced of this fact: most of its rock is wholly undividedr to a height of a thousand feet, and what few master joints traverse the westernr r r portion are spaced hundreds of feet apart. On the other hand, the deeply cutr side gorges of the Kings River Canyon, and the little gulches incised into ther lips of its few hanging valleys, all traverse rocks sufficiently fractured to give ther eroding agents a good hold.r

r r

r But that, after all, is only a small part of the story. The significance of ther hanging valleys themselves must be taken into account. They are the telltaler features of the landscape that give us the key to the mysteries of the early historyr and the ultimate origin of the two chasms.r

r r

r It has been commonly supposed that the hanging valleys whose waters pourr into the Yosemite chasm are, like most hanging valleys in glaciated mountainr regions, products of glaciation mainly; or, to state it more accurately, that theyr have remained suspended high above the chasm's floor largely because the feebler branch glaciers that occupied them were unable to excavate as effectively as ther powerful Yosemite Glacier. Undeniably great disparity in eroding power betweenr the main glacier and its tributaries was a potent factor in developing andr accentuating the discordance between the main chasm and its side valleys, butr one would greatly err in giving it sole credit for producing the entire discordancer in every case.r

r r

r As far back as 1913, when the farthest limits reached by the Yosemite Glacierr were for the first time definitely mapped by the writer, it became evident thatr hanging valleys occur not only within the glaciated area of the Yosemite region,r but also outside of it. A number of them actually occur on both sides of ther lower Merced Canyon, many miles below El Portal, in whose vicinity the glacierr terminated. A similar state of things has since been found in the unglaciatedr lower portions of Tuolumne, Stanislaus, and San Joaquin canyons. The ancientr glaciers did not reach within thirty miles of the base of the range, yet typicalr hanging valleys, with cascades tumbling from their mouths, occur within a veryr few miles of the foothills.r

r r

r How are these facts to be accounted for? Were the side streams, perhaps,r unable to trench as rapidly as the master streams? And if so, why?r

r r

r The Sierra Nevada, it is to be borne in mind, consists of a huge block of ther earth's crust that lies strongly tilted, with its eastern edge raised to a great heightr above its western edge. Whenever the slope of a block range of this kind isr sharply accentuated by renewed earth stresses, the streams that run down itsr back, finding their paths appreciably steepened, will flow with greatly increasedr velocity and correspondingly increased eroding power. As a consequence theyr r r will rapidly deepen their beds and in the course of time entrench themselvesr in narrow gorges. But with this rapid trenching their feebler tributaries will ber unable to keep step, and this is true especially of those tributaries which flow atr right angles to the direction of the tilting, for they remain unsteepened andr unaccelerated. Inevitably, therefore, the valleys of these tributaries will be leftr suspended high above the main canyon—they will come to be "hanging" valleys,r simply as a result of the uplift of the range and without the intervention ofr glacial processes.r

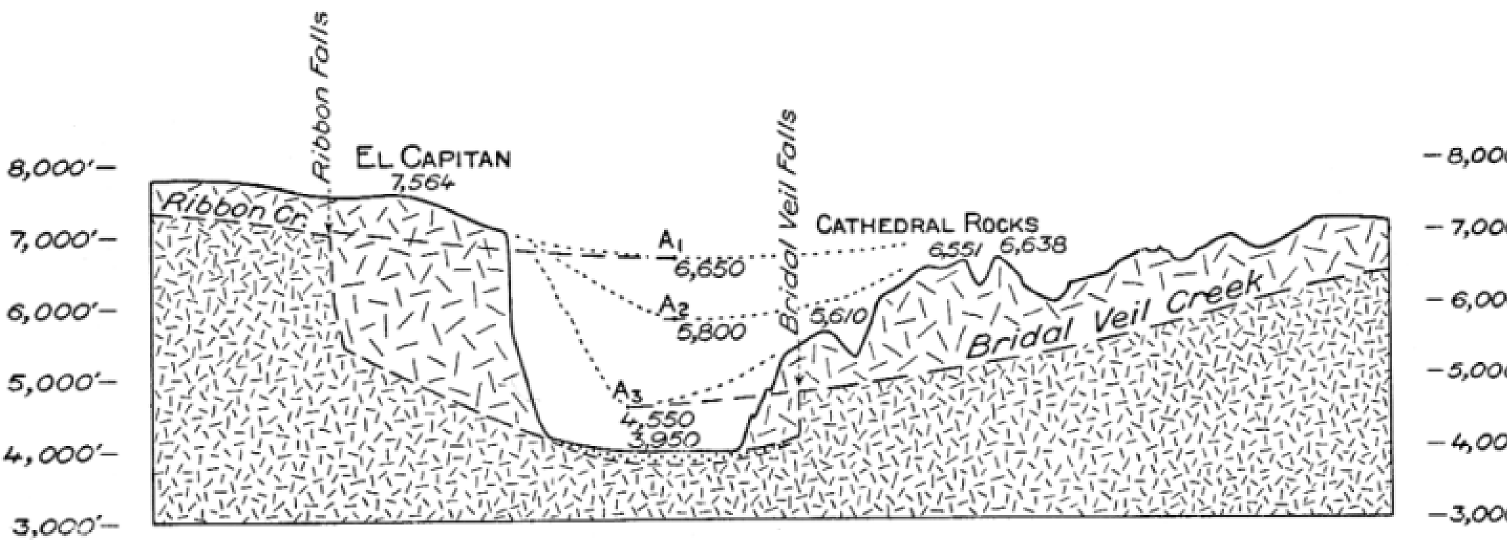
r r

r Precisely this is what has happened in the Sierra Nevada. The Merced, flowing, as it does, directly down the western slope, as a result of the last strongr tilting movement has been accelerated to torrential speed and ever since has beenr actively intrenching itself in a narrow gorge. But only its larger tributaries haver been able to keep up with this trenching, the lesser ones, and especially thoser arranged at right angles to the direction of the tilting, having remained suspendedr high above the main canyon.r

r r

r That this is the true explanation of the hanging side valleys of the unglaciatedr lower Merced Canyon there can be not the slightest doubt; but it is not so easyr to decide in how far this explanation applies also to the hanging side valleys ofr r r r

r r



r

r r r

r r Figure 4.—Section across Yosemite Valley from El Capitan to the Cathedral Rocks. Projectedr r on this section is another drawn along Ribbon Creek and Bridalveil Creek. The vertical andr r horizontal scales are strictly equal. By extending forward the profile of Ribbon Creek, whoser r hanging valleys belong to the upper set, there is found a former level (A_1) of the Merced River;r r A_2 is a lower level, indicated by the profiles of Indian Creek and the other hanging valleys ofr r the middle set; and A_3 is a still lower level, indicated by the profile of lower Bridalveil Creek,r r whose gulch belongs to the lower set. There are thus indicated three successive stages in ther r cutting of the Yosemite chasm—what are believed to be the late Miocene, the late Pliocene,r r and the early Pleistocene. Glaciation did not set in until after the third stage (A_3) had beenr r reached. The dotted lines show the approximate form of the chasm at each stage.r

r

r r r the profoundly glaciated Yosemite Valley. To settle that question the writerr plotted accurately to scale the longitudinal profiles of all these hanging valleys,r as well as of those along the lower Merced Canyon. Then, by extending ther smooth curve of each profile forward over the axis of the main canyon (in ther manner shown in Fig. 4), he determined the former level of the Merced to whichr each side valley had been adjusted. (Of course a correction had to be made inr each case for the erosion effected in the side valley by stream or glacier since itr was left hanging, but the corrections required were as a rule quite small and notr difficult to evaluate.) All the A points, finally, were plotted on a longitudinalr profile of the main canyon, and here is what was found:rr r

r There are in the Yosemite region three distinct sets of hanging valleys, disposed at different levels one above another. The valleys of Ribbon Creek,r Yosemite Creek, and upper Bridalveil Creek belong to the upper set; the valleysr of Illilouette Creek and Indian Creek belong to the middle set; the gulchesr of lower Bridalveil Creek and Cascade Creek belong to the lower set. The Ar points of each set, moreover, are remarkably accordant among themselves andr establish unmistakably a former profile of the master stream. There are thusr three such profiles, each indicating a definite stage in the cutting of the chasm.r

r r

r Now the middle profile accords closely with the profile established by ther hanging valleys in the lower Merced Canyon. It follows that the valleys ofr Illilouette Creek and Indian Creek owe their hanging character in the firstr instance to rapid gorge-cutting by the Merced in consequence of the last Sierrar uplift. These valleys were hanging before glaciation set in, but their heightr has since been greatly increased by the glacial deepening and widening of ther main chasm. It follows, further, that the upper set of hanging valleys is also ofr preglacial origin—that is, it became suspended as a result of rapid gorge-cuttingr induced by an earlier uplift. Only the lower set of valleys, or gulches, owes itsr height above the floor of the chasm to glaciation.r

r r

r *r The story told by the hanging valleys of the Yosemite region, then, is ar story of two long chapters of gorge-cutting by the Merced due to two greatr uplifts of the Sierra Nevada, followed by a chapter of glaciation.r* r

r r

r The depth of the Yosemite at each stage being known, it is not difficult tor draw its approximate cross-section for each stage (Fig. 4), and to determine itsr relations to the surrounding country. In this way it has been ascertained that ther chasm began its existence as a broad, flat valley only a few hundred feet deep,r flanked by a lowland covered with rolling hills. The present billows on ther r r uplands are these same hills lifted to a higher level. In the second stage ther Yosemite had the depth and aspect of a mountain valley. It was cut about 1000r feet below the rolling country on either side and already had hanging side valleysr from whose mouths the waters descended in broken cascades. In the third stager the Yosemite had the appearance of a rugged canyon with a narrow inner gorge,r its total depth averaging about 2500 feet. It had two sets of hanging valleys, ar high and a low one, and its sides consequently were adorned by many gloriousr cascades. Finally the canyon was profoundly remodeled—deepened and widenedr —by the glaciers of the Ice Age, and its cascades were transformed to leapingr waterfalls.r

r r

r There being no fossil-bearing deposits in the Yosemite region, the writer atr first was at a loss to find a way to determine the geologic age of any of its pre-glacialr stages. In 1921, however, he succeeded in carrying his work northward tor the nearest locality where fossils are known to occur. This locality was noner other than Table Mountain—the Table Mountain where resided Bret Harte'sr Truthful James! And there the writer was fortunate enough to be guided to ther right spot by that veteran miner and lover of the earth sciences, Mr. J. B.r Pownall, of Stockton and Sonora, and excellent casts of leaves from the hardenedr silts of a "fossil stream channel" were secured. Through the courtesy of Dr. Johnr C. Merriam, again, the casts were submitted for identification to Dr. Ralph W.r Chaney, Research Associate of the Carnegie Institution; and by him they werer pronounced to be in all probability of late Miocene age.[4] And thus it has beenr established, as definitely as is possible with the scanty palaeontologic materialr at hand, that the earliest recognizable stage of the Yosemite Valley—that indicated by the upper set of hanging valleys—antedated the close of the Miocener epoch. The first great uplift, it may be presumed, therefore, took place about ther dawn of the Pliocene epoch, and it was during that epoch that the first set ofr hanging valleys was produced. The second uplift took place probably about ther close of the Pliocene, and consequently, by the beginning of the Pleistocener epoch (which included the Ice Age), the second set of valleys was suspended.r

r r

r In the present landscape of the Yosemite region, then, the billowy uplandsr and their associated hanging valleys represent remnants of the ancient landscape of late Miocene time, preserved by reason of the exceedingly resistantr r r r nature of the massive granite. The valleys of Illilouette Creek and Indian Creek,r which lie at a considerably lower level, are remnants of the Pliocene landscape,r somewhat modified by glaciation; and the gulch of Bridalveil Creek is a prominent feature of the early Pleistocene canyon stage of the Yosemite that hasr escaped destruction by the ice.r

r r

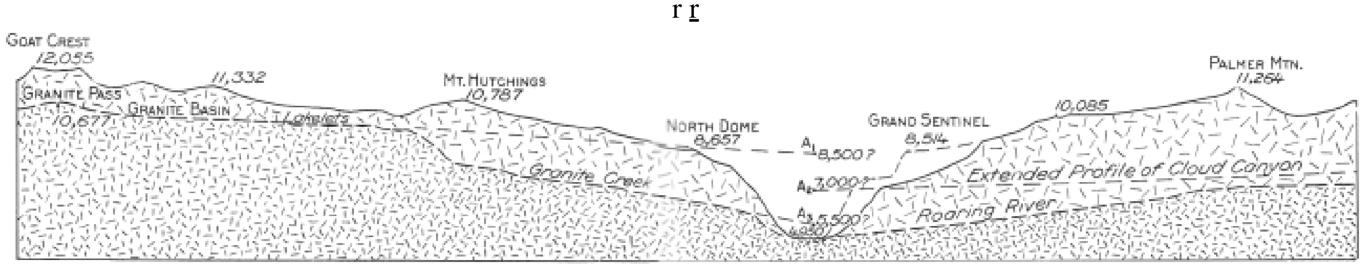
r In the Kings River region, owing to the poor preservation of the hangingr valleys, and also because of the lack of an accurate large-scale map, the successive stages in the development of the main chasm are much more difficult tor determine. Nor is it easy to single out remnants of the Miocene and Pliocener landscapes on the flanking mountain massifs. Indeed, but for the guidancer afforded by the analyses made in the Yosemite region and in other parts of ther Sierra Nevada, probably little headway would be possible in the spelling out ofr the story of the development of the Kings River Canyon. As it is, however, muchr can be accomplished in spite of the existing handicaps.r

r r

r There is little doubt, for instance, that Mount Mitchell, the level upland tor the north of it, and all of Sentinel Ridge are remnants, almost untouched by ther ice of glacial times, of the late Miocene landscape. Other remnants of thisr r
r
r r r

r r Figure 5.—Section across Kings River Canyon from Goat Crest, onr r the Monarch Divide, over North Dome and the Grand Sentinel tor r Palmer Mountain. Projected on this section is another drawn alongr r Granite Creek and Roaring River. The vertical and horizontal scalesr r are equal. A_1 represents what is believed to be the late Miocene stager r in the development of the chasm, indicated by the extended profile ofr r Granite Basin; A_2 represents the late Pliocene stage, indicated byr r the extended profile of Cloud Canyon; and A_3 represents the earlyr r Pleistocene (preglacial) stage, indicated by the lower valley of Graniter r Creek. (All such determinations are necessarily tentative.)r r
r r r

r r



r

r r r r landscape, more or less glaciated, may be identified on the crest of the Monarchr Divide. Of these, Granite Basin, indeed all of the elevated upper valley ofr Granite Creek, is of peculiar interest; for its longitudinal profile, extendedr forward to the axis of the main chasm (Fig. 5), would seem to indicate ther approximate level of the master stream for that early epoch. The South Fork,r it will be seen, then lay in a wide-flaring valley 3600 feet shallower than ther present chasm, yet already carved 3000 feet below the summits of the Monarchr Divide.rr r

r Again, there is reason to believe that the longitudinal profile of Cloudr Canyon (not shown in Fig. 5), duly corrected for glaciation, indicates ther level to which the main chasm was cut during Pliocene time. Sugarloaf Valleyr probably also belongs to the ancient landscape of that epoch. Finally, it is notr impossible that the lower valley of Granite Creek affords some indication ofr the depth of cutting achieved by the South Fork immediately prior to the comingr of the glaciers.r

r r

r Thus, tentatively and by degrees, one may find the way into an analysis ofr the features of the Kings River region. Possibly someday when that region shallr be included in a great national park, as it well deserves to be, a more detailedr map of it will become available, and the foundation will be laid for an intensiver and quantitative study such as has been made of the Yosemite Valley. What ar wonderful thesis for a future student of geomorphology that would be!r

r r

r *Reprinted from* Sierra Club Bulletin, *1926, pages 224-236.*r

r r

r [1]Here is meant, of course, that broad-floored stretch of the South Fork canyon which extendsr from the mouth of Bubbs Creek westward to Cedar Grove—the "Kings River Yosemite" of Johnr Muir. (See U.S.G.S. topographic map of Tehipite Quadrangle.)r

r r

r [2]In sufficient detail to permit the drawing of a contour map from which a relief model of ther preglacial Yosemite chasm can be constructed.r

r r

r [3]See footnote on page 62.—Ed.r

r r

r [4]See Appendix for table showing Major Divisions of Geologic Time in use by the U. S. Geologicalr Survey, and the time values for these divisions as determined by the Committee on the Measurementr of Geologic Time, National Research Council.—Ed.r

r r r r
r r

---

r r

r **r Next: Devil's Postpile •r Contentsr • Previous: Cockscomb Crestr** r

r r r

r

r r

r

r r

r r r r r r r r r r r r r r

r

r r

r r

r

r r r

r **Next: Shepherd's Crest •r Contentsr • Previous: Kings River Canyonr** r

r r r

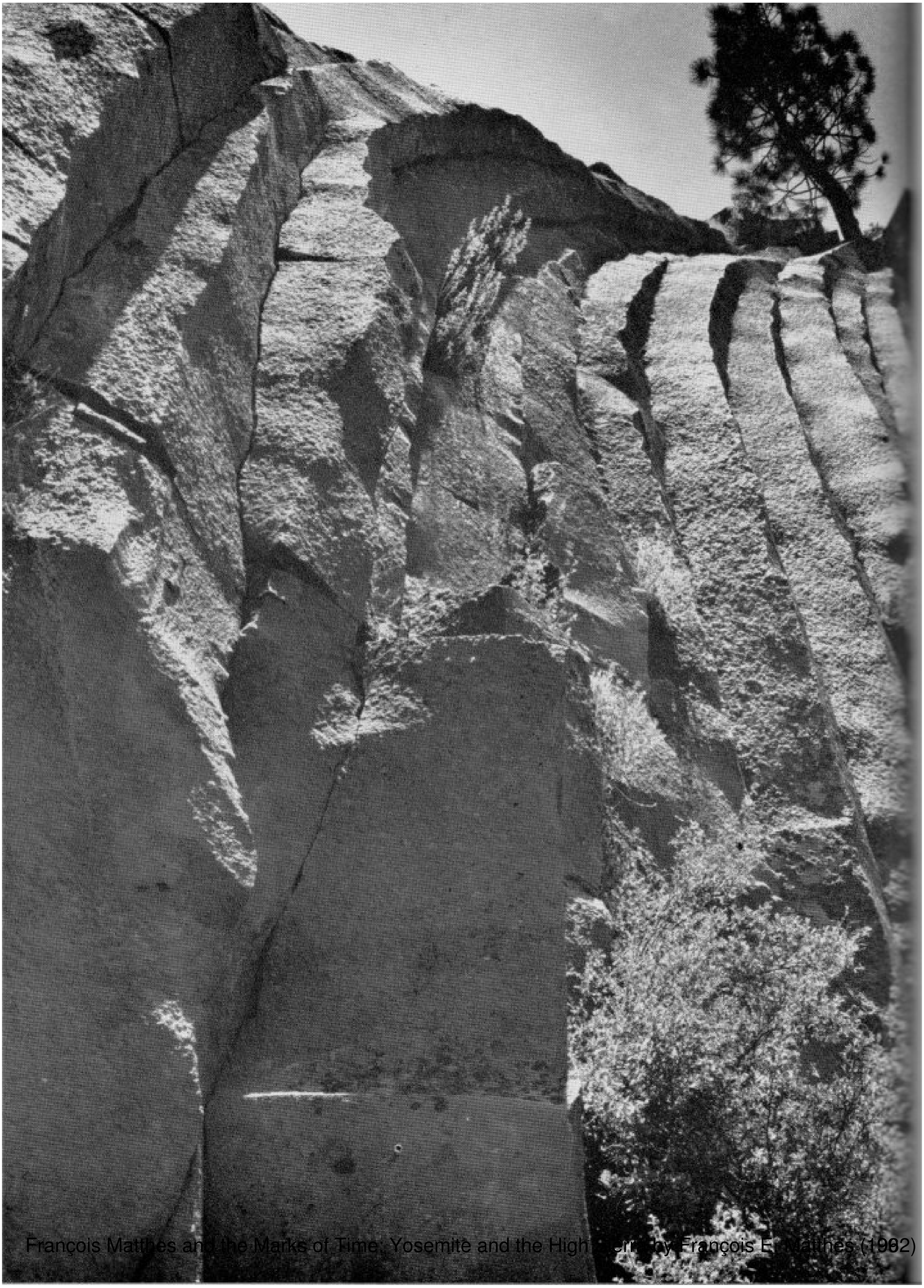
François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

---

r r r r

r r



r

r r r

r r Devil's Postpile, Devil's Postpiler National Monument, California. By William Hailr

r r r r

THE DEVIL'S POSTPILE AND ITS STRANGE SETTING

r r r

r r The Sierra Nevada,r r geologists tell us, consists essentially of one vastr block of the earth's crust that lies tilted toward the southwest, its northeasternr edge elevated to form the crest line. The surface of the block, in general, slopesr gently down to the Great Valley of California; the steep eastern side, exposedr by the uplift, and in part, probably, by the subsidence of the earth blocks underlying Owens Valley and the Mono Basin, forms the imposing eastward-facingr mountain front. A cross-section of the Sierra Nevada, accordingly, is like thatr shown, with vertical dimension somewhat exaggerated inr Figure 6.r

r r

r To an aviator soaring high above the range, its block form and its westerlyr slant are readily manifest, but to the mountaineer who, like a pygmy ant, crawlsr among the peaks and canyons of its surface, they are not obvious. Only fromr some of the higher summits on the main crest can he obtain a sufficiently comprehensive view to perceive the general form of the range. A great satisfaction it is,r if you have the tilted-block concept in mind, to see it thus impressively demonstrated: Southwestward from Mount Dana or Mount Whitney, for instance, ther range falls away gradually, its slope diversified by minor crests and ridges; tor the northeast it drops off with amazing abruptness, to a depth of more than 6000r feet from the summit of Mount Dana, to a depth of 11,000 feet from Mountr Whitney. To the northwest and the southeast the crest of the range extends asr far as the eye can see, studded with boldly sculptured peaks. There is additionalr satisfaction in finding that, although the range is deeply furrowed by canyonsr and gulches, the divide between the easterly and westerly waters coincides inr the main with the crest line.r

r r r r r

r If now you are fully convinced of the soundness of the tilted-block idea,r and if perchance you are inclined to feel cocksure about it—even scientists occasionallyr have spells of cocksureness, 'tis only human—take yourself to the headwatersr of the Middle Fork of the San Joaquin, the land of the Devil's Postpile,r the Mammoth Pass, and the Ritter Range. There the main crest of the Sierrar Nevada sags down ignominiously to a low, flattish ridge, a third-rate feature ofr the sort that elsewhere in the Sierra Nevada would scarcely attract attention.r No alpine "High Sierra" here, nor any amazing drop to the eastern foot of ther range! From the Mammoth Pass the descent to the east is only 1500 feet, andr from the saddle north of Mammoth Mountain, which is slightly lower than ther pass, the descent is even less, and mostly in the form of a slope.r

r r r r

r r 

r

r r r

r r Figure 6r

r r r r

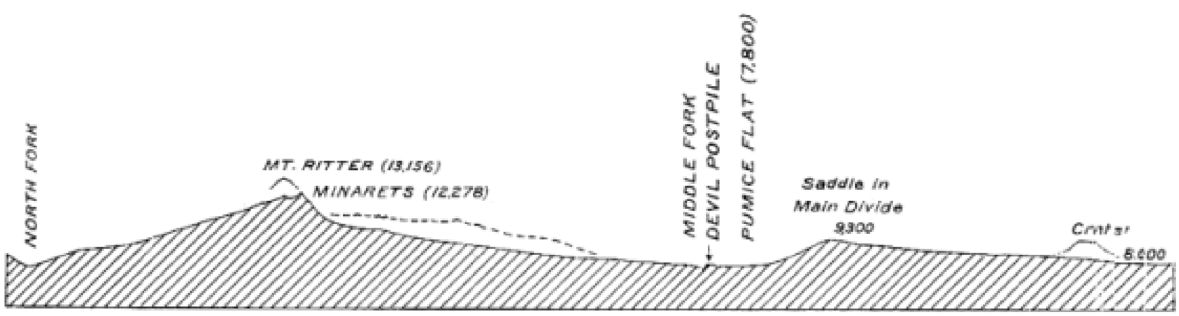
r It is rather disturbing to one’s ideas of the nature of a tilted-block range,r further, to discover that the canyon of the Middle Fork, immediately west ofr the saddle in the divide, is considerably lower than the country to the east. Ther altitude of Pumice Flat, north of the Devil’s Postpile, is 7700 to 7800 feet; thatr of Reds Meadow 7500 feet; the saddle in the divide is about 9300 feet, and ther sloping plain directly east of the saddle averages over 8000 feet. To enhance ther anomaly of the situation, there rises, west of the Middle Fork, an exceptionallyr bold, spectacular group of mountains that dwarfs the divide into insignificancer —the group of which Banner Peak, Mount Ritter, and the Minarets are ther principal summits. Over 13,000 feet in altitude, Mount Ritter towers more thanr a mile above Pumice Flat and the Devil’s Postpile, and fully 3800 feet above ther saddle in the divide. Even Mammoth Mountain is outtopped more than 2000r feet. A profile line over the Ritter Range, across Pumice Flat, and over ther divide, plotted without vertical exaggeration from the contour lines of the topographic map,r turns out as shown inr Figure 7.r

r r

r How are these singular facts to be reconciled with the tilted-block form ofr the Sierra Nevada? Or is that form only a myth? Why is the main divide nearr the Devil’s Postpile so much lower than the Ritter Range? Why is not that loftyr range, which connects at the north with Mount Lyell, itself the divide? How didr r r the Middle Fork of the San Joaquin, which heads on the east flank of Bannerr Peak, succeed in cutting its canyon around the southern end of the Ritter Range?r Why is the floor of its canyon in the vicinity of the Devil’s Postpile so much lowerr than the country east of the divide? And what, finally, is the real nature of ther Devil’s Postpile? These are the questions that anyone who has visited the regionr is bound to ask himself.r

r r

r It will be a comfort to those who still have a lingering faith in the tilted-block theoryr to note, in the first place, that though the crest of the Sierra Nevadar in the vicinity of the Devil’s Postpile seems strangely low, nevertheless its lowestr r r r

r r 

r

r r r

r r Figure 7r

r r r saddle, north of Mammoth Mountain, is only 600 feet lower than the Tiogar Pass, which thrills the motorist with its great altitude (9941 feet). The fact is, ther main divide near Mammoth Mountain is not abnormally low for the central partr of the Sierra Nevada. It merely seems low because it is overshadowed by ther Ritter Range and because the drop to the country to the east is slight. The latterr circumstance is, however, readily explained by the fact that the country east ofr the divide is built up with volcanic materials—lava and pumice. The total thickness of these materials can only be surmised, but it is probably not less thanr 2000 feet. The pumice alone must have great thickness, for it forms the longr slope, more than 1000 feet high, that leads up to within 300 feet of the saddler in the divide. There can be no doubt that it conceals bold cliffs, and it mayr reasonably be supposed that if the pumice and the other volcanic materialsr underneath were removed, there would be found here, as elsewhere along ther northeast flank of the Sierra Nevada, an abrupt and imposing escarpment.rr r

r What is this pumice, and whence did it come? It consists of small fragmentsr and lumps of highly siliceous lava, literally steam-shredded, that were blown byr spasmodic explosions from a series of craters to the east of the range. Therer are fully thirty of these craters, extending in a row from Mammoth Mountainr northward to Mono Lake. Some are only a few hundred feet high, the largestr r r more than 2000 feet. Their alignment (see Mount Lyell quadrangle) suggestsr strongly that they are associated with a great fracture, or a zone of fractures,r in the crust of the earth. The bulk of the pumice naturally showered downr immediately about the craters from which it was ejected, but the finer particlesr drifted some distance with the wind, and as a consequence there is a sprinklingr of pumice over a considerable part of the Sierra Nevada. The Mammoth Passr and the divide for several miles to the north are most thickly covered, andr Pumice Flat, as its name implies, is well supplied with it. Even at Reds Meadowsr and farther south along the Middle Fork there is a thin veneer of pumice. Ther dust it creates wears the skin off one’s fingers, as those who have camped inr those parts have reason to remember.r

r r

r The fractures in the earth, indicated by the row of craters mentioned, in allr probability do not stop at the foot of the Sierra Nevada, but penetrate somer distance into the body of the range. For not only does Mammoth Mountain,r itself the remnant of an old volcano, stand in line with them, but so do the littler Red Cones perched on the east side of the canyon of the Middle Fork, andr Pumice Butte, north of Fish Creek. The famous hot spring near Reds Meadow,r though somewhat west of the line, doubtless is connected with it.r

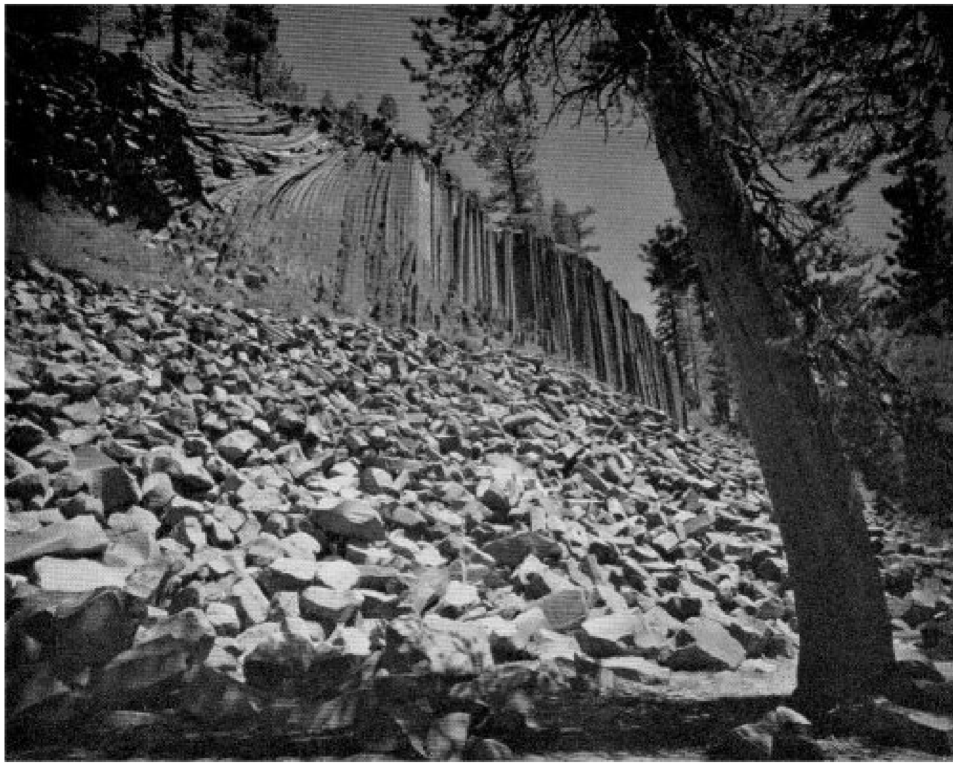
r r

r A bubbling hot spring of this type, it is now realized, is essentially a volcanicr phenomenon. It is fed in part by steam emanating from hot lava in process ofr crystallization, in part by surface water that has seeped down to great depthsr and has been heated by the steam. Water generated directly by igneous rocksr is what geologists please to call “juvenile” water, in distinction to “meteoric”r water, which falls upon the earth from the clouds. Let those who would maker their ablutions in the hot spring bear this in mind. Perhaps they will feelr rejuvenated as well as cleansed, if only as a result of the therapeutic value ofr the thought that the water is in part new-born, straight from Mother Earth.r

r r

r Volcanism appears to have been active along the line of fractures at widelyr different dates in geologic history. The explosions of pumice represent but ther latest chapter. They began toward the end of the Ice Age, and continued atr intervals probably until fairly recent times. It is certain in any event that ther pumice at Reds Meadow fell a long time after the Middle Fork Glacier hadr melted back to its source. Mammoth Mountain, on the other hand, dates backr to preglacial time, and must be well over a million years old. By the long-continued disintegration of its volcanic rock it has long since lost its originalr crater form and has been reduced to a shapeless hump.r

r r r r

r Intermediate between the formation of Mammoth Mountain and the eruptions from the pumice craters there occurred another remarkable volcanic outbreak: Right in the Mammoth Pass a fissure opened and let forth a flood ofr black basaltic lava. By far the greater part of this fluid material poured intor the canyon of the Middle Fork and there spread out in an elongated mass thatr r r r r r  r

r r r

r r Devil’s Postpile, Devil’s Postpile National Monument, California. By Cedric Wrightr

r r extended from the head of Pumice Flat southward beyond the site of the Rainbow Falls. The total length of this mass (which may possibly have been suppliedr in part from other vents) was about six miles; its thickness ranged from 100 tor perhaps 700 feet. The outpouring took place during the interglacial epoch thatr preceded the last glaciation in the Sierra Nevada—presumably between 100,000r and 200,000 years ago.rr r

r The Middle Fork Glacier, when for the last time it readvanced, found thisr mass of basalt obstructing its path. Being about 1000 feet thick, it had no difficultyr r r in overriding the obstruction. Moreover, the basalt, having cracked intor columns by contraction while cooling, was readily quarried away by the glacier,r column by column. During the thousands of years that the ice held sway, therefore, most of the basalt was removed and the canyon re-excavated nearly, inr places all the way down to the granite. Only the more obdurate parts of ther basalt mass were left standing. Of these the largest is that strange hump in ther middle of the canyon, about 300 yards long and 200 feet high, which, becauser of the fancied resemblance of its tall, straight columns to posts stacked togetherr in upright position, has been facetiously—and quite aptly—named the Devil’sr Postpile.r

r r

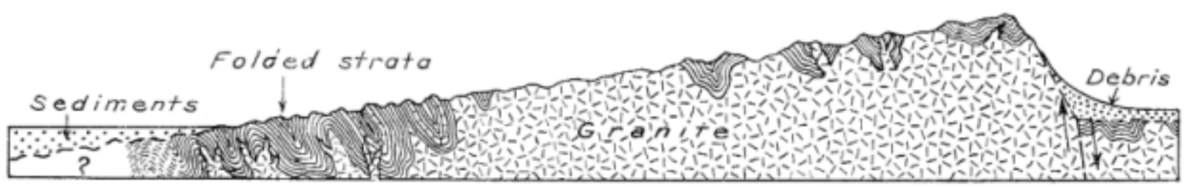
r A mere hummock in a landscape dominated by mile-high peaks, the Devil’sr Postpile is nevertheless a feature of unusual interest to the scientist as well asr to the layman. The columns that form its steep west front, facing the river, arer exceptionally high, straight and cleancut; those at its southern end are remarkable for their curvature and their radial arrangement with respect to a center atr the top of the pile. Strikingly beautiful, also, are the six-sided or five-sided endr facets of the columns which in places still gleam with the polish that wasr imparted to them by the overriding glacier.r

r r

r But now let us return to the interpretation of the larger features of ther region. The full significance of the broad sag in the crest of the range is yet tor be revealed. In all likelihood it is the mouth of an ancient valley which extendedr far to the eastward and whose stream emptied into the Middle Fork of the Sanr Joaquin at that remote epoch when the Sierra block was not yet uptilted andr when the waters from the country to the east still drained seaward across itsr surface. At that time, of course, the Middle Fork had not yet cut its profoundr canyon, but flowed in a relatively shallow valley slightly below the level of the sagr and below the shoulders that now flank the canyon. It seems probable, furthermore, in view of the depth and breadth of the sag (Mammoth Mountain did notr then exist), that the valley indicated by it was the pathway of a large river—r indeed, of the main San Joaquin—and that that part of the present Middle Forkr which pursues a southeasterly course from Thousand Island Lake to the Devil'sr Postpile was merely a tributary of the master stream. The San Joaquin River,r as we now know it, therefore appears to be a "beheaded" stream, its originalr upper course having been cut off by the uptilting of the Sierra block. Severalr other Sierra streams beside the San Joaquin, that now begin in gaps in the crestr of the range, doubtless were similarly decapitated.r

r r r r

r It is significant that, although the main San Joaquin flows southwestward,r quite normally down the slope of the range, a number of its tributaries haver southeasterly or northwesterly courses, in disregard of the general slant of ther Sierra block. Not only the head of the Middle Fork, but the North Fork, Graniter Creek, and Chiquito Creek have southeasterly courses; Fish Creek and ther South Fork have northwesterly courses. All owe their trends to the constrainingr influence of more or less prominent ridges that themselves have a generalr northwest-southeast trend. A similar state of things is found in certain parts ofr the drainage basins of the Merced, Tuolumne, Kings, and Kaweah rivers. Therer is a definite reason for this. The area now occupied by the Sierra Nevada borer at an earlier time in geologic history—namely, during the Cretaceous period[1]—r r r r

r r 

r

r r r

r r Figure 8r

r r r a series of roughly parallel mountain ranges that had a general northwest-southeast trend. Although this ancient mountain system, as a result of streamr erosion during more than a hundred million years, was in large part worn downr before the Sierra block first became outlined and gained a westerly slant, nevertheless a number of the higher northwest-southeast ranges and the valley troughsr between them were perpetuated. The new Sierra Nevada, therefore, inheritedr these features from the ancestral mountain system. When the Sierra block wasr uptilted, all the ranges and valleys on its surface were tilted with it. Indeed,r our Sierra Nevada is to be regarded as something greater than a simple mountainr range. It is of the order of a mountain system. Its areal extent equals that of allr the Swiss, French, and most of the Italian Alps together!rr r

r The ancient mountain ranges of the Cretaceous period were not block ranges.r They were carved from great wrinkles in the crust of the earth (Fig. 8) produced by the compression and folding of a series of strata that lay originallyr flat, having been deposited on the floor of the ocean—strata of sandstone, limestone, shale, and clay aggregating at least a mile in thickness. While the foldingr was in progress molten granite surged up and invaded the folds from below.r Squeezed by the intense pressure and baked by the heat of the granite, ther r r r stratified rocks were "metamorphosed" to quartzite, marble, schist, and slate.r Large bodies of these metamorphic rocks still remain in different parts of ther Sierra Nevada, and by their contorted structure give evidence of the formerr existence of the mountain ranges, and even indicate their trend, their parallelism,r and their general character, which must have been analogous to that of ther present Appalachian Mountains. As a matter of fact the geologist finds incorporated in the Sierra block remnants of two such series of folded strata thatr differ widely in age, and thus he knows that two systems of mountains have inr turn occupied the place of the present Sierra Nevada in times gone by.r

r r

r The foothills and the choppy ridges through which the Merced River cutsr its canyon below the Yosemite are composed largely of these metamorphic rocks.r The mountains fronting upon the Mono Basin similarly are made of them. Somer of the high crests that have inherited their northwesterly trends from the mountains of the Cretaceous period consist of smaller bodies. The Le Conte Divide,r near the head of the South Fork of the San Joaquin, is a notable example. Ther Ritter Range is another but rather complicated example. The structure of ther metamorphic rocks is most readily traced along its northeast base. The bedsr there stand vertical or at high angles, and have northwesterly trends. Grayr schists and variously colored quartzites predominate. The upper canyon of ther Middle Fork, from Pumice Flat to Thousand Island Lake, cuts lengthwiser through these rocks and to them probably owes its position and its trend. Ther Ritter Range itself is composed in part of dark mottled rocks that representr ancient lavas metamorphosed out of all semblance to their former selves. Associated with these is a complex of dark igneous rocks that doubtless were injectedr in a molten state into the arch of one of the great upfolds of the ancient mountains. It is the exceedingly obdurate nature of these rocks that has permittedr the Ritter Range to maintain its great height. The range notably terminates atr the south where these rocks end. When, therefore, you climb Mount Ritter, your climb the core of one of the ancestral mountains that were formed more than ar hundred million years before the present Sierra Nevada was uplifted.r

r r

r *Reprinted from* Sierra Club Bulletin, *1930, pages 1-8*.r

r r

r [1]Seer footnote on page 97,r and Appendix.—Ed.r

r r r
r r

---

r r

r **r Next: Shepherd's Crest •r Contentsr • Previous: Kings River Canyonr** r

r r r

r

r r

r

r r

r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r The Little “Lost Valley” on Shepherd’s Crest >r

r r

r

r r r

r **r Next: Tuolumne Meadows •r Contentsr • Previous: Devil’s Postpiler** r

r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

r r r

THE LITTLE “LOST VALLEY” ON SHEPHERD’S CREST

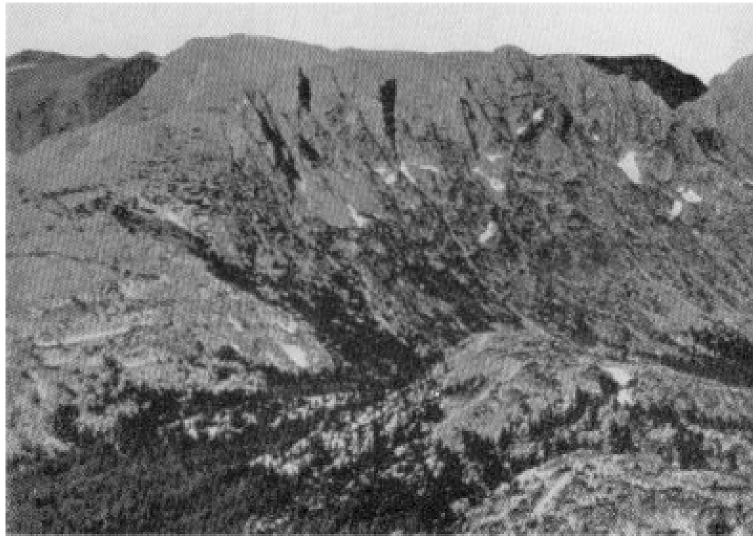
r r r

r r Last summer,r r while roaming over the High Sierra with the Scout Naturalist Expedition, it was my good fortune to become acquainted with a piece ofr mountain sculpture of a very exceptional sort.[1] Though presumably not withoutr parallel in the Sierra Nevada, it is nevertheless of a type that from the veryr nature of things cannot be represented by more than a few examples. Ther feature in question is on the top of the mountain known as Shepherd’s Crest,r which stands forth prominently on the east side of Virginia Canyon, a mile orr more above the McCabe Lakes. To many members of the Sierra Club, doubtless,r this mountain is a familiar landmark; for all I know, it has been climbed andr explored from end to end; but to me it was new and its summit sculpture ar revelation, the more unexpected since the small-scale topographic map, which Ir had duly scanned in advance, gave scarcely a hint of its unusualness.r

r r

r Viewed from any low point to the southwest, Shepherd’s Crest appears surmountedr by a row of blunt pinnacles, all curved in the same direction, andr rising from a sheer wall that is cleft at almost regular intervals. Not havingr seen the mountain before, one might readily suppose these jagged teeth tor constitute the main summit crest; but on viewing it from other directions andr from higher vantage-points, one perceives that there is a second crest, higherr and smoother, some distance to the north of the first. Between them lies a bitr of rolling upland that seems wholly unrelated to the sheer glacier-trimmed sidesr of the mountain, and, what is most remarkable, this bit of upland consists of ar r r r V-shaped valley instead of a convexly moulded summit. From each of the twor confining crests the surface slopes inward to an old stream-channel that drainsr out at the western point of the mountain. This channel is, however, much nearerr to the low southern crest than to the high northern crest, which culminates in ar summit almost 400 feet above the valley, and so the feature as a whole is strikingly asymmetric.r

r r

r The accompanying photographs, taken by members of the Scout Naturalistr r r r r  r

r r r

r r Shepherd's Crest from the southwest. By Robert Bransteadr

r

r r Expedition, will help to make clear the odd configuration of the little valley.r There are added a sketch map and a bird's-eye view designed to bring out itsr character more completely; these are based merely on the topographic map, ther photographs, and my own observations, not on instrumental surveys of anyr sort. The little upland area, it will be seen, is roughly triangular in outline, andr measures three-quarters of a mile in length from northwest to southeast, andr one-quarter of a mile in greatest breadth. Its lowest point, at the lip of ther valley, is just above the 11,500-foot contour line; the highest point on ther northern crest reaches an altitude of 11,860 feet. The floor of Virginia Canyon,r near by, is somewhat below 9000 feet.rr r r r

r In the view from Mount Conness (below), Shepherd's Crest is discernibler in the left middle distance, mainly by the gentle slope that leads up to its highr northern crest. The little valley itself is not visible; being masked by ther pinnacled southern crest, nor is its actual extent apparent, yet its isolated position amidst the titanic environment of craggy peaks and profound canyons isr almost dramatically revealed. It seems like a little secluded skyland realm, cutr off from the fierce world around it by impregnable cliffs.r

r r r r

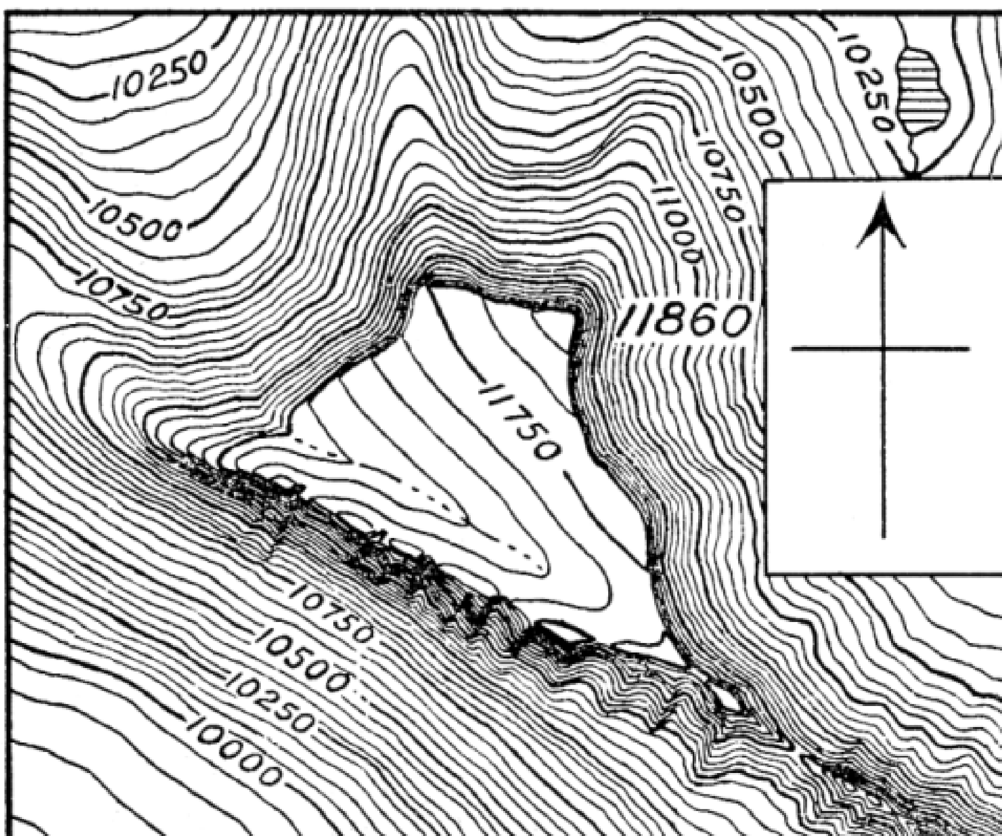
r r  r

r r r

r r Looking north from Mount Conness. In the lower part of the view is ther
r nivated west slope of North Peak. A bit of the upland surface on Shepherd’sr
r Crest is visible in the left middle distance, at the far end of a long arête.r
r By Richard M. Leonardr

r
r r

r That this little “lost valley,” as the boys called it, is a lone remnant, a surviving bit of an ancient landscape of moderate relief that once had wide extent,r but that has been largely consumed by the incision and widening of the deepr newer canyons, readily suggests itself to one who observes it critically. Certainlyr to a geologist trained in the interpretation of topographic forms the fact is atr once manifest from the very contrast between the flowing contours of the littler upland valley and the stark sculpture of the canyon walls below. Moreover,r in the foreground of the view from Mount Conness one beholds the smoothr r r westerly slope of North Peak, which is in the same general range of altitudesr as the valley on Shepherd’s Crest and represents another remnant of the samer ancient landscape. On the west it connects with still other smoothly curvingr remnants on Sheep Peakr (not visible in photo on page 111).r To the southeastr of Mount Conness, again, one looks down upon a gently sloping tableland thatr exhibits the same subdued style of topography at the same general level. Fartherr to the southeast is the long flattish top of White Mountain, and beyond that ther nearly level Dana Plateau, the largest tabular summit of this type. To the eastr r r r

r r 

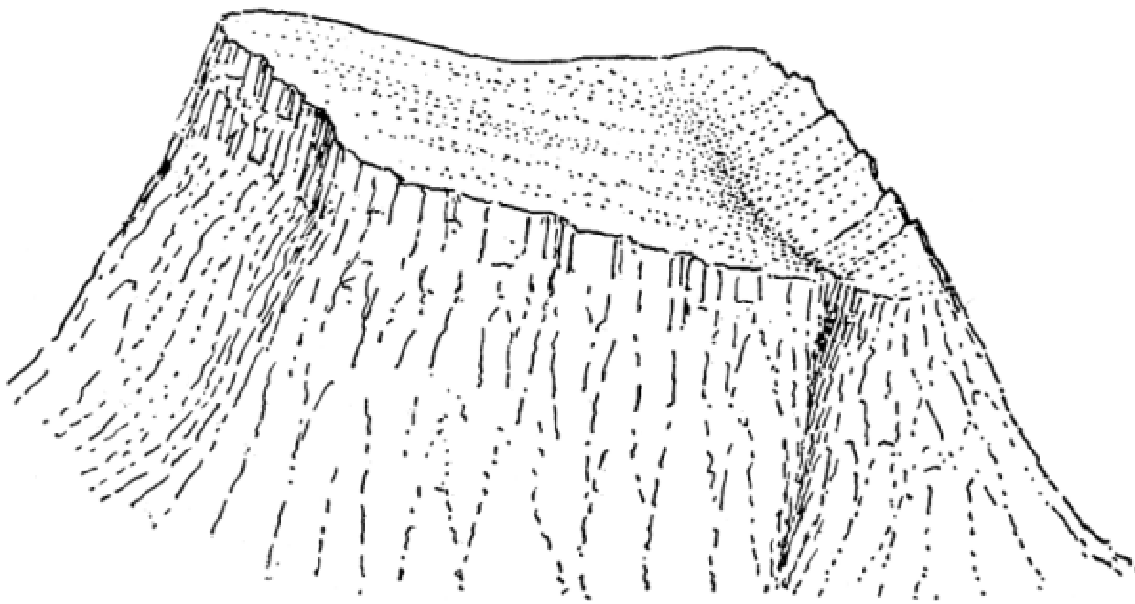
r

r r r
r r Figure 9.—Sketch map of Shepherd’s Crestr

r
r r and the northeast of Mount Conness, finally, are the smoothly rounded summitsr of the Tioga Crest, about three miles in aggregate length.rr r

r Though these different fragments of the ancient landscape (or erosion surface, as geomorphologists would term it) lie so far apart that the missing portions between them can hardly be reconstructed in imagination, it is possible,r nevertheless, to make local restorations and to visualize to some extent ther progressive destruction of the old topography by the development of the new.r There can be no reasonable doubt, for instance, that the long attentuated arêter which ties Shepherd's Crest to the main divide of the Sierra Nevada was once ar massive ridge broad enough to bear a strip of the ancient topography throughoutr its entire length. By the glacial enlargement of the deep canyons on both sidesr r r to capacious cirques it has been gradually reduced in width until now there isr left only a thin, sharp knife-ridge, a cleaver,2 as such a feature would be termedr in the Mount Rainier country. By the divergence of the two cirque glaciersr Shepherd's Crest and its little upland valley happily were saved from a similarr fate, but the broadening of the cirques nevertheless has progressed far enoughr to destroy in large part the two spurs of the upland topography that originallyr flanked the little valley. The two crests that now enclose it are not the tops ofr those ancient spurs—they are merely the sharp edges in which the encroachingr cirque walls without cut the gentle slopes of the valley within.r

r r r r



r r r

r r r

r r Figure 10.—Bird's-eye view of the Little Lost Valleyr
r on Shepherd's Crestr r

r
r r

r But has not the little valley itself been glaciated? you will ask. No, it exhibitsr none of the characteristic signs of glaciation—that is, of erosion by a movingr ice mass shod with rocks. According to the report of Scoutmaster Richard M.r Leonard, who with several of the boys climbed up to the little valley by way ofr the spur that leads to its lip, polished and striated, or even simply smoothed rock-surfacesr and rounded ledges, such as are common features of glacier-beds, arer wholly absent from it; neither are there any accumulations of rock debrisr resembling moraines. On the other hand, he found its slopes encumberedr throughout with angular blocks, large and small, loosened and heaved by ther freezing of water in joints and crevices; and most of these blocks, he observed,r r r r lie on or near their places of origin—no forces other than those of frost, snow-pressure,r and gravity, apparently, have acted upon them. Such a mantle ofr frost-riven fragments is a characteristic feature of high mountain slopes thatr have borne no active glaciers, but only inert drifts or fields of snow. It is ther product of that slow and unspectacular rock-shattering process due to oft-repeatedr alternations of frost and thaw, unaccompanied by any adequate transporting agency, for which some years ago I proposed the term nivation, inr contradistinction to *glaciation.*[3]r

r r

r While alternating freezings and thawings occur almost everywhere at highr altitudes, the special combination of conditions that results in nivation occursr typically only on high summits and slopes that annually bear snowdrifts forr long periods. For both the recurring drifts and the porous rock mantle tend tor prevent the melt-water from gathering into vigorous transporting and erodingr streams, and instead to distribute it into many feeble rills. Nivated slopes,r accordingly, not only are mantled with rock debris that remains in situ (exceptr as it is affected by local creeping movements known as “soil flow”),[4] but theyr are devoid of sharply cut stream-channels as well.r

r r

r The little valley on Shepherd’s Crest exhibits both of these effects of nivation.r Its sides are rock-strewn throughout, and also unfurrowed by stream-wornr ravines. Nevertheless, these facts alone cannot be accepted as absolute proofr of its non-glaciation, for it is conceivable that the little valley was glaciated atr a very early date in the Ice Age—so long ago that the nivation process has sincer had time to obliterate all traces of ice wear. At least three, and possibly fourr epoch[5] of glaciation have been recognized in the Sierra Nevada, and the earliestr of these occurred presumably not less than half a million years ago. Such a spanr of time might have been long enough to give the little valley a thoroughly nivatedr aspect. However, it is to be observed that the valley retains the V-shape characteristic of stream erosion as well as remnants of a stream-channel, now apparentlyr r r r no longer functional, at the bottom of the V. These facts constitute almostr irrefutable proof of non-glaciation, for even moderate glacial action would haver sufficed, considering the jointed structure of the granite of Shepherd’s Crest, tor remodel the valley into a fairly smooth U-shape and to wipe the central stream-channel out of existence; and no amount of nivation would have transformed ar glacial U-shape back to a V-shape, or would have produced a new central channel. Its distinct V-shape, therefore, together with its nivated aspect, proves conclusively that the little valley on Shepherd’s Crest has remained unglaciated.r

r r

r Perhaps it will seem as though this conclusion had been reached with needless caution; but it is to be borne in mind that a hollow feature such as a valleyr is inherently well-adapted for the catchment of large quantities of snow andr for the generation of a glacier—much better adapted than a tabular or convexr r
r
r r

r
r r Ancient landscape on North Peak, Mount Conness in right background. Taken from the topr r of the avalanche chute at the head of Little Lost Valley. The nivated slope of North Peakr r contrasts strikingly with the glacial sculpture roundabout. By Alfred Doler
r r r
r

r r r

r

r r r r r summit. The non-glaciation of the little valley on Shepherd's Crest thereforer seemed rather unexpected, and it called for particularly convincing proof.rr r

r Such proof having been found, there opens at once a new vista of thought onr the subject of the non-glaciation of the high tabular summits of the Sierrar Nevada in general. All the tabular summits I have been able to examine bearr the earmarks of prolonged nivation, yet corroborative evidence of their non-glaciation is not in every instance afforded by their topography. However, if ther valley on Shepherd's Crest has definitely escaped glaciation, then the presumption is all the stronger that these tabular summits—or at least a large proportion of them—have escaped glaciation also.r

r r

r Now, these summits, mark you, are situated in the highest parts of ther range, whence emanated the mighty ice-streams of the glacial epoch—ice-streams that attained lengths of thirty to sixty miles and depths of 2000 to 4000r feet. Shepherd's Crest itself stands between two large cirques that formerlyr held glaciers a thousand to fifteen hundred feet in thickness, and it fronts onr Virginia Canyon, which was the pathway of a trunk glacier fourteen miles inr length and 2000 feet in thickness. The unglaciated slope on North Peak andr the gently sloping platform to the southeast of Mount Conness are both literally surrounded by deep cirques that sent forth good-sized ice-streams. Ther same is true of the level top of White Mountain, of the Dana Plateau, of ther tabular summits of Mount Gibbs, Kuna, Koip, and Blacktop peaks, andr amongst many others farther south, of Mount Darwin and Mount Whitney.r How then, it may be asked, does it happen that all these high-level tracts haver escaped the heavy hand of the ice which wrought destruction all around them?r

r r

r One reason readily suggests itself from the fact that they are all so orientedr as to be exposed to the heat of the midday sun as well as to the southwesterlyr winds—which are the prevailing winds in the High Sierra, as is so eloquentlyr attested by the asymmetric and even recumbent forms of the timberline trees.r Everyone of the tabular summits and slopes before mentioned is inclined to ther southwest, the west, or the south. Even the little valley on Shepherd's Crest,r although its axis trends northwestward, has in the main southwesterly exposure,r for the row of pinnacles on its southern edge is too low to create a “wind shadow”r of any consequence. Moreover, any westerly air-currents that enter the littler valley at its lip must in part be deflected by the high northern crest so as to turnr directly up the valley.r

r r

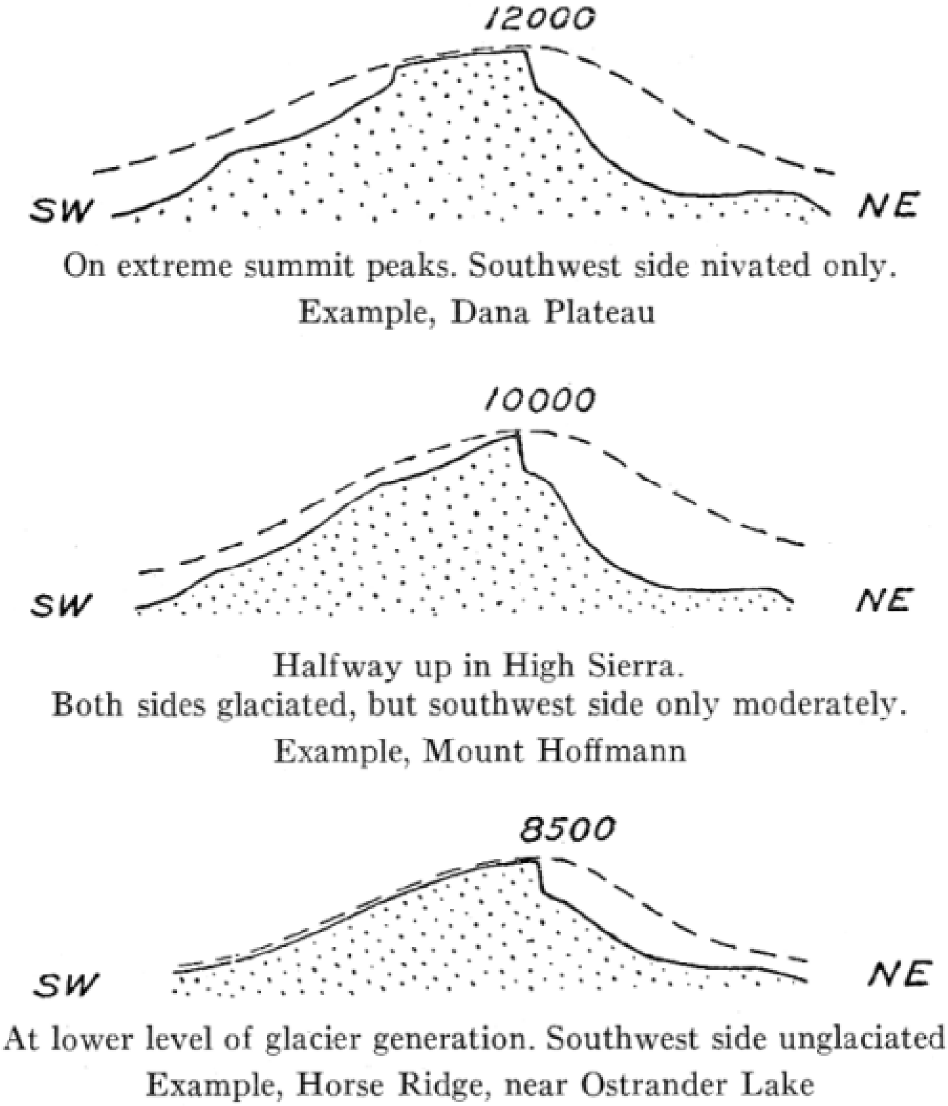
r Now, it is a fact of observation that the southwesterly winds blow the bulkr r r of the snow, while it is still in a powdery state, from the exposed slopes up overr the mountain crests, and fling it in great banners, as Muir aptly called them,r out to the northeast, to let it swirl down at last in the sheltered valley below.r Whatever snowdrifts remain untouched by the wind are later consumed by ther rays of the sun, and so toward midsummer all southwesterly and southerlyr mountain sides are wholly bared, whereas the northeasterly and northerly sidesr are still generously flecked with snow, and in some places even retain perennialr ice bodies.r

r r

r In an article which he published in the *Sierra Club Bulletin*, as well as in ther *Journal of Geology*, the late Dr. G. K. Gilbert[6] pointed out that during ther Ice Age this markedly unequal distribution of snow, due to the combined actionr of wind and sun, must have tended to minimize glacial action on the southwesterlyr and southerly sides of the mountain crests and to intensify it on their northeasterlyr and northerly sides. As a consequence, many of these crests are nowr decidedly asymmetric in form, their southwesterly and southerly sides slopingr at moderate angles, and their northeasterly and northerly sides being veryr abrupt, in part composed of unscalable cliffs. Dr. Gilbert saw, furthermore,r that this asymmetry becomes more pronounced toward the lower levels of ther High Sierra, where the windswept and sunny slopes were only feebly glaciated,r and that it reaches an optimum at what may be termed the lower limit of glacierr generation, where small glaciers could exist only on the sheltered northerly andr northeasterly sides of the ridges, and where the southerly and southwesterlyr slopes remained wholly unglaciated. The contrast there is between the hacked-inr headwalls of small cirques, on the one hand, and the gentle contours due tor normal weathering and stream erosion, on the other hand. But, curiously, Dr.r Gilbert did not complete his analysis. He did not see that the asymmetry of ther crests becomes more pronounced also toward the upper levels of the High Sierra,r and reaches another optimum on the lofty, tabular summit peaks, where ther contrast again is between intense glaciation, on the one hand, and complete non-glaciation, on the other.r

r r

r Three circumstances account for the non-glaciation of the tabular summitr peaks of the Sierra Nevada and the little valley on Shepherd's Crest: First, ther southwesterly winds attain much greater velocity and sweeping power at ther crest of the range than at lower levels on its west slope; second, because of ther r r cold and the dryness of the air at the higher altitudes, the snow there remainsr longer in a powdery state and susceptible of being shifted about by the wind;r and third, less snow falls in the winter on the main summit peaks than at levelsr 2000 to 3000 feet lower down. The last statement, it is true, is not supported byr actual measurements of snow at different elevations on the west slope, but it mayr r r r



r r r

r r r

r r Figure 11.—Profiles of asymmetric crests inr
r Sierra Nevada.r

r

r r safely be inferred from the fact that the clouds which blow in from the Pacificr Ocean discharge the bulk of their snow approximately at the level at which theyr strike the chilling body of the range—at altitudes between 8000 and 11,000 feet.[7]r Thence upward they inevitably discharge diminishing quantities as they riser toward the summit. In these respects the conditions in the Sierra Nevada arer analogous to those that obtain in many other mountain ranges of great height,r notably the Swiss Alps, the Pyrenees, the Caucasus, and the Andes of Southr r r America. In all these ranges the zone of maximum snow precipitation is knownr to lie several thousand feet below the summit peaks.rr r

r During the more severe climate of the glacial epoch, naturally, the snow-cloudsr hung even lower on the Sierra Nevada than they do today, and the zoner of maximum snow precipitation was correspondingly lower on its west slope.r The tabular summit peaks then received proportionately less snow than now,r and rose into regions of relative aridity. In that wintry epoch too, no doubt, ther southwesterly winds went roaring over the crest of the range with greater furyr than at the present time, and so, for both of these reasons, the conditions werer peculiarly favorable for the non-glaciation of the higher wind-swept slopes.r Paradoxical though it may sound, then, it is because of their great heightr that the tabular summit peaks and the little valley on Shepherd’s Crest haver remained unglaciated.r

r r

r Remains the question: How old is the little valley on Shepherd’s Crest? Or,r more generally, how old is the “ancient landscape” of which it and the numerousr tabular summit-tracts in the High Sierra are the remnants? Is it possible tor determine its age in any way? Yes, it is possible, though only roughly and byr roundabout methods.r

r r

r It will be remembered that the Sierra Nevada consists essentially of a vastr block of the earth’s crust that lies tilted to the southwest, so that its easternr edge forms the crest line and its western edge lies deeply buried beneath ther sediments in the great valley of California. This great earth-block gained itsr tilted attitude not at one bound but by successive hoists separated by longr intervals of relative stability—intervals to be reckoned in millions of years.r With each uplift the streams coursing down its west slope were tremendouslyr accelerated and intrenched themselves in narrow steep-sided canyons. Duringr each interval of repose their downward cutting slackened, the canyons widenedr out to valleys by the weathering and erosion of their sides, the tributary streamsr cut ramifying valleys, and there was developed a landscape or “erosion surface”r with a topography of its own. Naturally the canyons and valleys of each newr cycle of stream activity were cut into the topographic forms left by the preceding cycle, and so each new landscape was developed at the expense of ther previous one.r

r r

r On the west slope of the Sierra Nevada there can be distinguished four setsr of topographic forms recording the work of as many cycles of stream erosion.r The newest forms are the narrow V-shaped canyons in which the main streamsr r r now flow. They were carved in consequence of the last uptilting of the Sierrar Block, which occurred probably early in the Pleistocene epoch.[8] Less than ar million years old, they are still being actively deepened by the streams andr remain youthful in aspect.r

r r

r To a close observer it is patent that these Pleistocene canyons were cut intor the broad floors of mature valleys of an earlier cycle. The Big Meadow flat,r which lies more than 2000 feet above the Merced River at El Portal, is a remnantr of such an older valley. The gently sloping platform about Turtleback Dome,r over which the new highway to the Yosemite Valley is laid, is another remnant,r and so is the entire Illilouette Valley, which has never been trenched. Examplesr are plentiful also along the other canyons of the Sierra Nevada, notably alongr those of the Stanislaus and San Joaquin. These older valleys, which attain greatr breadth on the lower slope of the range, are the products of a much longer cycler of erosion—a cycle that comprised probably all of the Pliocene epoch.r

r r

r Big Meadow, Turtleback Dome, and the Illilouette Valley in their turn lier 2000 to 2500 feet below the general level of the little valleys on the uplands thatr flank the Yosemite. These billowy uplands are, indeed, portions of a still earlierr landscape—a landscape that was produced during a very long cycle of erosionr comprising most of the Miocene epoch and probably large parts of the precedingr Oligocene epoch. Its age cannot be determined in the Yosemite region for wantr of telltale fossils, but it is indicated as probably late Miocene by fossils foundr near the old mining town of Columbia, north of the Tuolumne Table Mountain.r

r r

r High above the Miocene landscape, which remains preserved on many of ther extensive intercanyon tracts, stand the peaks and ranges that give the Highr Sierra its alpine character; and it is on some of the loftiest of these peaks andr ranges, 2000 to 3000 feet above the Miocene hills, that are found the gentlyr sloping, tabular remnants of the ancient landscape to which the little valley onr Shepherd's Crest belongs. The age of this landscape is indicated approximatelyr by the fact that in the northern parts of the Sierra Nevada remnants of it lier 1000 to nearly 2000 feet above the "fossil stream-beds" that contain the earlierr gold-bearing gravel. These stream-beds, which were preserved by masses ofr indurated volcanic ash (rhyolite tuff), have yielded fossil plant remains ofr middle Eocene age. It follows that the ancient landscape in question goes backr at least to early Eocene, possibly, even, to late Cretaceous time.r

r r

r That any parts of a landscape so ancient could remain preserved in exposedr r r r mountaintops may at first seem incredible. Yet in the Sierra Nevada the fact isr hardly open to doubt. Three circumstances, it would appear, have operated tor preserve those bits of the early Eocene landscape that form the tabular summitsr of the highest peaks—namely, the resistant nature of the granitic rocks ofr which those peaks are made; the position of those peaks at the extreme headsr of the rivers, where the streams are smallest and have the least cutting power;r and their complete exemption from glacial erosion. Of course, it is not contendedr that these residual summit tracts have suffered no degradation whatever sincer early Eocene time; but the fact is stressed that they have suffered but veryr little change as compared with the deep canyons that surround them—so little,r that they retain the gentle slopes and rounded contours that were imparted tor them when the Sierra region still was a land of moderate elevation.r

r r

r Of all the ancient summit-tracts in the High Sierra, certainly the little valleyr on Shepherd's Crest seems most remarkable; for a valley, being the pathway ofr a stream, is inherently more likely to be cut away during the uplift of a mountain range than is a ridge or a summit. Only some special circumstance couldr have saved it. Perhaps the streamlet on Shepherd's Crest was unable to competer with its neighbors because its water was entrapped by vertical fissures thatr developed across its path—the same fissures that separate the pinnacles of ther south crest from one another. Again, the little valley seems remarkable becauser it has escaped glaciation, although valleys inherently afford good sites forr glaciers. And, finally, to a student of the High Sierra it seems particularlyr precious because its non-glaciation, so well attested by its form, confirms ther non-glaciation of many of the lofty tabular summits of the Sierra Nevada.r

r r

r *Reprinted from* Sierra Club Bulletin, *1933, pages 68-80.*r

r r

r [1]The topographic features referred to in this essay are in the headwaters area of the Tuolumner River. See the topographic map of Yosemite National Park.—Ed.r

r r

r [2]Might not the expressive English word *cleaver* be more generally adopted in our vocabulary ofr mountain terms, in place of the alien and often mispronounced *arête*, thus leading the way, perhaps,r to the expulsion of terrible *bergschrunds* and fanciful *roches moutonneés?*—F. E. M.r

r r r

r [3]Matthes, F. E. Glacial sculpture in the Bighorn Mountains, Wyoming: *U. S. Geological Survey,r 21st Annual Report, part 2*, 1900, pp. 167-190.r

r r r

r [4]Soil flow is relatively rare on the granitic peaks of the Sierra Nevada, but evidences of it werer observed last summer on the Dana Plateau. Both nivation and soil flow are common phenomena inr Alaska, and they occur on a large scale in northern Greenland, where, in spite of the high latitude, nor glaciers ever existed.r

r r r

r [5]Blackwelder, Eliot. Pleistocene glaciation in the Sierra Nevada and Basin Ranges: *Geologicalr Society of America Bull.*, vol. 42, 1931, pp. 865-922.r

r

r r Matthes, F. E. Geologic history of the Yosemite Valley: *U. S. Geol. Survey Prof. Paper 160*, 1930.r

r r

r [6]Gilbert, G. K. Systematic asymmetry of crest lines in the High Sierra of California:r *Journal of Geology*, vol. xii, no. 7, 1904, pp. 579—588; *Sierra Club Bulletin*, vol. v, 1905, pp. 279—286.r

r r r

r [7]These figures are for the latitude of the Yosemite region. They are rough approximations. Morer accurate data are desired.r

r r r

r [8]Seer footnote on page 97,r and Appendix.—Ed.r

r r r r
r r

---

r r

r **r Next: Tuolumne Meadows •r Contentsr • Previous: Devil’s Postpiler** r

r r r

r

r r

r

r r

r r r r r r r r r r r r r r

r

r r

r r

r

r r r

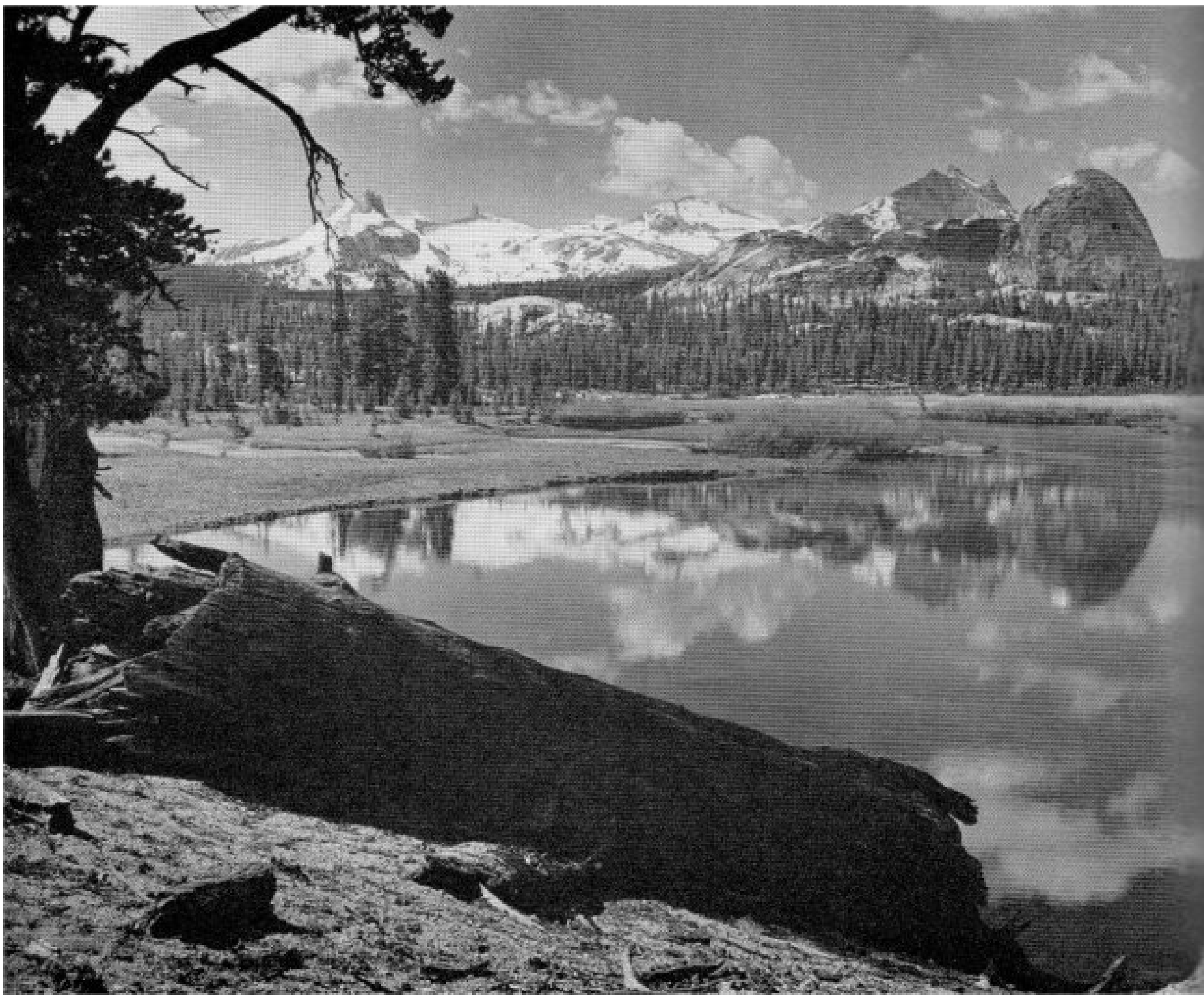
r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

---

r r r r

r r  r

r r r

r Tuolumne Meadows. Yosemite. By Cedric Wright r

r r r r

TUOLUMNE MEADOWS AND VICINITY

r r r

r r Tuolumne Meadowsr r is situated in the midst of the broad Upperr Tuolumne Basin, near the confluence of the Dana Fork and Lyell Fork of ther Tuolumne River. During the glacial epoch two great ice streams, one comingr from Mount Dana, the other from Mount Lyell, came together at the same spot.r These two glaciers and a number of lesser ones that originated in the amphitheater-like hollows or "cirques" on the surrounding crests, filled the Upperr Tuolumne Basin with ice to a depth of 2200 feet, as is clearly shown by ther "ice lines” on Ragged Peak, to the north, and Johnson Peak, to the south. Theyr created a “mer-de-glace” or ice sea 140 square miles in extent, the largest in ther Sierra Nevada.r

r r

r From this vast ice reservoir flowed the mighty Tuolumne Glacier, which wasr the longest and largest ice stream in the Sierra Nevada. It reached a maximumr length of slightly over 60 miles and filled the Grand Canyon of the Tuolumne tor the brim. At Pate Valley the Tuolumne Glacier attained the prodigious depth ofr 4500 feet, as is shown by the height of the moraines or debris ridges at the sidesr of the canyon.r

r r

r In spite of its enormous size, however, the Tuolumne Glacier was unable tor carry off the ice as fast as it accumulated in the Upper Tuolumne Basin. As ar consequence overflows took place in different directions through gaps in ther surrounding mountain crests. The largest volume escaped over the low, hummocky divide between Cathedral Peak and Tuolumne Peak and invaded ther Tenaya Basin. It formed the bulk of the Tenaya Glacier, which was tributaryr to the Yosemite Glacier. Smaller outflows took place southwestward, over ther Tuolumne Pass, southeastward over the Donohue Pass, eastward over ther Mono Pass (into Bloody Canyon), and northeastward over the Tioga Pass.r

r r

r As a result of its glacial history the Upper Tuolumne Basin is replete withr r r features of unusual interest. On the rock floor, which is exposed to view in manyr places (notably along the lower course of the Dana Fork), grooves and striaer produced by boulders and smaller rock fragments that were dragged by the ice,r are abundant. Over large areas the granite still gleams with “glacier polish,”r imparted to it by the scouring of the fine rock powder carried by the glaciers.r Boulders and blocks, large and small, torn from the mountain sides and droppedr by the ice, as it melted, are strewn about here and there; and moraines or ridgesr of rock debris that accumulated along the margins of the glaciers occur inr parallel series at the edges of the basin.r

r r

r Of peculiar interest are those rocky knobs that were overridden by ther glaciers, worn smooth and rounded on their upstream sides, but left more orr less hackly on their downstream sides, where the ice plucked more than itr ground. These asymmetric rock forms are known by the Swiss name ofr *roches moutonneés* (sheep-like rocks). Lembert Dome, which is about 500 feet high,r exhibits this characteristic glacial form on a large scale. It was overwhelmed byr the ice to a depth of 1500 feet. The most remarkable and highest rock monument of this type is Fairview Dome, which stands at the lower end of ther Tuolumne Meadows. It might seem incredible that this sugarloaf dome, 1000r feet in height, was overtopped by the ice, yet such is clearly attested by itsr *roche moutonneé*r form, by the patches of glacier polish on its crown, and by the heightr of the “ice line” on Cathedral Peak, which is 700 feet above its summit.r

r r

r Moraine ridges are most numerous on the north side of the basin, especiallyr in Moraine Flat. Dog Lake occupies a hollow between moraines. In its vicinityr strips of meadow land frequently occur between parallel moraines marking successive stages in the melting down of the last glacier that filled the Tuolumner Basin. Terminal Moraines, such as are formed at the fronts of glaciers, occurr nowhere except immediately in front of the small glaciers that still remain onr some of the higher peaks. The explanation is, doubtless, that the ancient glaciersr melted back rather steadily when the Ice Age drew to a close, and did not pauser long enough at any point to build up a strong ridge of debris at their front.r

r r

r Tuolumne Meadows is an excellent central base from which to make tripsr to the "living" glaciers that still remain on the high peaks round about. Therer are within the Tuolumne Basin and its immediate vicinity seven of these livingr glaciers—a greater number than is to be found in any other area of equal extentr in the Sierra Nevada. They are of small size, it is true, and hardly comparabler to the famous glaciers on Mount Rainier, or to those in the Swiss Alps or inr r r Alaska. The longest of them measure less than a mile in length, but they arer nevertheless glaciers in the true sense of the term and not mere snow fields, forr they are composed of hard, granular ice, they move slowly downhill with ar slow flow-like motion, and they are broken by crevasses in consequence of theirr motion over irregular beds. Moreover, just as is the case with the large glaciersr mentioned, so at the extreme head of each of these small glaciers there is betweenr the ice and the rock of the mountain a gaping cleft (the *bergschrund* of Swissr mountaineers) that opens periodically as a result of the forward movement ofr the ice.r

r r

r The largest ice body in the Tuolumne Basin lies on the north side of Mountr Lyell. It is commonly known as the Lyell Glacier, but it consists in reality of twor glaciers separated by a rocky spur. They might well be called the West Lyellr and East Lyell glaciers. The ascent of Mount Lyell is usually made over ther sloping surface of the West Lyell Glacier. The only obstacle that makes ther climb difficult, especially in late summer, is the *bergschrund* at the head of ther glacier.r

r r

r A short distance farther west, on the north side of Mount Maclure, is ther Maclure Glacier, a single, simple ice tongue, tapering downward to a blunt point,r and enclosed by a massive moraine loop. Below the loop is a picturesque lakeletr that reflects the glacier and the towering peak above.r

r r

r Entirely different in character is the Dana Glacier, which occupies a deepr cirque on the north side of Mount Dana. It is much broader than long, and,r curiously, lies, not at the head of the cirque, which opens towards the northwest,r but against its shady south wall, A moraine loop of great height encircles ther ice front, showing that the glacier formerly was much larger and thicker than itr is at present. The great volume of morainal material is accounted for by ther fact that the ancient volcanic rocks of which Mount Dana is largely made breakr up rather readily under the repeated attacks of frost—more readily than ther relatively massive granites that prevail throughout the High Sierra.r

r r

r Two small glaciers lie tucked away under the north slopes of Kuna Peak andr Koip Peak. They are readily reached from the trail that leads over the Parkerr Pass. Of much larger size is the Conness Glacier, which occupies a sheer-walledr cirque on the northeast side of Mount Conness. Like the Dana, Kuna, and Koipr glaciers, the Conness is much broader than long. It measures about three-fourthsr of a mile in breadth and a quarter of a mile in length. From the summit ofr Mount Conness one looks down upon the entire expanse of ice, but to reach ther r r foot of the glacier one must go by way of the Tioga Pass and the Saddlebagr Lakes.r

r r

r Measurements by the National Park Service are being made annually to ther fronts of all the glaciers described for the purpose of determining the extent tor which they have advanced or melted back. This work is being done as a part ofr a general plan of glacier measurements throughout the western United Statesr and Alaska that was put into operation a few years ago by the Committee onr Glaciers of the Geophysical Union (Branch of the National Research Council inr Washington). The principal object is to obtain systematic records of the advancer or recession of the glaciers that will indicate the trend of climatic changes nowr in progress.r

r r

r All of the glaciers in the Sierra Nevada have been melting back more or lessr constantly ever since the seventies of the last century. The little glacier whichr John Muir discovered in 1871 (on the Clark Range) has melted away entirely,r and a host of small cirque glaciers of the same type doubtless have vanishedr from the range within the last fifty years.r

r r

r The features of the Upper Tuolumne Basin are carved very largely fromr granite, a material of igneous origin that welled up in a molten state andr crystallized into hard rock as it cooled. It was not, however, lava properlyr speaking, for it did not flow out upon the surface of the earth. It occupied vastr subterranean chambers beneath the buckled and broken strata of an ancientr mountain system that stood on the site of the present Sierra Nevada morer than a hundred million years ago.r

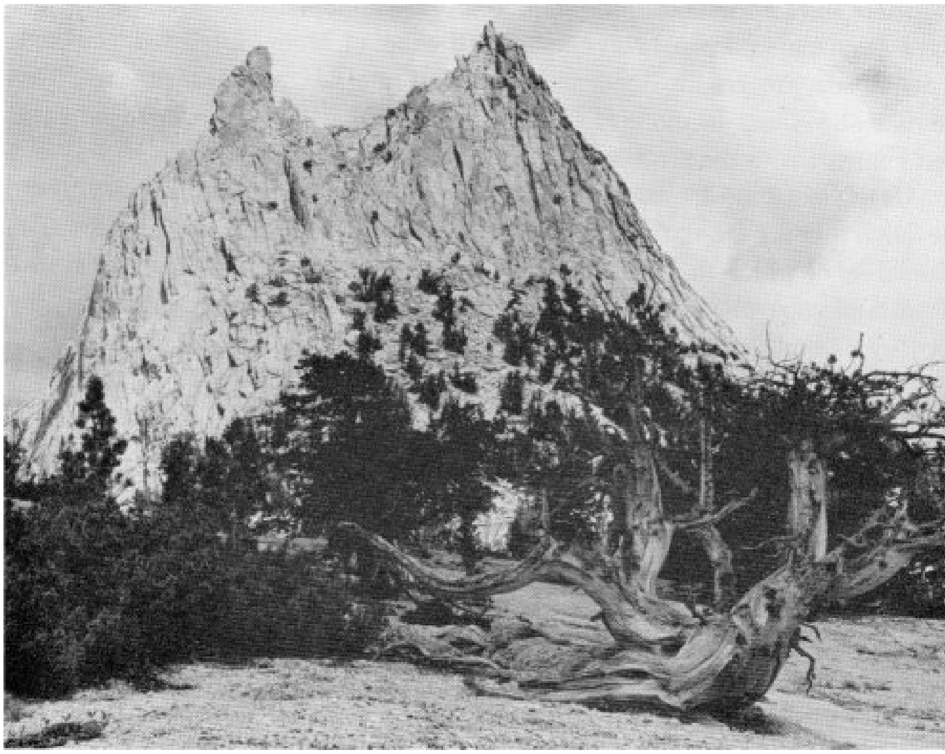
r r

r The reason why the granite is now exposed at the surface throughout ther Upper Tuolumne Basin, and indeed throughout a large part of the Sierra Nevada,r is that the ancient mountains that covered it have been completely worn down,r the rocks as they weathered and disintegrated, being removed, fragment byr fragment, grain by grain, by washing rains and the running water of brooksr and rivers.r

r r

r The granite peculiar to the Upper Tuolumne Basin is known as Cathedralr Peak granite and is readily distinguished from the other types of granite in ther Sierra Nevada (which represent different upflows of molten material) by ther large, approximately rectangular crystals of whitish feldspar which it contains.r In the ice-polished rock floors these crystals, which measure from one to twor inches in length, resemble lumps of domino sugar disseminated through a buffr or pinkish groundmass.r

r r r r

r Of the older rocks that originally overlay the granite and made up the bulkr of the ancient mountains just referred to, considerable masses remain on ther peaks surrounding the Upper Tuolumne Basin, notably on Mount Dana, Mountr Gibbs, Parker Peak, Koip Peak and Blacktop; likewise on Parsons Peak andr Simmons Peak, and in a narrow belt extending along the northeast slopes ofr r r r r  r

r r r

r r Cathedral Peak. Yosemite. By Philip Hyder

r

r r r Mount Maclure and Mount Lyell. Their strata, which originally were flatlying,r in many places now stand vertical or nearly so, and elsewhere appear buckledr and folded in various ways. It is in this buckling and folding of the strata thatr geologists find evidence of the former existence of a mountain system that antedated the present Sierra Nevada.rr r

r As a result of the intense pressure to which they were subjected when ther ancient mountains were formed, the rocks were greatly altered in consistency,r r r indurated and rendered crystalline—they were metamorphosed, as geologistsr say, and they are therefore properly referred to as metamorphic rocks. Amongr them were originally sandstones, shales, and limestones of marine origin. Ther sandstones have become quartzites; the shales, schists; and the limestone,r marble.r

r r

r There were, however, also large masses of lava and other volcanic rocks,r and these have become metamorphosed into peculiar schistose rocks of variousr types. Such metamorphic lavas abound at the foot of Mount Lyell and on Mountr Dana. They are readily recognized by their mottled appearance, the steamr cavities or vesicles in the lavas having been filled with light colored mineralsr that contrast with the somber hue of the rocks themselves.r

r r

r All the metamorphic rocks except the marble (of which there is but little inr the High Sierra) are dark in general tone as compared with the granites. Ther mountains of which they are composed consequently have a dusky appearancer in the landscape, alongside of the bright, granitic peaks—they seem overcast byr perpetual cloud shadows.r

r r

r *r One of several essays written by Dr. Matthes in the middle '30's at the request of the Yosemiter Park and Curry Company in connection with the plan, initiated as early as 1923, to establish lodgingsr for the use of hikers from Yosemite Valley who wished to make overnight excursions into the highr country. The history of these lodgings, known first as "Hikers' Camps" and later as "High Sierrar Camps," has been told by Dr. Carl P. Russell*r (One Hundred Years in Yosemite: The Story of ar Great Park and Its Friends, 1947 edition, *pages 113-115). Though widely used in typewritten form,r so far as known the essays were never printed.r* r

r r r
r r

---

r r

r **r Next: Tenaya Lake •r Contentsr • Previous: Shepherd's Crestr** r

r r r

r

r r

r

r r

r r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r The Scenery about Tenaya Lake >r

r r

r

r r r

r **r Next: Merced Lake •r Contentsr • Previous: Tuolumne Meadowsr** r

r r r

r r r r r

---

r r r

THE SCENERY ABOUT TENAYA LAKE

r r r

r r Tenaya Laker r lies, like a sapphire gem, ensconced in the bosom of ther Tenaya Basin, near the headwaters of the stream that dashes down ruggedr Tenaya Canyon. The lake is situated at an altitude of 8141 feet, somewhatr more than 4000 feet above the level of the Yosemite Valley, and is surroundedr by peaks of massive and imposing sculpture that rise to elevations betweenr 10,000 and 11,000 feet. To the visitor who comes up from the valley by ther Tenaya Lake Trail or the Tioga Road, the Tenaya Basin is the first bit of realr High Sierra, fascinating both by reason of its scenic aspect and because of ther extraordinarily vivid evidences of glacial action that appear on every hand.r

r r

r On the west and northwest sides the basin is enclosed by Mount Hoffmannr (10,836) and Tuolumne Peak (10,875) which form really a continuous range.r On the northeast side stands sharp-spired Cathedral Peak (10,933); overlooking the lake from the east is blunt sheerwalled Tenaya Peak (10,300), andr beyond it loom the clustered pinnacles of the Echo Peaks (11,000).r

r r

r Directly from the north shore of the lake rises a smaller, roundish mountainr of massive and almost wholly bare granite, which is known as Polly Domer (9786). It deserves more attention than is usually bestowed upon it, for itsr smoothed and in part polished sides and crown proclaim the fact that ther glaciers of the Ice Age have repeatedly overwhelmed it. There are even glacialr lakelets perched high up on its slopes. Polly Dome stands 1645 feet abover Tenaya Lake, and so it is evident that the ice here attained a depth of morer than 1600 feet.r

r r

r To one not familiar with the details of glacial action in the High Sierra itr might seem well nigh incredible that the ice could have attained so great ar depth in the Tenaya Basin, yet Polly Dome does not even afford the full measure. Tenaya Peak, which rises 2160 feet above the lake, also was overswept,r r r r as is clearly proved by its ice-smoothed summit and the “erratic” boulders thatr are scattered upon it. To find the highest level attained by the glaciers oner must go to the base of the pinnacles of the Echo Peaks or the neighboring crestr of Columbia Finger. The frail, splintered forms of those pinnacles show thatr they have never been overridden by the ice, while the smoothly rounded mountains which they surmount have clearly been abraded. The *ice line* lies fullyr 2460 feet above Tenaya Lake.r

r r

r Where did these vast quantities of ice originate, you may ask? The greatr bulk of it came from the upper Tuolumne Basin, of which the Tuolumne Meadows are now the central feature. That basin was formerly an immense icer reservoir, the largest of its kind in the High Sierra. Into it flowed dozens ofr sluggish ice streams from the amphitheater-like hollows or "cirques" on ther sides of Mount Lyell, Mount Maclure, Kuna Crest, Mount Dana, and ther other peaks round about. From it issued the mighty Tuolumne Glacier, whichr reached a length of 60 miles and was the largest ice stream in the Sierra Nevada.r This great trunk glacier, nevertheless, was unable to carry off the ice as fast asr it accumulated, and as a consequence the level of the ice sea rose until at lastr overflow took place in various directions through gaps and saddles between ther peaks. By far the largest amount spilled over the hummocky divide that separates the Tuolumne Basin from the Tenaya Basin. It was a flow four miles wide,r between Cathedral Peak and Tuolumne Peak. This ice flow invaded the Tenayar Basin, where its volume was augmented by local ice streams that issued fromr cirques on Cathedral and Tenaya peaks, Sunrise Mountain, and Mt. Hoffmann.r

r r

r So abundant was the ice in the basin that the outflowing Tenaya Glacier,r although 2500 feet thick, was unable to draw off all of it, and as a consequencer a broad ice sheet spread over the rugged upland north of Tenaya Canyon, asr far west as Porcupine Flat. Even Mount Watkins, which as viewed from Mirrorr Lake seems like another El Capitan, was completely overwhelmed. This factr is attested by several huge ice-borne boulders that lie on its bald, roundedr summit (which, by the way, is easily accessible and well worthy of a visit).r

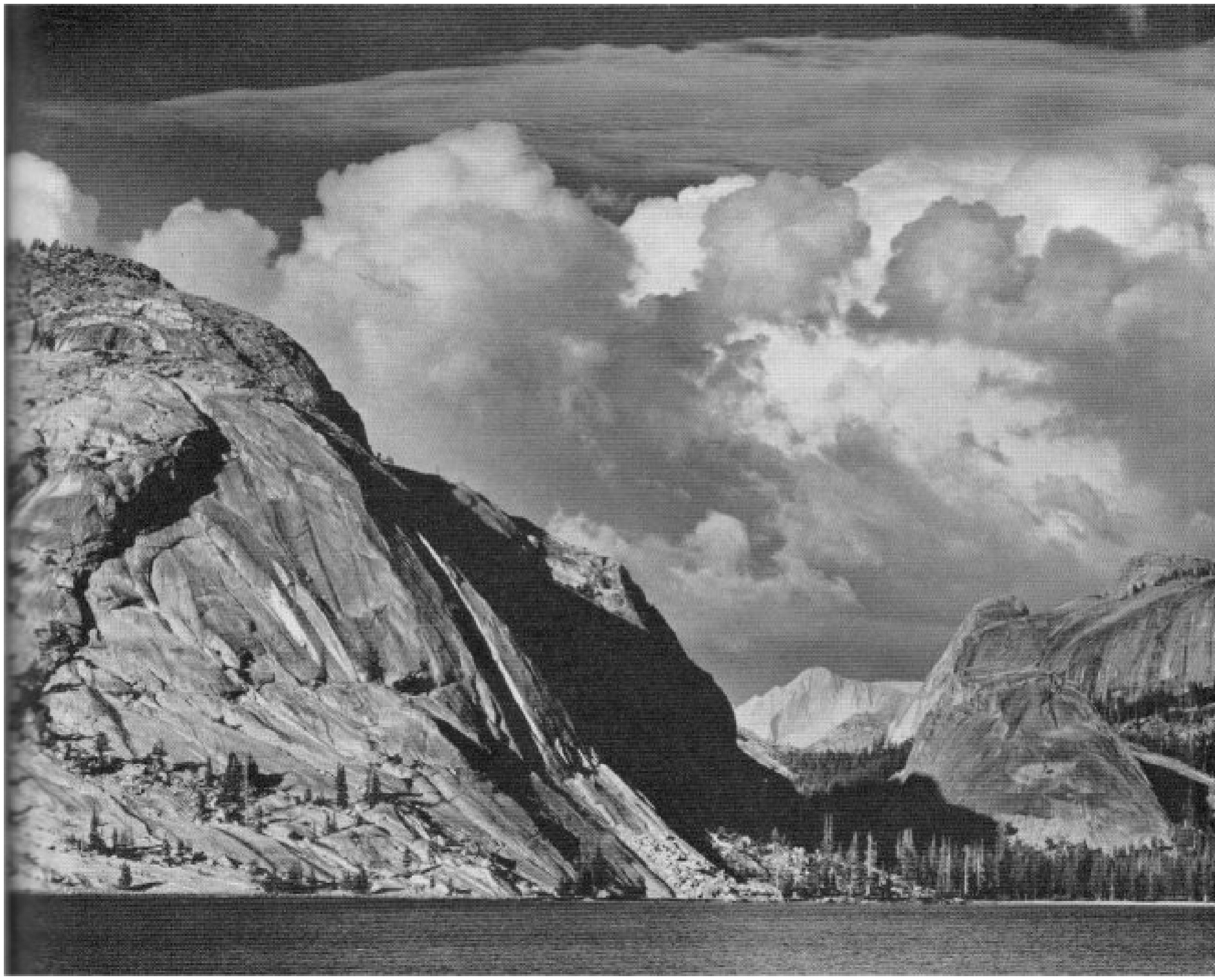
r r

r In the central portion of the Tenaya Basin the eroding action of the icer was most vigorous, and there, consequently, only a sprinkling of boulders wasr left on the rock floors; but at the margins the rock debris was piled up inr ridges or "moraines." These are most numerous on the south side of the basin,r where the Forsyth Trail comes down. They extend approximately parallel tor one another, in concentric curves.r

r r r r

r Naturally the Tenaya Basin exhibits in practically all its features ther effects of the intense erosive action of the ancient ice floods. Tenaya Lake, itsr central feature, occupies a hollow that was literally gouged out in its rockr floor. The lake has a sounded depth of 114 feet. Not all this depth is to ber accredited to glacial excavation, however, for at its lower end the lake isr enclosed by glacial and stream-borne rock debris of unknown thickness. In thatr r
r
r r

r r Tenaya Lake, Yosemite. By Ansel Adamsr
r r r
r r



r

r

r r r r respect Tenaya Lake is closely analagous to the much larger body of waterr which at the end of the Ice Age filled the bottom of the Yosemite Valley. Ancientr Lake Yosemite lay in a glacially excavated rock basin five and a half milesr long, but its outlet was across a moraine which raised the level of the waterr somewhat. Ancient Lake Yosemite has long since been filled with gravel andr sand dumped into it by the Merced River and Tenaya Creek, and is nowr replaced by a level floor—the beautiful parklike tract on which most of ther tourist camps are pitched. Tenaya Lake likewise will be filled some day, butr that time is still far off, for the only two streamlets that enter it carry butr little sand.rr r

r The filling is accomplished not by the settling of sediment in layers overr the entire lake bottom, but by the forward growth of the deltas which ther streamlets are building at their mouths. The extent to which these deltas alreadyr have encroached upon the lake is shown by the stretches of low sandy groundr covered with willows and pines at the mouths of the streams. So extremelyr slow is the rate of advance of the delta that the waves stirred up by the dailyr southwest winds have no difficulty in keeping its front trimmed to a smoothr curve.r

r r

r At the Foot of Tenaya Lake is a feature of a relatively rare type thatr deserves a word of explanation. The shore there is raised to the form of a low,r hummocky ridge crowned with glacial boulders. This ridge is only from oner foot to three feet high above the level land immediately back of it, and is sor unobtrusive that it might readily be overlooked. Similar hummocky ridges occurr along the shores of a number of other lakes in the High Sierra—notably Irelandr Lake—and also of many lakes in Wisconsin and Minnesota. For a long timer the origin of such ridges was in doubt, but it is now known from actual observation that they are built of material that is literally shoved out of the lakes byr the ice that forms on them in winter. These ridges are therefore appropriatelyr known as "ice ramparts."r

r r

r An ice rampart is formed, in brief, as follows. The ice that freezes on a lake,r although seemingly inert and unchanging, in reality contracts and expandsr appreciably with variations in the daily temperature. During a cold spell, withr temperatures well below zero, the ice contracts sharply, and if it can not pullr away from the shore becomes rent by open fissures. Water at once fills theser fissures and, upon coming into contact with the cold air, freezes in them, therebyr reuniting the sheet, which now fits snugly in the lake basin. With the next warmr r r spell the ice again expands and as a consequence it pushes with great forcer against the shores. Either the ice breaks a short distance from shore and pilesr up in a pressure ridge, or its marginal portion is shoved bodily up on the land,r carrying with it the rocks and mud that are frozen in it. The latter action mayr be repeated several times during a winter, and so in the course of time ther lake bottom for some distance out from the shore is cleared and smoothed, andr the material shoved up on the shore is piled together in a low, jumbled ridge.r The tremendous force that is exerted by the ice in this apparently insignificantr process is strikingly attested at Tenaya Lake by the large size of the bouldersr in and on the ice rampart.r

r r

r To return to the evidences of glacial erosion in the Tenaya Basin: Ther walls, the slopes, and the floors of solid granite almost everywhere are abradedr to smooth-flowing curves. Over considerable areas they still retain the polish,r striae, and grooves that were imparted to them by the rock fragments held byr the slow-moving ice mass. Indeed, next to the upper Merced Basin the Tenayar Basin offers the most impressive exhibit of glacially-worn rock that is readilyr accessible in the High Sierra. Some of the polished and gleaming granite is tor be seen from the automobile road, especially along the shore of Tenaya Lake.r Highly appropriate was the old Indian name for the lake—Py-we-ack, meaningr the "water of shining rocks." (The name Tenaya was given to it by the historicr Mariposa Battalion, the first group of white men to set foot in the Yosemiter Valley, in 1851, in memory of Chief Tenaya, of the Yosemite Indians, whomr they captured at the lake.)r

r r

r Glacier polish is, even to the casual observer, an intensely fascinating thing,r for it attests most vividly the grinding power of the ancient glaciers and byr reason of its good state of preservation over large areas impresses one with ther relative recency of the Ice Age. The fact is that glacier polish, because of itsr very smoothness, acts somewhat as a protective coating that retards the weathering of the rock. It permits water to run off more promptly than it would fromr a rough surface, and thereby lessens the proportionate amount that soaks intor the rock. And this, again, retards the growth of mosses and lichens from whoser decay are derived the acids that decompose the weaker minerals. It is a notabler fact, that may be observed in many places in the High Sierra, that whereverr the glacier polish finally scales off rock weathering is at once resumed at ar relatively rapid rate (the normal rate).r

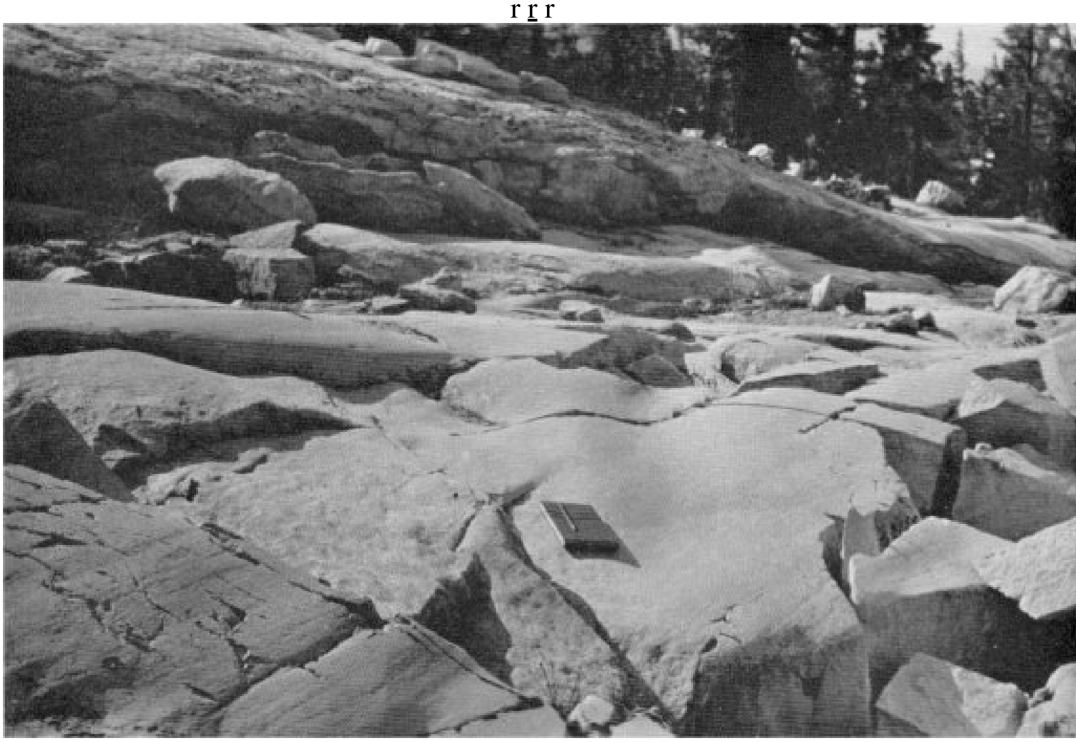
r r

r The gleaming polish itself is produced, of course, by abrasion with the finer r r rock powder which the glacier carries in its lower layers. Far more impressive,r as regards the pressure which the ice mass exerted on its bed, is the testimony ofr the grooves and striae. They show that the force was sufficient to cause angularr blocks dragged by the glacier to furrow sound, unweathered granite to depthsr of a quarter or even a half inch, and to cause individual rock grains (of quartz,r presumably) to leave tiny furrows (striae) of their own.r

r r

r The pressure can be calculated from the known thickness attained by ther ice. Since a column of glacier ice 1000 feet high weighs about 30 tons per squarer foot, the pressure on the rock floors about Tenaya Lake at the time of maximumr glaciation (when the ice was about 2400 feet thick) must have been about 74r tons per square foot. And to this must be added the forward thrust due to ther gravitation of the ice mass. Much of the grooving and scratching, however, mustr have been done with less pressure than that stated, for many of the prominentr grooves are still rough and fresh looking, from which circumstance it is evidentr r r
r
r r

r r Glacier polish and striae on aplite. Blocks disrupted by postglacial frost work.r By François Matthesr
r r r



r r r
r
r r r r that they were made but a short time before the ice melted. Were they older,r they would now appear smoothed and polished.rr r

r One factor that accounts for the unusually fine display of polish, grooves,r and other glacial markings in the Tenaya Basin is that the granite there is veryr massive—that is, it is broken by joint fractures only at long intervals. Normallyr granite is jointed at intervals of a few feet. The partings run in parallel sets,r and there are three or more different sets that intersect one another at variousr angles so as to divide the rock into angular blocks and slabs. Wherever ther rock is so divided glacier polish is apt to be scarce, for the glacier, instead ofr merely grinding, quarries out the blocks and slabs. The Yosemite Valley wasr quarried out in this fashion, and its walls in consequence are for the most partr hackled and faceted, and bear glacier polish only in a few spots. But in ther Tenaya Basin the joints are often scores and even hundreds of feet apart, sor that the glacier could not quarry but only grind and polish the surface of ther r
r
r r

r r  r

r r r

r r Glacier polish, head of Tenaya Canyon. By David Browerr

r

r r r r rock. Such abrasion is of course a much slower process than quarrying, especiallyr in hard and tough granite. The smoothed and polished walls and floor of ther Tenaya Basin, therefore, show, if anything, that the glacier there excavatedr with great difficulty and accomplished relatively small results.rr r

r In the Tenaya Basin curving shells due to exfoliation are to be seen inr many places, but they are not plentiful because the most of those that werer loosened were quarried away by the glaciers, and sufficient time has notr elapsed since the end of the Ice Age for the production of any new shells. In ar general way, therefore, the smoothly curving, billowy rock forms of the Tenayar Basin have been fashioned in part by exfoliation and in part by glacial action.r

r r

r Of the older rocks that formerly roofed over the granite a few remnantsr still exist in the vicinity of May Lake. The ridge that encloses the lake basinr on the east side consists in part of brown quartzite and white marble, and ther slope of Mount Hoffmann immediately above the lake is composed of similarr materials. The quartzite is an ancient sandstone that was altered and mader crystalline by the intense pressure and heat to which it was subjected when ther strata were folded as the earlier mountain system arose. The marble was produced by the same process from limestone. The sandstone originated probablyr as sand on the shore of the continent, and the limestone was built up as a reefr by corals and algae in a shallow sea.r

r r

r It may seem surprising that these remnants of quartzite and marble occurr at the base of Mount Hoffmann and not on its summit, which consists of purer granite. The explanation is that a large body of these metamorphic rocks hungr down from the roof into the fluid granite, forming a dividing wall between twor upwelling masses. Of that wall only the lower portions remain, the upper portions having long since been destroyed together with the roof. Many similarr instances occur in different places in the Sierra Nevada.

Among the most spectacular is a mass of contorted strata that hangs on the northwest slope ofr Tuolumne Peak.r

r r

r *See note on page 128*.r

r r r
r r

---

r r

r **Next: Merced Lake •r Contentsr • Previous: Tuolumne Meadowsr** r

r r r

r

r r

r

r r

r r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r Merced Lake and Its Environment >r

r r

r

r r r

r **Next: Tokopah Valley •r Contentsr • Previous: Tenaya Laker** r

r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

---

r r r

MERCED LAKE AND ITS ENVIRONMENT

r r r

r r The Upperr r Merced Canyon, in which Merced Lake is situated, may wellr be termed a lesser Yosemite, still unfinished. Like the main Yosemite Valley itr is broadly U-shaped and has imposing walls of granite and waterfalls that leapr down from lofty side valleys, but its floor is for the most part still unmade.r

r r

r The level, parklike floor of the main Yosemite, which adds so much to ther charm and livableness of that valley, was formed by the filling of a glaciallyr excavated lake basin with sand and gravel brought down by the Merced Riverr and Tenaya Creek. Those materials were not spread in layers on the floor ofr the basin but were deposited at the head of the lake in fan-shaped deltas, oner at the mouth of each stream. The two deltas grew forward until they coalesced,r and then a single large delta, built jointly by the two streams, advanced steadilyr until in the course of thousands of years it reached the lower end of the basin.r As the late David Curry used to express it in his campfire talks: When ther delta bumped its nose against the moraine at the foot of the lake, the fillingr was completed.r

r r

r Merced Lake, though of much smaller dimensions, is the counterpart ofr ancient Lake Yosemite, except that it has no morainal dam at its lower end.r It occupies a basin that was excavated in the rock floor of the canyon by ther powerful Merced Glacier. Soundings have shown the basin to be about 80 feetr deep. At the head of the lake the Merced River is even now building a delta ofr sand and gravel, and that delta, as it grows forward, will ultimately fill the laker and replace it with a level floor. The Sierra Nevada will then have gained oner more Yosemite. But that event lies far in the future, for the delta front isr advancing at an extremely slow rate—so slowly that the vegetation is amplyr able to keep up with its progress. Grass grows right up to the edge of the beach;r willows and bushes follow within a few yards; and the forest trees are not farr r r r behind. Indeed, there is no danger that beautiful Lake Merced will diminishr appreciably in size within our time or even in centuries to come.r

r r

r That the lake lies really in a rock bowl and has no other kind of barrier isr evident from the nature of its outlet. There the water slips out over a smoothr barrier of extremely massive granite. So far apart are the fractures or “joints”r r
r
r r

r r  r

r r r

r r View diagonally across Merced Lake. showing exfoliating cliffs on the south side, the forestedr r delta of the river at the head of the lake, and part of the Merced Canyon above. Yosemiter r National Park, California. By François Matthesr r

r

r r in that rock mass that the Merced Glacier could only grind—"sand paper"r its surface. The lake basin, on the other hand, was excavated in a place wherer the rock was cut by many intersecting joints, so that it could be "quarried"r out in blocks by the moving ice. Wherever the joint structure of the granite inr the Sierra Nevada permitted the glaciers to quarry out blocks on a large scale,r the canyons were profoundly modified by glaciation; but wherever the graniter r r was massive, so that glaciers could only grind, the changes effected were relatively small.rr r

r Washburn Lake, which lies 3 miles up valley from Merced Lake, is also ar typical glacial lake occupying a rock basin enclosed by a barrier of massiver granite. It has a sounded depth of 86 feet, but at its outlet the water is hardlyr two feet deep. The rock barrier is in plain view from the foot bridge that spansr the outlet. Washburn Lake also has a delta at its head and already has lostr about 500 feet of its original length by the forward growth of that delta.r

r r

r It may seem strange that Merced Lake and Washburn Lake, though lessr than a mile long each, are still so largely unfilled, whereas ancient Lake Yosemite, which measured five and a half miles in length and probably at least 200r feet in depth, has been extinct for a long time. The reason is, in the main, thatr during the last glacial epoch the glaciers made two major advances separated byr a long interval. Only the first advance penetrated the Yosemite Valley, whiler the second reached no farther than to the mouth of the Little Yosemite. Ther filling of Lake Yosemite therefore began many thousand years before Mercedr Lake and Washburn Lake were uncovered by the slowly melting ice. A secondr reason is that the Merced River and Tenaya Creek for a long time poured intor Lake Yosemite large quantities of rock debris derived from the still extensiver and active glaciers in the High Sierra, whereas the Merced River in its headwater reaches naturally carried only a small load.r

r r

r Many other glacial lakes and lakelets in the upper Merced Basin are accessible from Merced Lake. Some of the most picturesque lie on the broad rockr benches at the base of Merced Peak, Ottoway Peak, and Red Peak. Othersr lie strung like turquoise beads in the high-level canyon of the Lyell Fork andr in the vicinity of the Isberg Pass. These are readily reached from the Isbergr Pass Trail.r

r r

r Of particular interest is Babcock Lake, which lies tucked away in a recess,r two miles to the northeast of Merced Lake and nearly 2000 feet above it. Inr that recess the glacier that came southward from the twin valleys of Emerickr and Fletcher creeks was deflected abruptly toward the east and at the turnr developed tremendous excavating power. The granite there being traversedr by rather widely spaced but strongly developed master joints, the glacier torer out great rectangular blocks and slabs, leaving the basin with remarkablyr straight sides, so that it now looks as if it had been sawed out with a cyclopean saw.r

r r r r

r The depth which the Merced Glacier attained in the neighborhood of Mercedr Lake is indicated by the height of the lateral moraines (ridges of rock debris)r which it left on the shoulders of the canyon. These moraines lie fully 2200r feet above Merced Lake and Washburn Lake. Those on the northeast side ofr the canyon are readily inspected from the Isberg Pass Trail, which parallelsr them for miles. As the canyon has suffered no further deepening since theser moraines were laid down, there can be no doubt that the ice was about 2200r feet thick. When glacial conditions reached an optimum it probably was evenr somewhat thicker. The pressure which the Merced Glacier exerted upon itsr bed, due to its weight alone, must therefore have been fully 66 tons to ther square foot. Added to that was the powerful forward thrust due to the gravitation of the ice mass and to the pressure of the many tributary glaciers thatr converged upon it from many different directions. The sum total of the Mercedr Glacier's energy in the canyon must therefore have been very great, and ther depth of the lake basins is thus readily accounted for.r

r r

r Other evidences of the tremendous pressure which the Merced Glacierr exerted upon its bed are to be seen in the grooves, striae, and polish whichr abound on the rock floor of the canyon. These fascinating products of glacialr action are displayed in the vicinity of Merced Lake on an unusually grandr scale, because of the prevalence of massive granite. The most impressiver exhibits are along the old trail below Merced Lake, which is laid over the barer rock for long distances. The trail there is indicated by a row of stones, therer being no other way of marking it across the featureless flats. Elsewhere in ther Sierra Nevada, and in most other glaciated mountains, one may see glacierr polish by the square yard, but here one beholds it literally by the acre. Evenr the walls of the canyon gleam with glacier polish up to a great height.r

r r

r The polish was imparted to the granite by the fine rock dust which ther grinding glacier carried in its bottom layers. The striae were produced by smallr angular fragments of hard rock, mostly quartz, and the grooves by large, heavyr blocks that were dragged along by the slow-moving ice stream. Some of ther grooves are from a quarter inch to a half inch in depth—truly amazing depthsr considering how hard and tough fresh, unweathered granite is.r

r r

r Most amazing are the slanting grooves to be seen on the steep rock facer to the north of the outlet of Merced Lake. There the ice rode up at a highr angle to surmount a rock spur that projected into its channel. The groovesr consequently slant upward, not downward, in the direction in which the icer r r moved. During the middle of the day these slanting grooves are inconspicuous,r but in the early forenoon they stand out very prominently and are readilyr photographed.r

r r

r Associated with the grooves, in many places on the floor of the canyon,r are two kinds of curving fractures in the granite that afford impressive testimonyr of the glacier's disrupting power. These are known as *chatter marks* andr *crescentic gouges*. The chatter marks are the most abundant. They are finer cracks that are bowed upvalleyward and have a spread ranging from a fewr inches to a foot or more. They occur in series, spaced a fraction of an inchr apart, each series astride of a more or less distinct groove. It is evident thatr they are tension cracks produced by the terrific pull exerted by the draggedr boulders. Naturally they are most abundant in the more brittle kinds of rock,r such as the aplite, a fine grained, cream colored rock that cuts across the granite here and there in so-called "dikes." In some localities chatter marks arer confined wholly to the aplite, dying out in the neighboring granite, which isr tougher.r

r r

r The crescentic gouges are bowed downvalleyward and although relativelyr uncommon, are very conspicuous wherever they do occur. They also arer arranged in series, but there are seldom more than four or five in any oner series, and they are spaced several inches or even more than a foot apart. Theyr resemble the hoof marks of a gigantic horse—a horse that strode down ther valley, stubbing its toes with terrific force so as to spall off flakes from ther rock floor. These flakes were thickest at the outer curve and thinned inwardr to a knife edge. That the gouges are due to great pressure can not be doubted,r but the precise manner in which they were made still remains a mystery.r

r r

r A word about the origin of the granite, which is the prevailing country rockr throughout the High Sierra. It is a material that welled up in a molten stater from the depths of the earth and crystallized as it cooled. It did not, however,r flow out upon the surface of the earth like lava, but remained confined in vastr subterranean chambers beneath the outer crust. In the Sierra Nevada thisr crust consisted of strata of slate, schist, quartzite, and marble—the samer materials that are still visible in the Merced Canyon below El Portal. Theser strata, originally flat lying, were buckled into huge wrinkles so as to give riser to a system of parallel mountain ridges with northwesterly trend. Those mountain ridges stood on the site of the present Sierra Nevada more than a hundredr million years ago, but in the course of time they were completely worn away,r r r their rocks, as they weathered and disintegrated, being carried away fragmentr by fragment, grain by grain, largely by washing rains and by brooks and rivers.r Probably not less than two miles of rock have thus been removed by whatr geologists term the processes of erosion, and so the granite has been laid barer over large areas.r

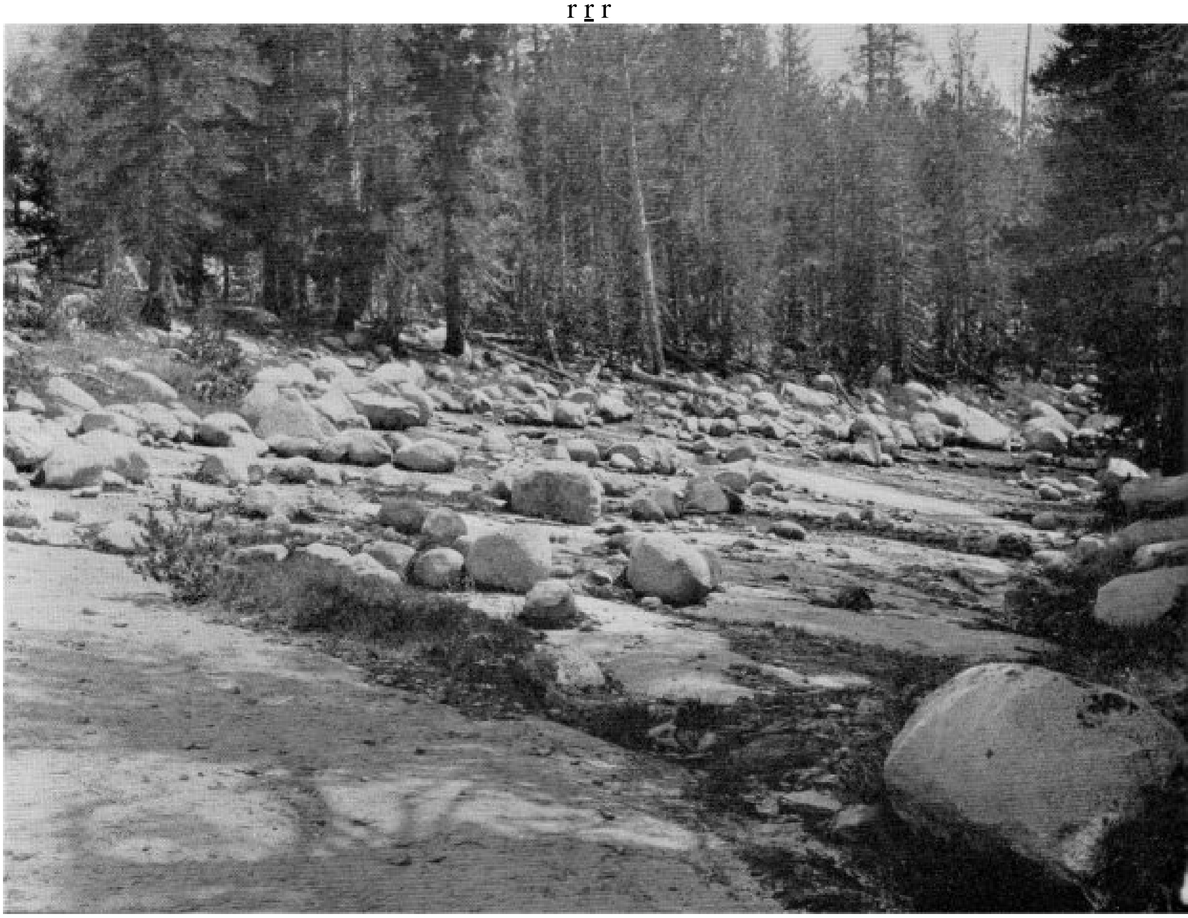
r r

r There were many upwellings of this molten material and as a consequencer there are now many different types of granite in the Sierra Nevada. Two typesr occur in the upper Merced Basin—the Half Dome "quartz monzonite" andr the Cathedral Peak granite. The former, named for Half Dome, makes upr the lower part of the basin and all of the Little Yosemite region. The latterr occurs chiefly in the Cathedral Range and in the country about the Tuolumner Meadows.r

r r

r The two rocks are readily distinguished from each other by the fact thatr the Half Dome granite is even textured, whereas the Cathedral Peak graniter contains unusually large crystals of white or pinkish feldspar—about two inchesr in length and approximately rectangular in outline. As the granite disintegratesr these large feldspar crystals are liberated and remain lying on the ground.r Quantities of them may be picked up along the trail to the Tuolumne Pass andr r r
r
r r

r r Glacial boulders deposited on glacial-polished floor near the trail to Merced Lake.r
r By G. J. Youngr
r r r



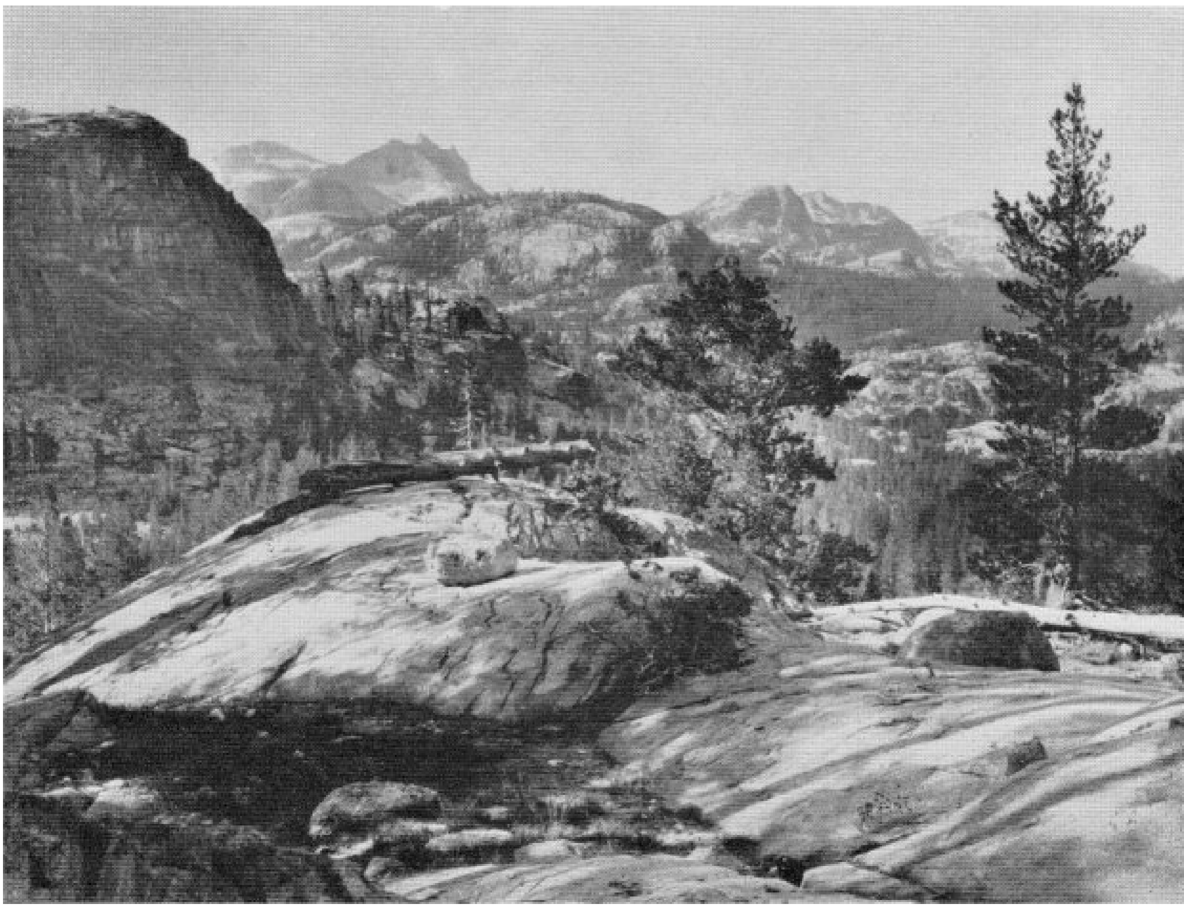
r r r
r
r r r r r also along the Isberg Pass Trail. In the glacially-polished rock floors theser crystals lie embedded as in a mosaic—they remind one of lumps of dominor sugar.rr r

r Of the older rocks that formerly overlay the granite and made up the bulkr of the ancient mountain ranges already referred to, a few small patches remainr on the peaks surrounding the upper Merced Basin. Of greatest interest, perhaps, is the mass of yellowish quartzite that is situated on the north spur ofr Mount Clark, east of Clark Canyon. This quartzite is an ancient sandstoner that was altered—metamorphosed, as geologists say—by the intense pressurer and heat to which it was subjected when the ancient mountains were createdr by the buckling and folding of their strata.r

r r

r The massive granite in the upper Merced Canyon on which the glacierr polish is so extensively preserved is all of it Half Dome granite. Indeed, thisr granite excels among the many different types of granitic rock in the Sierrar Nevada by its remarkably massive structure. As a rule granitic rocks arer traversed by many natural partings, or joints, as they are called, that developr while the mass was solidifying. Additional fractures may be produced laterr r
r
r r

r r The domes of the Merced Canyon—like those elsewhere in Yosemite—owe their smoothlyr r rounded forms to long-continued exfoliation. many successive shells having been cast off fromr r their bodies in the course of time. By G. J. Youngr
r r r



r r r
r
r r r r by stresses within the crust of the earth. Commonly the joints occur in parallel sets, spaced from one foot to several feet apart, and three or more suchr sets of joints intersect one another so as to divide the rock into angular blocksr and slabs. But in the Half Dome granite not infrequently joints are whollyr absent over distances of hundreds and even thousands of feet, horizontallyr and vertically. Such is notably the case in Half Dome itself, which consistsr essentially of a single, huge monolith. Most of the great cliffs of the Littler Yosemite, of Lost Valley, and along the upper Merced Canyon are likewiser composed of enormous masses of unfractured rock. The few master joints thatr traverse them are all the more prominent because of their isolation. Only inr those joints can the vegetation find a root hold, and it is for that reason thatr the smooth cliffs, rock floors and rock terraces in the upper Merced Canyonr are largely bare.rr r

r In reality this massive granite has not always been without fractures. Ther numerous dikes of aplite that traverse it in various directions show that it wasr once broken by many fissures. But into those fissures the hot, liquid apliter shot up and, as it crystallized, it sealed them tightly, uniting all the great fragments again into one solid, continuous mass. All along the upper Merced Canyonr aplite dikes abound. They are readily recognized by their creamy or light buffr color, which contrasts with the darker hue of the speckled granite. Some of themr stand out slightly above the surface of the granite, because of their superiorr resistance to the weather. The dikes vary in width from a few inches to severalr feet; they even taper down to mere threads, showing that the molten apliter was an extremely fluid substance that could penetrate into the finest cracks.r

r r

r In some places there are two sets of dikes, one cut through by the other.r Frequently in such cases the older dikes appear offset by a few inches or evenr a foot, the great blocks of granite having been moved and dislocated. Therer is a certain fascination in the thought that by a little patient study one canr today ascertain in some detail what manner of processes went on at a depthr of two miles beneath the surface of the earth—under a mountain system thatr is no longer in existence—more than a hundred million years ago.r

r r

r A peculiar feature of massive granite is that it tends to cast off thick, curving shells or plates from its surface. Such curving shells are to be seen on allr the great domes of the Yosemite region, and on the walls of the Little Yosemiter and the upper Merced Canyon. The explanation in all probability is that ther granite, having crystallized under tremendous pressure, beneath miles of super-incumbent rock,r r r tends to expand when freed from its load. In normally jointedr granite the expansion is accommodated by slight movements on the intersectingr fractures, but in massive granite it results in the bursting off of shells or platesr approximately parallel to the exposed surface. Geologists term this processr “exfoliation.”r

r r

r The domes of the Yosemite region unquestionably owe their smoothlyr rounded forms to long-continued exfoliation, many successive shells havingr been cast off from their bodies in the course of time. It was believed formerlyr that the domes had been rounded by overriding glaciers; but that is nowr realized to be a fallacy, for some of the most typical domes—notably Sentinelr and Half Dome—were never overtopped by the ice, as is now positively knownr from a detailed survey of the glacial moraines. The lower domes were overridden, but they are no rounder than the higher unglaciated ones.r

r r

r Dome-like rock forms and smoothly curved cliffs predominate throughoutr the Little Yosemite, Lost Valley, and the upper Merced Canyon. They are tor be interpreted as having been shaped in part by exfoliation, in part by glacialr grinding. Doubtless all of them were heavily covered with shells before the Icer Age began. The old preglacial shells were, however, all plucked off duringr the first stage of glaciation, and the granite cores were probably ground andr reshaped by the ice. Then, during the ensuing interglacial stage, exfoliationr again proceeded undisturbed. The newly-formed shells were again removedr during the next glacial stage; and so the two processes worked in alternationr throughout the Ice Age, which in the Sierra Nevada comprised at least threer stages of glaciation.r

r r

r The rock forms as they now appear are still substantially as they werer molded by the last glaciers. Over large areas, in fact, no new shells have beenr produced in all the time that has elapsed since the end of the Ice Age. When itr is realized that that interval in the High Sierra was probably between 10,000r and 20,000 years long, the extreme slowness of the exfoliation process will ber apparent.r

r r

r *See note on* *page 128*.r

r r r r
r r

---

r r

r **Next: Tokopah Valley •r Contentsr • Previous: Tenaya Laker** r

r r r

r

r r

r

r r

r http://www.yosemite.ca.us/library/matthes/merced_lake.htmlr

r r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r Lodgepole Camp and Tokopah Valley >r

r r

r

r r r

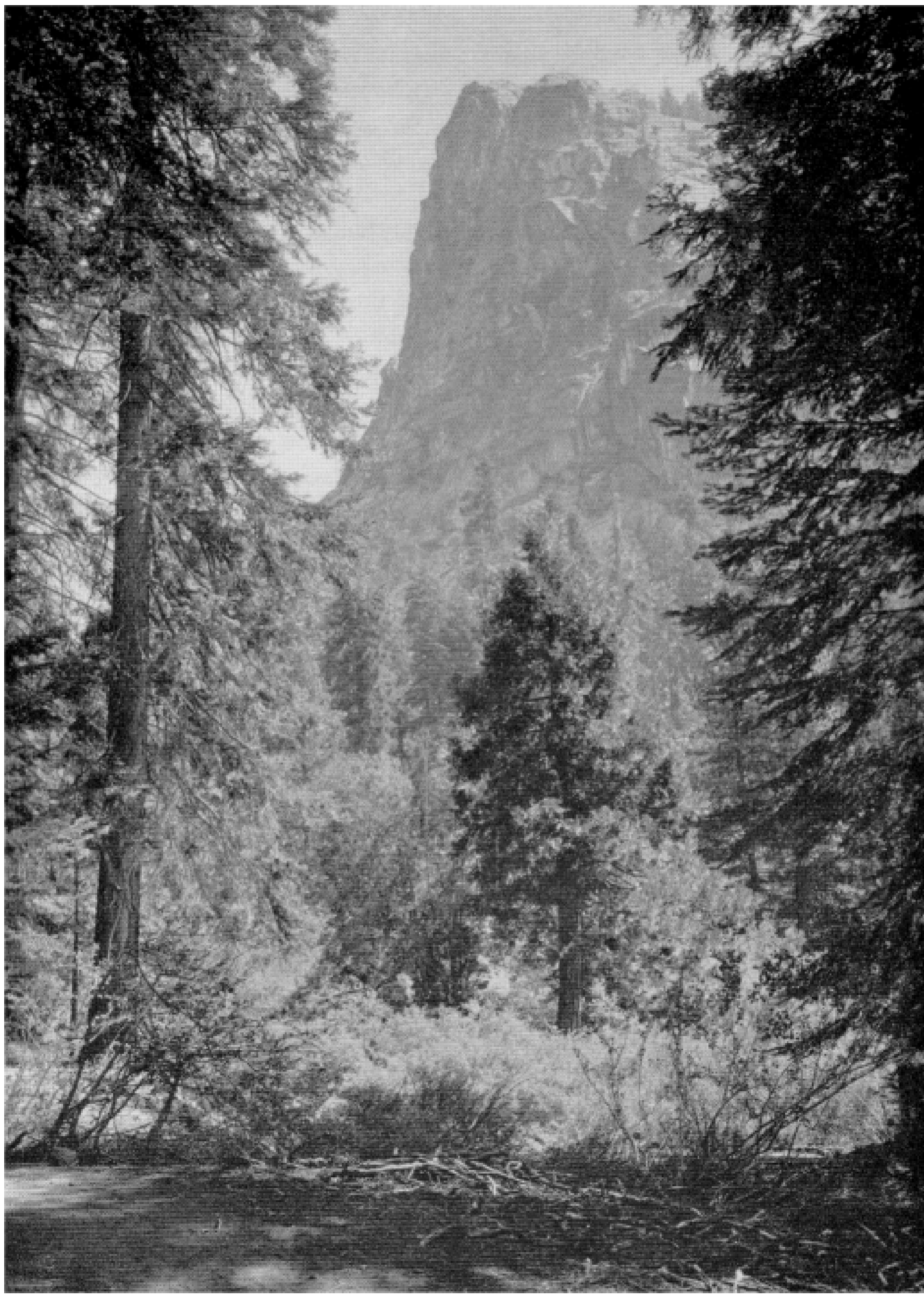
r **Next: Avalanche Sculpture •r Contentsr • Previous: Merced Laker** r

r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

r r r r

r r  r

r r r

r r The Watchtower, Tokopah Valley. Sequoia National Park, California.r
r Courtesy George Mauger, Sequoia and Kings Canyon National Parks Companyr

r
r r r r

LODGEPOLE CAMP AND TOKOPAH VALLEY

r r r

r r Lodgepole Campr r is situated at an elevation of more than 6700 feetr in what is properly termed the middle course of the Marble Fork Canyon.r Tokopah Valley, which lies immediately upstream from it, is really its continuation, still in a pristine state of lovely wildness. Tokopah differs fromr Lodgepole chiefly in that it is flanked by towering cliffs instead of forestedr slopes. Both have broad and in places nearly level floors and are particularlyr inviting by reason of their charming groves of pine and fir and the pleasingr alternations of pools, cascades, and riffles in the stream.r

r r

r Below, from the highway bridge down to the junction with the Middler Fork of the Kaweah, is the lower canyon, through which the Marble Forkr makes a tumultuous descent, falling as much as 1000 feet in a single mile,r and dropping a total of 4800 feet. It is an extremely rugged canyon that attainsr a maximum depth of 3000 feet, west of the Giant Forest, and in some stretchesr is utterly impassable, even to the boldest mountaineer. It is so notably at ther Marble Falls, where the river is actively cutting its channel across greatr upstanding beds of white and bluish marble—whence the name Marble Fork.r

r r

r Above Tokopah Valley—that is, above the 1300-foot cliffs over whichr the Tokopah Falls descend—is the upper canyon, which again differs whollyr in character from the middle and lower canyons. It is a broadly open basin,r flanked by mountains of great height—Mount Silliman (11,188) on the north,r and Alta Peak (11,211) on the south, and enclosed at its head by a loftyr plateau, known as the Tableland, 11,300 feet in altitude. Its most remarkabler characteristic is its barrenness. It presents a vast expanse of smooth, barer granite, from which all soil and vegetation have been removed. There are, itr is true, a few groves of lodgepole pine and fir in its lower portion, but theser seem, in a comprehensive view such as may be obtained from the Watchtower,r r r merely dark, wooded islands in a dazzling, billowy sea of granite. The riverr there has but a shallow channel and races, white with foam, over the smooth,r but scaling rock.r

r r

r Why, it may be asked, are the lower, middle and upper portions of ther Marble Fork Canyon so entirely unlike in form and aspect, and how does itr come that Lodgepole and Tokopah in the middle course are so lovely andr attractive, from man's point of view, whereas the lower and upper canyons,r though scenically impressive and in some respects amazing, are rather lackingr in attractive qualities?r

r r

r First of all it should be explained that the steep lower canyon is a muchr younger, more recently carved feature of the landscape than the middle andr upper canyons. It was cut by the river, and is still in process of being cut, inr consequence of a great uplift that added several thousand feet to the heightr of the Sierra Nevada, and steepened the river's course, thereby acceleratingr its flow and increasing its cutting or eroding power. The middle and upperr canyons, on the other hand, are relatively ancient features dating back to ther period that preceded the great uplift, when the Sierra still had only moderater height. Lodgepole and Tokopah have not yet been reached by the vigorousr canyon cutting below, which is proceeding from the foothills upward.r

r r

r The Giant Forest, it may be remarked incidentally, stands on a portion ofr the same ancient landscape to which Lodgepole and Tokopah belong. Ther lower Marble Canyon has been trenched deeply beneath its surface, and so hasr the great canyon of the Middle Fork, and as a result the Giant Forest nowr stands on an elevated plateau. From the southern edge of that plateau, whichr has an altitude of about 6500 feet, to the channel of the Middle Fork belowr there is a drop of fully 4000 feet.r

r r

r The plateau on which the Giant Forest stands is, however, by no meansr the highest part of the region, for above it rises Alta Peak, 11,211 feet in height.r That peak, moreover, is merely the culminating point of a ridge about 1 1/2r miles in length that connects at the northeast by a shallow saddle with ther Tableland. And the Tableland itself is without doubt a large remnant of ar landscape far more ancient still than that on which the Giant Forest stands,r indeed many millions of years more ancient. It antedates an earlier uplift ofr the range as a result of which the Marble Fork cut its course down to the levelr of Lodgepole Valley and the Giant Forest plateau. Small remnants of thatr very ancient landscape, or erosion surface, as geologists would call it, existr r r r r

r r  r

r r r

r r Tokopah Falls on the Marble Fork of the Kaweah River, Sequoia.r

r Courtesy George Mauger, Sequoia and Kings Canyon National Parks Companyr r

r

r r on a number of the higher peaks of the Sierra Nevada, notably on Mountr Whitney, Mount Langley and Table Mountain on the Great Western Divide.r There are thus indicated in the features of the range two distinct periods ofr uplift and consequent canyon cutting.rr r

r In this connection it may be explained that the Sierra Nevada, taken as ar whole, is essentially one huge block of the crust of the earth, 430 miles long,r that lies in a tilted position with its eastern edge upraised so as to form ther crest line. Measured from the crest line to the western foothills the block isr 40 to 80 miles broad, but as its surface dips under the silts that fill the Greatr r r Valley of California and probably continues beneath them for many milesr more, the total breadth of the Sierra block may be considerably over 100 miles.r That the Sierra Nevada is actually a tilted crust block, as here described, hadr long been recognized by geologists, but the history of the successive upliftsr by which it has gained its great altitude was not known until the geologicr history of the Yosemite Valley was worked out, in 1913 and 1914.r

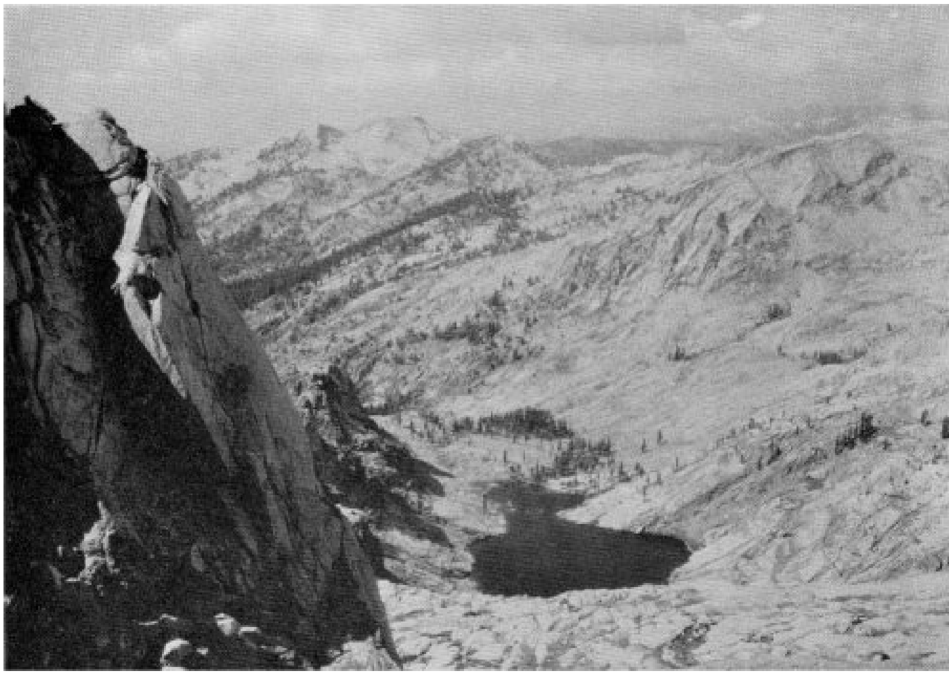
r r

r To return to Lodgepole and Tokopah, these portions of the middle courser of the Marble Fork Canyon, though undoubtedly forming part of the ancientr landscape on which the Giant Forest stands, nevertheless now present a veryr different appearance from that which was given them by the river. For duringr the Ice Age, which followed upon the last great uplift, they became the pathway of a glacier and for many thousand years were subjected to its excavatingr and remodeling action. That glacier originated on the Tableland, which wasr completely covered by ice, as is still clearly shown by the glacier polish andr scratches on its surface; and it was reinforced by a number of short tributaryr glaciers that issued from deep semi-circular pockets, or “glacial cirques,” inr the north flank of Alta Peak—the cirques in which lie Heather Lake, Emeraldr Lake, and Pear Lake. Other small branch glaciers came down the flanks ofr Mount Silliman, on the north side, and all united to form one mighty trunkr glacier which plunged into Tokopah Valley, doubtless forming magnificentr ice cascades. It moved probably at a rate of only a foot or two per day, butr its motion was rapid enough to cause the relatively brittle ice in the upperr layers to break and become rent by innumerable intersecting fissures orr “crevasses.”r

r r

r As the snow continued to accumulate, owing to the severity of the climate,r the Tokopah Glacier, as it may be called, grew thicker and longer, until at lastr it reached a point in the canyon about three miles below the site of the presentr highway bridge. Its total length, measured from the top of the Tableland to itsr terminus was therefore about nine miles. It was one of the smaller glaciers ofr the Sierra Nevada, but nonetheless an extremely interesting one.r

r r

r How can the former extent of such a glacier be determined, it may be asked?r The glacier polish and scratches might suggest themselves as good evidence, butr unfortunately they are not permanent enough, for the rock scales off as itr weathers. A more reliable method is by tracing the boulder ridges that accumulated along the margins of the glacier and at its front. The blocks and slabsr which the glacier plucked and quarried out in its upper course were depositedr r r as it melted in its lower course, and so it built up marginal ridges or “moraines,”r as they are termed by geologists, following the Swiss usage. These boulder ridgesr are enduring features and remain in existence for thousands of years after ther glacier has vanished, outlining faithfully its precise shape and extent. Well preserved, continuous moraines are to be seen on both sides of the valley in whichr Lodgepole Camp is situated. Particularly prominent are those on the south side.r r r r r  r

r r r

r r Alta Peak, Mount Silliman, Pear Lake and the Tableland.r

r Courtesy George Mauger, Sequoia and Kings Canyon National Parks Companyr

r

r r r The trail to Heather Lake, which starts at the upper Wolverton Creek bridge,r follows the crest of the highest moraine for part of the way, and where the crestr is too bouldery, follows the outer or south slope of the moraine. In some places itr follows the trough between two parallel moraines. Anyone who walks along thisr trail observantly will readily see that the glacier built two and in places threer parallel moraines. They record periods of maximum ice volume each of whichr doubtless lasted a century or more and was separated from the preceding by anr interval when the glacier, because of a short period of milder climate, had meltedr down somewhat.rr r r r

r From the crest of the highest moraine one looks down more than 100 feetr upon Wolverton Creek, which for a distance of nearly two miles runs along ther base of the embankment. Wolverton Creek, which heads in Panther Gap, runsr northwestward throughout its upper course (which has remained unglaciated)—r that is, it runs directly toward Lodgepole. Doubtless it continued northwestwardr all the way before the glacier came, but when the latter built its massiver morainal embankments, the stream was deflected and forced to run southwestward for two miles. Then it found a weak place in the moraine and broke through.r r r

r r Slopes of Alta Peak. winter. By David Browerr

r r r

r r  r

r r
r r r r

r On the north side of Lodgepole, Silliman Creek likewise breaks through ther morainal embankment, but that stream is not deflected. The reason is, no doubt,r that its upper valley formerly contained a glacier (which headed in two cirquesr on Mount Silliman), and when that glacier was actively melting, the stream hadr many times its present volume and correspondingly great eroding power. It isr entirely probable that when the Tokopah Glacier finally subsided, Sillimanr Creek broke through the morainal embankment rather suddenly, for its trenchr is flanked on each side by a ridge of boulders, and such “boulder levees,” it isr well known from observation on torrent channels, can be thrown up only by ar tremendous rush of waters.r

r r

r The top of the highest moraine on the south side of Lodgepole Valley indicates the highest level to which the ancient glacier’s surface rose. It is aboutr 1300 feet above the floor of the valley at the lower end of Tokopah, and accordingly it is clear that the ice there actually had a depth or thickness of 1300 feet.r Downvalleyward the depth of ice diminished by degrees until it was only aboutr a hundred feet at the terminus. On both sides of the valley the moraines canr readily be traced down to the highway, which cuts through them, revealing ther boulders, cobbles, and sand of which they are made up. The best example isr just below the Wolverton Creek bridge on the highway.r

r r

r Below the highway the moraines are very fragmentary and finally arer reduced to a few scattered boulders, the reason being that the rocky sides of ther gorge are too steep to give lodgement to loose material. Most of the glacialr boulders there have rolled down, and the sand has been washed away. As ar consequence the precise spot at which the Tokopah Glacier ended can not ber located definitely.r

r r

r As the Ice Age drew to a close the glacier melted back toward its sources, butr it made occasional feeble readvances as a result of climatic oscillations. Some ofr these readvances are attested by small moraines that extend from the sidesr of the valley partway across the floor. A particularly fine example of such ar “recessional moraine” is to be seen a short distance above the campfire place.r Another, somewhat less distinct recessional moraine is situated just above ther highway bridge. Each of these moraines originally extended across the entirer width of the valley in the form of a loop outlining the end of the glacier, butr all of them have been cut through and in part demolished by the river.r

r r

r During its further recession the Tokopah Glacier liberated enormous quantities of boulders, cobbles, and sand, and these were washed out from its frontr r r by the river and deposited in the deeper parts of the valley, and so it is thatr the latter is filled with “glacial outwash material” for considerable distances.r Most of the campsites are on the fairly even, yet bouldery surface of thisr filling, which varies in thickness from a few feet to as much as 30 feet in somer places. Since glacial times the river, being no longer overloaded, has trenchedr the filling, and it is at the present time still cutting the loose material away littler by little.r

r r

r The Ice Age, as a matter of fact, consisted not of a single longdrawn periodr of glacial conditions but of several distinct glacial epochs or “stages” that werer separated from one another by lengthy “interglacial stages” when the climater was fully as warm as it is today and when the glaciers melted far back towardr their sources or vanished entirely. The moraines just described are merely thoser of the last glacial stage, which ended 20,000 years ago. They are most readilyr recognized because freshest. But if one looks more closely one can also discernr moraines of the next earlier stage. They are poorly preserved, have lost theirr sharp crests, and are now composed largely of badly weathered, partly decomposed boulders. Their age is probably at least 250,000 years. The best places tor see these are in the road cuts along the highway. After one has passed Wolvertonr Creek (going towards Giant Forest) one can see yellowish boulders and cobblesr embedded in granite sand for a distance of nearly half a mile. Similarly whenr driving toward the General Grant Grove, after one has passed the outermostr moraine of the last glacial stage, half way between Silliman Creek and Cloverr Creek, one continues to see the yellowish, rotten boulders of the earlier glacialr stage for another mile or more—far beyond Clover Creek bridge.r

r r

r The Tokopah Glacier of the earlier ice stage reached much farther downr the canyon of the Marble Fork than its successor of the last ice stage. The exactr spot where it ended can not be determined for lack of morainal material onr the steep sides of the canyon, but to judge from the positions of the olderr moraines as far as they can be traced, the glacier in all probability reached nor farther than the mouth of Halstedt Creek. Since the glacier melted away, ther canyon has been deepened considerably by the river, and so all traces of ther earlier glaciation have been destroyed.r

r r

r *r An essay written by Dr. Matthes, probably in the middle or late '30's, in connection with ther interpretative program of Sequoia National Park. So far as known, it was not printed, but used onlyr in typewritten form.r* r

r r r
r r

---

r r

r **r Next: Avalanche Sculpture •r Contentsr • Previous: Merced Laker** r

r r r

r

r r

r

r r

r r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r Avalanche Sculpture in the Sierra Nevada >r

r r

r

r r r

r **r Next: Mount Whitney •r Contentsr • Previous: Tokopah Valleyr** r

r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

---

r r r

AVALANCHE SCULPTURE IN THE SIERRA NEVADA

r r r

r r Avalanchesr r of snow, their mode and frequency of occurrence in mountainsr of high relief, the menace they constitute to life and property, and theirr eroding action on cliffs and mountain slopes, have long been subjects of scientificr study in certain parts of Europe; but in the United States, whose lofty westernr ranges are but sparsely inhabited, and where the economic need for their studyr has thus far been relatively slight, avalanches have received until recentlyr hardly any attention from either geographers or geologists. During the summersr of 1935 and 1936, however, the author, while engaged in geomorphologic andr glaciologic studies in the Sierra Nevada of California, became aware of ther important part which avalanches there play, and have played throughout probably all of Pleistocene time, as eroding agents, more especially in the regionr above the timber line—the alpine zone—where they produce a distinctive typer of cliff sculpture. On and in the vicinity of Mount Whitney, the culminatingr peak of the range, and the highest in the continental United States, that type ofr cliff sculpture attains an exceptional degree of perfection and regularity, andr accordingly he feels impelled to offer this brief note as a firstling contributionr from the United States to the study of avalanche action.r

r r

r Perhaps it will duplicate in some measure the excellent work of Europeanr observers, notably that of Allix,[1] but he feels justified nevertheless in presentingr the results of his own studies, because they were made in a mountain districtr where topography, rock structure and climatic conditions together have permitted the three erosional processes characteristic of the alpine zone—glacialr r r r action, avalanche action and nivation—to produce their respective type formsr with great distinctness, and where because of slow rock weathering those formsr remain exceptionally well preserved.r

r r

r In order that the reasons for this singularly fine development of type formsr may be understood it should be explained, first, that the mountains in questionr are, in spite of their great altitude—which ranges from 12,000 to over 14,000r feet—prevailingly full-bodied, having escaped complete dissection during ther cycle of stream erosion which preceded glaciation. Many of them possess, inr consequence, gently sloping summit platforms of considerable extent that arer undivided by streamcut gulches but sharply bounded by the headwalls of glacialr cirques hewn in the sides of the mountains. These summit platforms, althoughr surrounded by the very sources of the Pleistocene glaciers, have themselvesr remained unglaciated, being windswept throughout. The snow that fell uponr them in glacial times was, as it is now, in large part blown away by the fiercer gales of winter, and was never permitted to accumulate to sufficient depth tor form gravitating glaciers. It lay only in stationary drifts and fields of moderate thickness, promoting with its melt-water the process of nivation.r

r r

r The summit platforms of Mount Whitney and of the other tabular peaks inr its vicinity are therefore typical nivated areas, where the rock has been rivenr into fragments, and is still being riven, by recurrent freezings and thawings,r but where no effective transporting agent in the form of stream or glacierr was available during glacial times, nor is at present, to remove the frost-splitr fragments.r

r r

r The cirques and canyons below, again, appear never to have been filled withr glacial ice to their full capacity, as were the cirques and canyons farther northr in the Sierra Nevada. The great majority of them were filled only to approximately one-half their depth, some of them even to less than one-half. This factr is shown clearly on their walls by the height of the upper limit of glaciation,r which, as may be seen in the photographic illustrations, is almost everywhererer conspicuous and unmistakable, because of the contrast between the angularr sculpture of the cliffs above it and the smooth forms of the glaciated rock surfaces below; also because the canyon walls have suffered on the whole but littler from postglacial weathering. The maximum depth which the glaciers of ther Wisconsin (Würm) stage[2] attained in the cirques and canyons of the Mountr r r r Whitney district can therefore be definitely determined as having ranged betweenr 500 and 1200 feet. As a rule it was less than 1000 feet,[3] and as a consequence ther rock walls rose from 500 to 1500 feet above the glaciers.r

r r

r It is on these unglaciated rock walls, at the heads of the cirques as well as onr the sides of the canyons, that the evidences of avalanche erosion are best displayed. These rock walls owe their steep profiles primarily to the undercuttingr r r
r
r r

r r  r

r r r

r r The gently sloping tabular summits of the Mount Whitney district are nivated but notr r glaciated. Their walls above the limit of glaciation are deeply fluted by alternating snow chutesr r and rock ribs. By François Matthesr

r
r r r action of the glaciers, which enlarged the cirques and widened the canyons atr the expense of the intermediate divides. Three dismantling processes, however,r have tended to maintain their profiles at angles

of less than 90° to the horizontalr —the freezing of water in joints and other fractures, resulting in the looseningr of blocks and slabs of rock; the pull of gravity on these loosened fragmentsr and all rock masses in unstable equilibrium; and the eroding action of recurringr avalanches of snow carrying abrading rock fragments with them.rr r r r

r The last named process deserves, in the author's opinion, more recognitionr than it has been generally accorded thus far; for his observations have shownr him that the distinctive type of cliff sculpture which it produces occurs in ar large percentage of the glacial cirques and canyons, not only in the Mountr Whitney district but elsewhere in the Sierra Nevada, and likewise in certainr parts of the Rocky Mountains and the Cascade Range. It occurs, in fact, whereverr r r
r
r r

r r  r

r r r
r r Typical snow chutes on the north face of Mount Hitchcock. The snow chutes are carved tor r depths of 50 to 100 feet in disregard of the joint structure of the granite. All terminate at ther r upper limit of glaciation which is clearly marked. Below is the glaciated floor of Whitneyr r Canyon. By François Matthesr

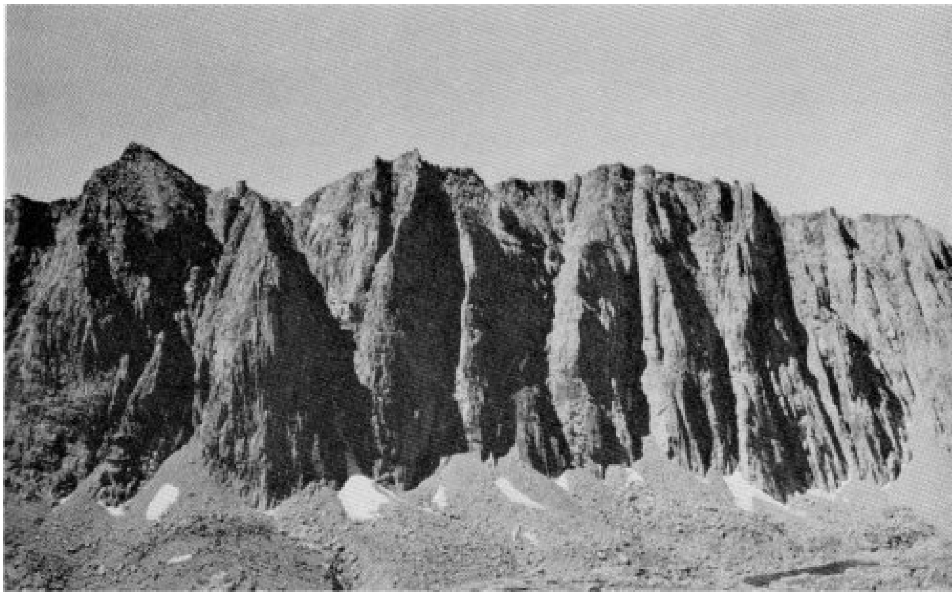
r
r r the rock structure does not interfere with the orderly development of ther forms.rr r

r Avalanche sculpture, wherever it is well developed, gives the cliffs a distinctlyr fluted appearance, there being an alternation of smoothly concave gullies andr sharp rock ribs, all trending downward roughly parallel to one another in ther direction of greatest declivity. That the smooth gullies are actually the pathways of recurring avalanches is known from direct observation and, besides, it isr evident from the fact that a large pile of snow usually lies beneath each of themr in the spring or early summer. In addition there is on the slope below each gullyr a cone of rock fragments carried down by the rushing snow masses.r

r r r r

r Allix has referred to the alternating gullies and rock ribs, appropriately, asr "cannelures."[4] That word, however, cannot well be taken over into the Englishr vocabulary, and accordingly it seems desirable to find a suitable English wordr to denote the features in question. The word gully, used above in a preliminaryr way, is decidedly inappropriate, being associated in the minds of geographers andr geologists with the action of

running water. It is therefore proposed to employr r r
r
r r

r r  r

r r r
r r Postglacial weathering and avalanche sculpture along zones of shearing.r
r East face of Mount Hitchcock. By François Matthesr r

r
r r the term “chute,” which implies a smoothly concave form through which massesr of incoherent material can rush down with a minimum of friction. And inasmuchr as it is desirable to link the forms with the material that passes through themr and is instrumental in producing them, it seems appropriate to call them “snowr chutes” and perhaps “avalanche chutes”—although the latter term is ratherr cumbersome and difficult to pronounce.rr r

r Snow chutes, as they will here be called, are not necessarily the equivalent ofr “chimneys” and “couloirs” of which alpinists make use in scaling peaks. Thoser r r narrow recesses in the flanks of mountains are produced primarily by differentialr weathering along vertical or nearly vertical zones of faulting or sheeted structures in the rock. The positions of many snow chutes, it is true, are determinedr by such structures, but it is equally true that many snow chutes occur in placesr where no lines or zones of weakness exist in the rock. On the cliffs of graniticr rocks in the Sierra Nevada they were observed to cross the jointing at variousr angles. The most perfect forms were found in massive granite, wholly devoidr of joint fractures. Such forms, produced solely by abrasion, are extremelyr smooth, with semi-circular or parabolic cross sections. To the mountaineer theyr offer no convenient routes for an ascent; on the contrary they are to be avoidedr by him, being too smooth and too slippery. Even in horizontally stratified rocksr of sedimetary origin very smooth and regular chutes are often worn by avalanches. Excellent examples of this kind were observed by the author in Glacierr National Park, Montana.r

r r

r How entirely regardless of structure snow chutes may develop in some cliffsr is well exemplified by the photograph onr page 158.r It shows a remarkablyr regular series of chutes worn in the north side of Mount Hitchcock (Sequoiar National Park, California), which is composed of vertically sheeted granite,r the strike of the fractures being from east to west—that is, at right angles tor the direction of the chutes. The latter are, by estimation, fully 50 feet deep.r A trickle of water is seen descending through one of the chutes. It appears as ar dark line that might readily be mistaken for a little stream-cut trench. Therer is, however, no such trench. The water merely finds its way down over ther smooth, concave bottom of the chute; it is in no wise instrumental in deepeningr the chute.r

r r

r Inspection of the photograph shows that many of the chutes are wider atr the top than at the bottom, and that not a few branch upward into two or morer minor chutes, separated by small, attentuated rock ribs. The reason appears tor be that the bulk of the windblown snow accumulates at the top of the cliff inr the form of a massive cornice, and it is the sudden breaking and slipping downr of sections of this cornice that initiates the avalanches. As the latter progressr downward, more and more of their volume is dissipated into whirling spray, andr as a consequence the lower parts of the chutes receive less wear than the upperr parts and remain relatively narrow. Not infrequently, moreover, an avalanche,r after rushing down through the upper half of a chute, comes to rest in the lowerr half, owing to the retarding action of snow that clogs its path.r

r r r r
r
r r

r r  r

r r r

r r Gigantic snow chute carved in massive granite, near Bearpaw Camp.r
r Sequoia National Park. By François Matthesr

r
r r r r

r It deserves to be pointed out, finally, that the snow chutes on a given canyonr wall all terminate at approximately the same height above the canyon floor—r namely at the upper limit of glaciation. This is illustrated onr page 158,r but itr can be observed in scores of glacial cirques and canyons throughout the Sierrar Nevada. It demonstrates clearly that the chutes were formed largely, almostr wholly, during glacial times, when the canyons were about one-half filled withr ice. Avalanche action has of course continued since the disappearance of ther glaciers and is frequent every winter at the present time; but the amount ofr erosional work that avalanches have accomplished in the resistant granitic rocksr of the Sierra Nevada during postglacial time is decidedly small and in placesr almost negligible. As may be seen onr page 158r cones of rock fragments beneathr the chutes on Mount Hitchcock, which give a measure of postglacial avalancher erosion, are of small or at best, moderate volume; they contain but a small fraction of the total amount of material that has been carved out of the chutes. It isr evident, moreover, that the chutes themselves have been prolonged downwardr but little below the upper limit of glaciation.r

r r

r In mountain regions where the rocks weather more rapidly than in ther Sierra Nevada, and where the canyon walls are dismantled at a correspondinglyr rapid rate, avalanche sculpture soon loses its characteristic forms and is likelyr to escape detection. Moreover, wherever the rock structure is highly irregularr or the cliff sculpture is controlled by rock masses that vary greatly in resistance,r the chances for the development of typical snow chutes are relatively small, andr such forms may never become distinct. Such is the case in many parts of ther Rocky Mountains, of the Cascade Range and of the great ranges of Alaska.r Such is the case also in many parts of the European Alps; and so it is, doubtless,r that avalanche sculpture has not been clearly recognized thus far, save in a fewr favorable localities, and has not yet taken its place along with the type formsr of glaciation and nivation as a characteristic part of alpine morphology.r

r r

> r *r Reprinted from "Transactions of the Meetings of the International Commissions of Snow and ofr Glaciers," Edinburgh, September 1936. International Association of Hydrology, Bulletin 23, pages 631-637. Riga, 1938.r* r

r r r

r [1]The author freely confesses that he was not acquainted with the results of Allix's studies whenr he made his own observations in the Sierra Nevada. His attention was invited to Allix's work onlyr recently, but, being out in the field and unable to visit a library, he has had to proceed with the writing of this note—in camp—without having had opportunity to familiarize himself with Allix's observations and conclusions.r

r r

r [2]Referred to in other essays as the later glacial stage, in distinction from the earlier of the twor well-recorded stages (the El Portal) in this part of the Sierra Nevada. "Würm" is the Europeanr equivalent.—Ed.r

r r r

r [3]These relatively shallow glaciers, it should be explained, were nevertheless many miles in lengthr and were tributary to the great Kern Glacier, which filled the Kern Canyon to depths of 2500 feetr and more, and attained a length of 26 miles.r

r r

r [4]Allix, André, "La morphologic glaciaire en Vercors,"r *Recueil des Travaux de L'Institut de Géographic Alpine de l'Université de Grenoble*,r Vol. II, 1914, pp. 109-110.r

r r
r r

r r

r **Next: Mount Whitney •r Contentsr • Previous: Tokopah Valleyr** r

r r r

r

r r

r

r r

r http://www.yosemite.ca.us/library/matthes/avalanche_sculpture.htmlr

r r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r The Geologic History of Mount Whitney >r

r r

r

r r r

r **Next: John Muir Glacial Theory •r Contentsr • Previous: Avalanche Sculpturer** r

r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

---

r r r

THE GEOLOGIC HISTORY OF MOUNT WHITNEY

r r r

r r To an easternr r friend familiar with the Swiss Alps I recently showed anr aerial photograph of Mount Whitney. “What!” he exclaimed, in evident disappointment, “is the summit of Mount Whitney flat and featureless? I hadr imagined our highest peak to be a towering rock monument with sharp, sky-piercing summit.” “Yes,” was my reply, “Mount Whitney’s summit is merelyr a broad, gently sloping platform, which, I suppose, holds little appeal for anr energetic mountaineer like you, but to a geologist specializing in the study ofr mountain uplifts and mountain sculpture that summit platform is a feature ofr quite unusual, indeed, altogether exceptional interest. I grant you that in point ofr spectacular beauty Mount Whitney cannot compare with the dazzling Jungfraur or the sharp-profiled Matterhorn, but, to one who can read it, the story told byr its flat summit is far more significant and goes back to much more remote agesr than any message conveyed by those glamorous alpine peaks. Indeed, the morer fully I comprehend its story, by dint of repeated visits to and flights around andr over Mount Whitney, the more venerable, the more precious seems that bit ofr flat land on its lofty summit. Upon it I have never set foot without a certainr sense of reverence.”r

r r

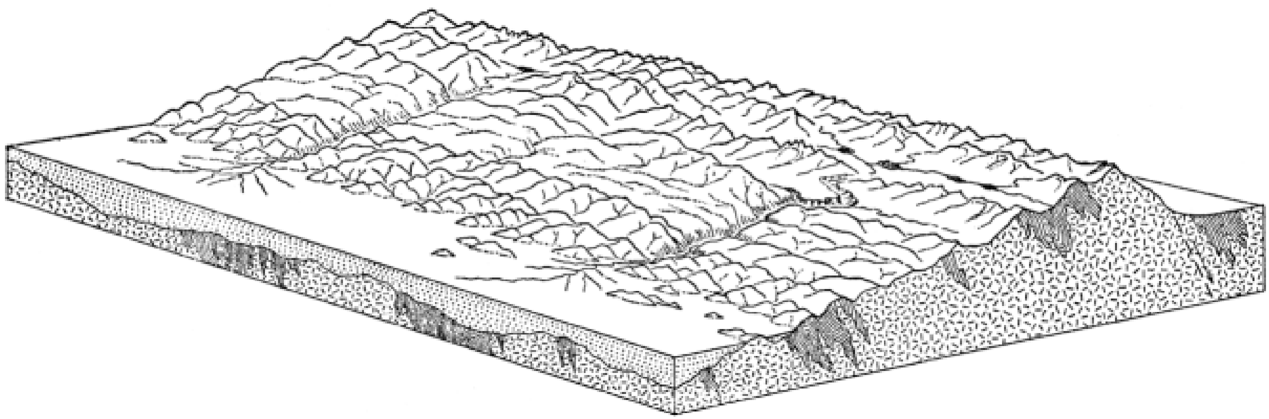
r Whereupon I was requested to explain.r

r r

r Broadly speaking, in a mountain region of great altitude that is profoundlyr and thoroughly dissected by canyons and valleys, sharp crests and pointed peaksr are the rule; for the precipitous sides of the canyons and valleys lead more orr less directly up to the dividing ridges and summits, and there meet one anotherr at acute angles. If, in addition, a region so dissected has been intensely glaciated,r the sharpness of its crests and peaks is likely to be still more pronounced; forr glaciers widen more than deepen the canyons they occupy, and this widening isr done at the expense of the intermediate divides. The widening process, moreover,r r r r is carried all the way to the extreme canyon-heads, and as a result theser are enlarged from V-shaped gulches and ravines to broadly U-shaped amphitheaters, or cirques. Biting into the mountains from opposite sides these cirquesr transform the crests and spurs between them to attentuated comb-ridges orr cleavers, and sharpen the peaks to three- or four-edged pyramids with concaver sides. These types of mountain sculpture are familiar to all who have climbedr in the Alps, or for that matter, in other strongly glaciated alpine regions. Theyr are characteristic also of the High Sierra, and predominate in any extendedr view of it.r

r r r r r r

r r



r

r r r

r r Figure 12.—Idealized representation of a portion of the tilted Sierra block, showing the “roots”r r of the ancestral Sierras penetrating deep into the granite; also longitudinal crests and valleys.r r Vertical scale exaggeratedr

r Figure 12.—Idealized representation of a portion of the tilted Sierra block, showing the “roots”r of the ancestral Sierras penetrating deep into the granite; also longitudinal crests and valleys.r Vertical scale exaggeratedr

r r r

r Mount Whitney’s gently sloping tabular summit, it will be readily seen,r belongs to an entirely different category. It is manifestly not an alpine mountainr form. It could not possibly have been fashioned at its present high level by ther erosional processes described. On the contrary, it is being destroyed by them;r for, as the surrounding precipices continue to crumble and spall off, the platformr will grow smaller and smaller until at last it will cease to exist. Evidently, it is ar much older feature than any of the sharply sculptured alpine peaks around it; itr is a remnant of an ancient landscape, the rest of which already has been carriedr away. What manner of landscape was this? How was it formed, and howr long ago?r

r r

r Be it understood, at the outset, that the Sierra Nevada, which is a huger tilted block of the earth’s crust, slanting toward the west, is not the first mountain range to occupy the region east of the Great Valley of California. Longr r r before it was uplifted, another mountain range, or to be more accurate, a systemr of mountain ranges, stood in the same place. And that earlier mountain system,r itself, was a late comer in geologic history; for it arose in the Mesozoic era, ther era of giant reptiles, only about one hundred million years ago, after the earthr had been troubled with spasmodic heavings and sinkings for upward of one andr a half billion years.[1] A complete record of all those successive disturbancesr probably will never be obtained, for the evidences grow more and more fragmentary, the farther back they are pursued; but this much is definitely known,r that during those vast stretches of time the area now occupied by the Sierrar Nevada was alternatingly ocean-bottom and land, and when it was land it bore,r as a rule, hills and even mountains of some height.r

r r

r With those remote and as yet vaguely known events we need not furtherr concern ourselves in this study of Mount Whitney—though merely to be awarer of their occurrence gives us a tremendous perspective of earth history. It isr with the mountain system that preceded the advent of the present Sierra Nevadar that we must begin. What has become of it? Are any of its mountains and valleysr still in existence? No, they have been completely annihilated, eradicated fromr the face of the earth; but fortunately some of the roots, if we may call themr such, remain incorporated in the body of the present Sierra, and from these itr is possible with some confidence to infer the structure and even the topographyr of those ancestral Sierras. They were carved evidently from great wavelike foldsr or wrinkles in the earth's crust produced by the buckling of originally flat lyingr strata, and they must have had the aspect of roughly parallel mountain ridgesr similar to those of the Appalachian system but trending in general from northwest to southeast. These ancestral Sierras were in existence for nearly 80 millionr years and in that time were gradually worn down by the processes of erosionr until nothing remained, presumably, but rows of hills in a lowland that slopedr gently down to the sea. Between those hills, which were composed of the morer obdurate rocks, the streams followed belts of less resistant rocks, mostly inr northwesterly or southeasterly directions.r

r r

r Then, about 50 to 60 million years ago, shortly after the dawn of ther Cenozoic era—the era of mammals and the latest great time divisions of geologicr history—began the first uplifts that led to the rise of the present range. Theyr tilted the Sierra region and the country to the east of it toward the southwest,r and as a result a new system of southwestward flowing master streams came intor r r r existence; but many of the lesser streams between the ridges, unable to shift,r maintained their southeasterly or northwesterly courses. Trenching deeper withr every succeeding uplift, they eventually cut through the lowest of the foldedr strata and graved their valleys in the granite underneath—the granite which hadr welled up in a molten state from the depths of the earth and had crystallizedr under the folds of the ancestral Sierras. And so the northwest-southeast trendr of those ancient mountains was perpetuated in the landscape of the present range.r

r r

r Little attention—altogether too little—has been paid to the significance ofr the crests and valleys of the Sierra Nevada that trend in northwesterly or southeasterly directions, roughly parallel to the main crest-line and at right anglesr to the master canyons, which drain more or less directly down the western slope.r These multiple crests, with their jagged peaks, have led us to speak, familiarly,r of "the Sierras" and justify the use of the plural form. They are now seen to ber the very oldest features in the landscape of the range, an inheritance from ther long departed ancestral Sierras.r

r r

r Some of the longitudinal crests of the Sierra Nevada are still composed ofr folded strata left from the earlier mountain system, but many of them are carvedr wholly out of granite. A striking example of the former kind is the Ritter Range,r which is made largely of ancient folded volcanic rocks. The southeastwardr trending upper canyon of the Middle Fork of the San Joaquin, which parallelsr the Ritter Range as far south as the head of Pumice Flat, is cut in other volcanicr rocks of the same relict mass, and closely follows the direction or "strike" of ther r r

r r Aerial view of Mount Whitney and the Upper Kern Basin, with Table Mountain in ther r distance. By Roy Curtis. Reno, Nevadar
r r r

r r r upturned beds. On the other hand, the Clark Range and the Cathedral Range,r in Yosemite National Park, are made entirely of granite, save for a few smallr patches of stratified rocks; and the upper Merced Canyon and Lyell Canyon arer cut in granite throughout. The Le Conte Divide, again, is carved out of anr isolated mass of stratified rocks, and Goddard Canyon is excavated in the samer dark-hued materials. Both trend with the northwesterly strike of the beds. Byr contrast, the Kaiser Crest, above Huntington Lake, and its southeastward extension, the Kaiser Ridge, together form a continuous rampart of granite 25 milesr in length. (Only one small strip of marble remains near the Twin Lakes, northr of the Kaiser Crest.) And the South Fork of the San Joaquin has cut its northwestward trending canyon in granite all the way from the head of Blaneyr Meadow to its junction with the Middle Fork.rr r

r Farther south, in the headwaters of the Kings River and in Sequoia Nationalr Park, where the folded structures of the ancestral Sierras bend gradually south-southeastward, the principal lineaments of the High Sierra notably bend in ther same direction, although they are carved for the greater part out of granite.r There, to mention only those most directly related to our theme, are the Greatr Western Divide, which contains stratified rocks in the vicinity of Mineral Kingr and in the Kaweah Group; the upper Kern Canyon, which is cut entirely inr granite, along a nearly straight north-south fault; and, to the east of it, ther culminating crest of the Sierra Nevada, which bears Mount Whitney and isr composed of granite throughout.r

r r r

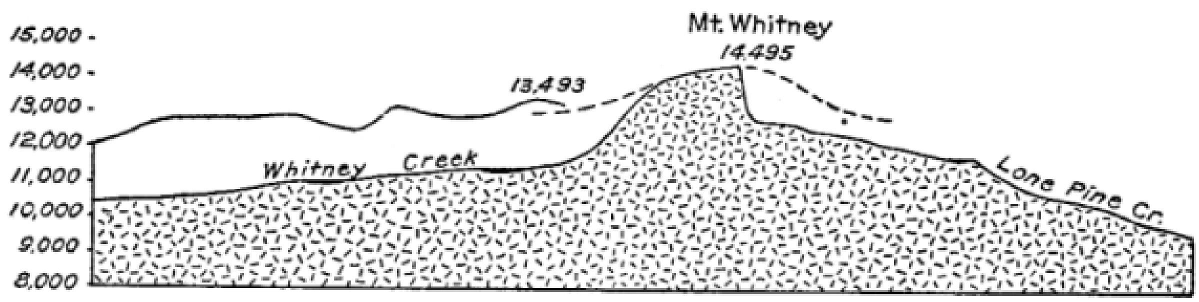
r Aerial view of Mount Whitney and Mount Young with the Kaweah Peaksr r beyond Kern Canyon. By Roy Curtis. Reno, Nevadar r

r r r

r r

r r r r

r The crest last mentioned deserves closer scruntiny. A distinct mountainr range it is, stretching in a south-southeasterly direction for a distance of 17r miles—from the Shepherd Pass on the north, to the Cottonwood Pass on ther south. Surmounted by seven of the eleven 14,000-foot peaks of the Sierra Nevadar —Tyndall, Williamson, Barnard, Russell, Whitney, Muir, and Langley—andr r r r r



r r r

r r r

r r Figure 13.—East-west profile of Mount Whitney. The broken liner
r indicates the approximate outlines of ancient ''Whitney Hill.''r
r Verticalr scale same as horizontal scaler

r

r r by several peaks only a few tens of feet below the 14,000-foot level, it is ther most lofty of all the longitudinal crests of the range. Curiously, it is still unnamed, although it certainly deserves and needs a name much more than some ofr the subordinate crests that are well provided for in this respect. In the followingr pages the immediate need of a suitable name for that distinct and culminatingr topographic unit of the Sierra Nevada will be manifest, and accordingly a namer is proposed for it here and now—*Muir Crest*.[2] Though not yet formally submitted for approval, that name will here be used, at least provisionally.rr r r That the Muir Crest, like the other longitudinal crests cited, has inherited itsr southeasterly trend from the ancestral Sierras, seems hardly open to doubt, forr there is nothing in the joint-structure of its granitic rocks that could have determined that trend. The Kern Canyon, to the west of it, differs it is true, from ther rank and file of longitudinal valleys in the Sierra Nevada in that its course isr determined by a fault, a long fracture in the Sierra block, but, to judge fromr the older features of its landscape and from its great breadth, the upper Kernr Basin as a whole has been developed from a very ancient valley and is essentiallyr analogous to Center Basin and the canyons of East Creek and Sphinx Creek,r to the north, and Cloud Canyon, to the northwest. It probably antedates ther fault, though it is possible that the fault, too, is of great antiquity.r

r r r r

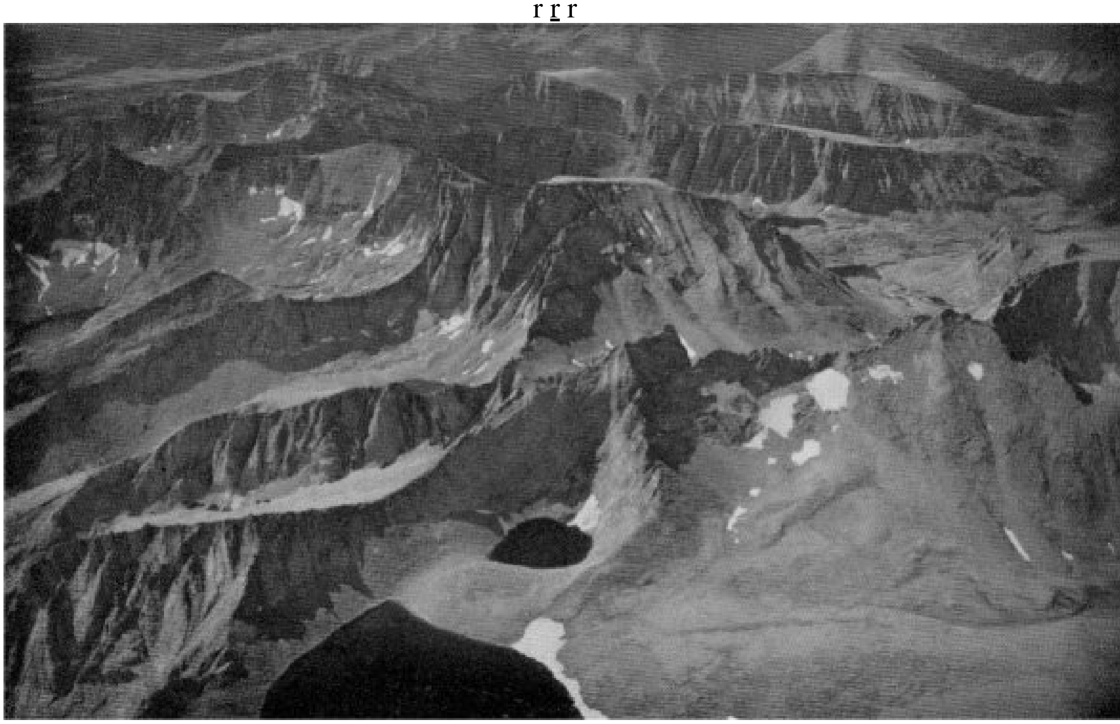
r A number of features on the east flank of the Muir Crest, furthermore,r point unmistakably to the former existence, several miles farther to eastward,r of another longitudinal valley of great antiquity, a valley that long antedatedr the down-faulting of Owens Valley and the formation of the imposing east frontr of the Sierra Nevada. Most definite is the evidence presented by the easternr spur of Mount Le Conte which terminates in Lone Pine Peak, and by similarr spurs east of Mount Langley. There is, therefore, ample warrant for the beliefr that the Muir Crest was developed, by valley-deepening to the west and ther east of it, from a row of lowland hills, relics of the destroyed ancestral Sierras.r

r r

r Is it then to be inferred, you may ask, that the summit platform of Mountr Whitney is a remnant of one of those ancient lowland hills? A daring thought,r it seems, yet that is precisely what its configuration appears to indicate. Indeed,r that summit platform has, so far as it is preserved, all the characteristics of ar lowland hill. Its gentle westward slope could not possibly have been fashionedr r r

r r Aerial view of Mount Whitney (from the north). Mount Russell. Mount Hitchcock,r r and Mount Langley. By Francis P. Farquharr r

r r r

r r  r

r r r by ordinary erosive processes at its present high level, 3000 feet above steep-walled Whitney Canyon, but must have been graded with reference to a relativelyr shallow vale or valley at its western base. The depth of that ancient valley canr be determined, at least approximately, by plotting, true to scale, the east-westr profile of Mount Whitney's summit from the contour lines of the topographicr map, and then extending that profile westward to the axis of Whitney Canyon inr a curve such as might be expected in a landscape of subdued hills. The profiler plot, shown inr Figure 13,r indicates a depth for the ancient valley of about 1500r feet. This figure can of course lay no claim to accuracy, for the contouring ofr Mount Whitney's summit on the small-scale map is necessarily generalized, butr the curve is drawn in accordance with the principles of geomorphology, ther science of land forms, and at least affords us a rough measure of the height ofr ancient "Whitney Hill." The altitude of "Whitney Hill" above sea level naturallyr was much more than 1500 feet, for the hill was situated fully 50 miles in air liner —more than 100 miles by the roundabout course of the Kern River—from ther seaboard, which then lay not far from the foothills of the present range. Fromr analogy with other lowlands produced by long-continued erosion, it may ber estimated that the valley at the west base of "Whitney Hill" had an elevationr of about 500 feet. Whitney Hill itself therefore rose probably as much as 2000r feet above the sea.rr r

r The landscape of the High Sierra affords many bits of supporting evidencer for this interpretation of Mount Whitney's origin. In the first place, Mountr Langley's summit, which is but a few hundred feet lower than Mount Whitney's,r is of the same gently sloping tabular type. Its summit profile, when carefullyr plotted like that of Mount Whitney, and then extended westward to the axis ofr Rock Creek Canyon, indicates for the original "Langley Hill" a height closelyr comparable to that of "Whitney Hill."r

r r

r Again, the Great Western Divide and its long north-northwestward andr south-southeastward trending spurs, which must have originated in much ther same way as the Muir Crest, bear several peaks with flat or gently slopingr tabular summits. Most noteworthy is Table Mountain (13,646), but hardlyr less typical, though less clean cut, is the tabular peak (13,300) between Milestone Mountain and the Colby Pass, which might well be called Milestoner Mesa. And on the Kern Ridge nearby are two more unnamed mountains withr gently sloping summit platforms, 13,560 and 13,206 feet high, respectively.r These tabular summits ranging within a few hundred feet of one another in altitude,r r r clearly represent remnants of a group of ancient hills. The fact that theyr average about 1000 feet lower in altitude than the comparable summits on ther Muir Crest does not argue against the probability of their having been derivedr from the same ancient landscape as the latter, for the Great Western Divider stands 10 to 15 miles west of the Muir Crest and consequently about a thousandr feet lower on the westward sloping body of the Sierra Nevada.r

r r r

r r  r

r r r

r r Aerial view of the Muir Crest. Lone Pine and the Alabama Hills in the foreground.r

r By Roy Curtis, Reno, Nevadar r

r
r r

r Farther north in the range still other tabular peaks dominate its sky line.r Notable examples are Mount Darwin, which has two detached summit platforms,r 13,841 and 13,701 feet in altitude, respectively; and Kuna, Koip, and Blacktopr peaks, in Yosemite National Park, which together form a continuous platformr 3 1/2 miles long and ranging between 12,500 and 13,000 feet in altitude. Parkerr Peak (12,850), Mount Gibbs (12,700), and Mount Dana (13,050) bear remnants of the same ancient undulating landscape. The acuminate peak of Mountr Dana is the most prominent hill of all, but even it rises only 700 feet abover r r the platform at its east base. To those who have firsthand acquaintance withr these crests it is readily evident that their tabular summits, which decline steadilyr northward with the entire body of the range, represent isolated remnants of ar once continuous landscape of moderate relief, an ancient lowland now raised tor great height on the present range.r

r r

r It is now in order to relate briefly how by successive steps lofty Mountr Whitney has evolved from lowly “Whitney Hill.” This story, of course, has tor do primarily with the successive uptiltings of the Sierra Nevada and the cyclesr of erosion that were initiated by them. But where, you will probably ask, is ther record of those uplifts to be found? In the features of the landscape itself. Professor Lawson was the first to spell out the principal chapters of that historyr from an analysis of the landscape of the upper Kern Basin, and that classicr analysis will here be followed, though with certain modifications and additionsr indicated by the more complete knowledge now at hand.[3]r

r r

r Be it observed, in the first place, that Mount Whitney outtops by fully oner thousand feet all the other mountains in its immediate neighborhood that haver rounded or gently sloping summits—notably Mount Young[4] (13,493) and Mountr Hitchcock (13,188). The disparity in height is manifest in the aerial view looking northwestward over Mount Whitney and Mount Young. It is likewise patentr from the profile plot inr r Figure 13,r which shows that the summit of Mount Youngr originally rose but a few hundred feet above the vale at the west base ofr "Whitney Hill." Mount Langley similarly outtops the rounded summit (13,481)r of the unnamed massif to the west of Rock Creek Canyon, as well as Lone Piner Peak (12,951), to the northeast, and Cirque Peak (12,863), to the south. Ther smoothly curving slopes of these lesser mountains, moreover, descend to levelsr close to 12,000 feet, and appear to have been fashioned with reference to muchr lower valley-floors than the summit platforms of either Mount Whitney orr Mount Langley. It is to be inferred, therefore, that the intial uplift of the regionr caused the streams to intrench themselves a thousand feet or more on both sidesr of the Muir Crest. During the ensuing stillstand of the earth's crust their valleysr widened gradually and the mountain slopes were worn back to moderate angles.r Mount Whitney, as a result of this first uplift, probably gained some twor thousand feet in altitude above the sea, and, because of the valley-cutting, camer r r r to stand 500 or 600 feet higher above its immediate base. Moreover, long spursr were carved on both sides of the Muir Crest, spurs such as are now representedr by Mount Young and Lone Pine Peak.r

r r

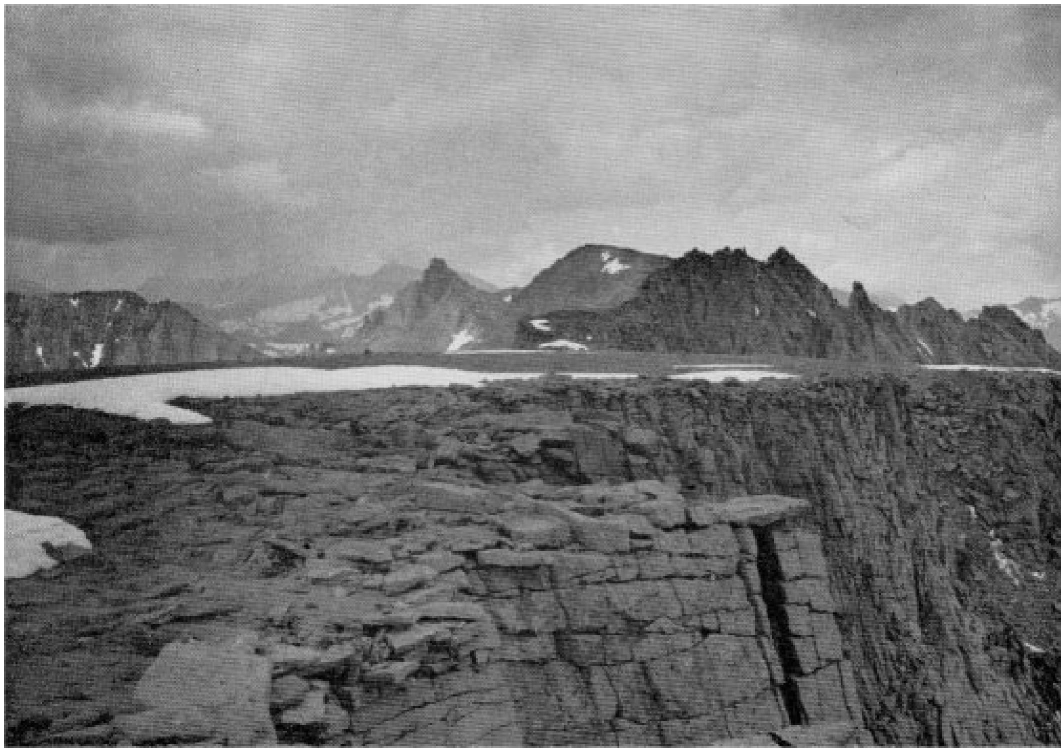
r To the west of Cirque Peak, and about 1500 feet below the level of itsr rounded summit, is an undulating plateau that stretches unbroken for a distance of seven miles toward the Kern Canyon. The principal valley on thatr plateau, broad and level, goes by the name of Siberian Outpost. For the summitr tract, which is of far greater extent than the valley, and even more frigid andr more windswept, the name Boreal Plateau has recently been proposed. Thisr plateau unquestionably represents a large remnant of an erosion surface ofr moderate relief that was formed throughout the upper Kern Basin during ar prolonged period of erosion following a second great uplift. Other remnants ofr this ancient erosion surface are Guyot Flat, to the northwest of Mount Guyot,r and the Bighorn Plateau, between Wallace Creek and Tyndall Creek. The valleyr profiles for this stage of development of the upper Kern Basin are not all drawnr at the time of this writing, and consequently only rough estimates can here ber given for the magnitude of the second uplift and the consequent further gain inr height of Mount Whitney. The peak was raised presumably about 3000 feetr higher, and therefore attained an altitude of, roughly, 7000 feet above the sea.r As a result of further valley cutting by Whitney Creek its height above its westr base was increased probably to somewhat more than 2000 feet.r

r r

r About 1500 feet below the general level of the Boreal Plateau, again, lier the broad, gently sloping rock-benches that flank the Kern Canyon proper.r Representative of these is the Chagoopa Plateau, which rises from an elevationr of 8600 feet at the canyon rim to about 10,500 feet at the base of the mountains.r Those benches clearly are remnants of a former floor of the Kern Basin that wasr developed to great breadth during an erosion cycle following a third uplift. Ther magnitude of that uplift also can, for the present, only be estimated roughly. Itr amounted probably to some 2000 feet, and therefore raised the summit of Mountr Whitney to an altitude of about 9000 feet.r

r r

r The Kern Canyon itself was, of course, trenched in consequence of the lastr great uplift. That uplift took place, to judge from the best data now available,r about the beginning of the Ice Age, and the canyon is therefore really a productr of alternating stream and glacial erosion. Like the Yosemite, its upper portionr was three times invaded and remodeled by a mighty trunk glacier, and to ther repeated glacial remodeling it owes its pronounced U-shape. The depth of ther r r r
r
r r

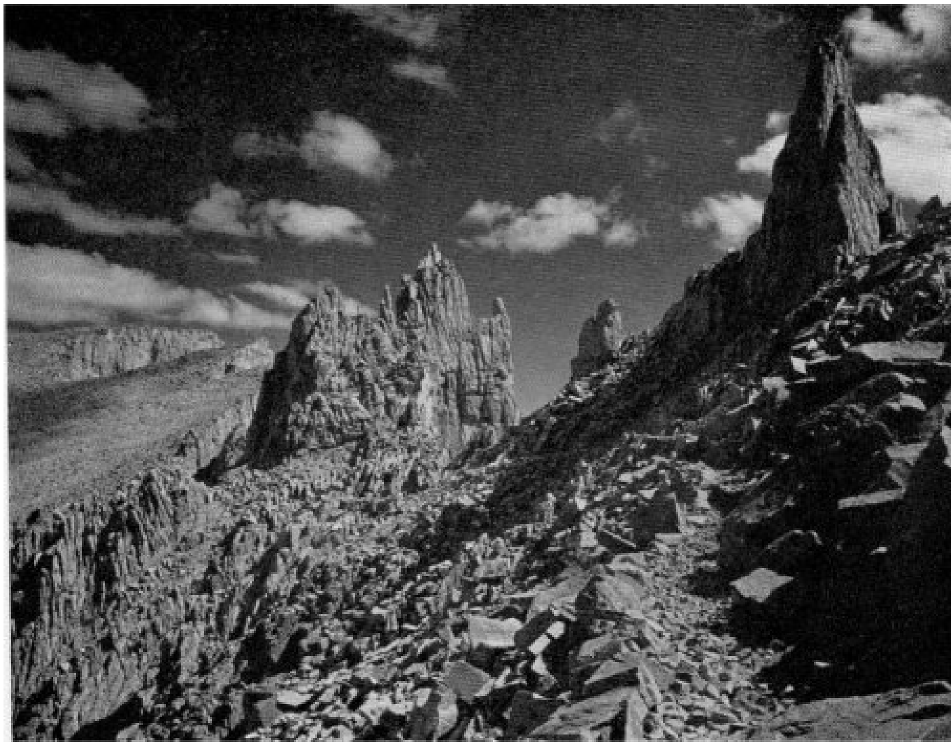
r r  r

r r r

r r Table Mountain on the Great Western Divide, with its gently sloping tabular summit,r r representsr the same ancient landscape surface as Mount Whitney and other summits onr r the Muirr Crest, ten miles to the east. Milestone Mountain in the middle distance with ther r Red Spur onr the skyline.r

r

r r canyon below the flanking benches of the Chagoopa cycle—2000 to 2500 feet—r affords, nevertheless, no index of the magnitude of the uplift, for that eventr occurred but a short time ago, in the geologic sense, and the river has not yetr had sufficient time to trench deeply. The cycle of erosion started by the upliftr is still in full swing today, and the river doubtless will continue to trench for ar long time to come. From studies made in the Yosemite region, meanwhile, it isr evident that the last uplift of the Sierra Nevada far exceeded all previous upliftsr in magnitude, adding about 6000 feet to the height of the central part of ther range. It may be presumed, therefore, that the Muir Crest was also raised atr least 6000 feet, and that Mount Whitney thereby gained substantially its presentr altitude.rr r

r The recency of the last uplift accounts also for the slight headway whichr Whitney Creek has made in cutting its valley down to the level of the mainr r r r r r r  r

r r r

r r Trail to Mount Whitney. By Cedric Wrightr

r

r r canyon. Like Wallace Creek and Rock Creek, it has cut a gulch only one miler long, and through that gulch it tumbles precipitously from a gently slopingr untrenched upland valley, a “hanging valley” comparable to those of ther Yosemite region. It follows that that upland valley has not yet felt the effectsr of the last cycle of erosion and still is a part of the landscape of the Chagoopar cycle, modified, of course by glacial action.rr r

r The extent to which the upland valley of Whitney Creek has been remodeledr by glacial action varies considerably in its different parts. In its lower portionr where the ice never exceeded 600 feet in depth—as is shown by the lateralr moraines—the valley suffered but moderate changes, but at the immediate baser of Mount Whitney, where the two branches of the “Whitney Glacier” coalesced,r a radical transformation was effected. The ice there attained a depth of overr 1000 feet, and because of this greater depth and the longer duration of its action,r it was able to add several hundred feet to the depth of the canyon and evenr more to its breadth. There can be no doubt that the present broad U-shape ofr r r Whitney Canyon was evolved by glaciation from a relatively narrow preglacialr V-shape, but so thoroughgoing has been the transformation that it is difficultr from the present topography to judge what the preglacial features may haver looked like.r

r r

r During the first half of the Ice Age there also took place the tremendousr dislocation of the earth’s crust that resulted in the formation of the imposingr eastern front of the Sierra Nevada. Opinions of geologists still differ as regardsr the precise nature of that dislocation, but it seems probable from the latest fieldr data now at hand, that it consisted in the main of a sinking of Owens Valleyr between parallel faults at the bases of the Sierra Nevada and the Inyo Range;r also, that this subsidence occurred after the Sierra Nevada had attained approximately its present height and had suffered its first glaciation. The dislocationr probably was not instantaneous, but was effected by many successive jerkyr movements spaced at intervals over a period thousands of years in length.r

r r

r While it was thus growing, the eastern front of the Sierra Nevada was constantly subject to erosion, the more intense because of its steepness, and so itr became deeply gashed by canyons and gulches. The extent to which it has beenr dissected and worn back is at first difficult to evaluate. Standing on the extremer summit of Mount Whitney, at the brink of its great east-facing cliff, one is aptr to gain the impression that the fault fracture is right at one's feet, yet it is manifest from the projecting spur that terminates in Lone Pine Peak, and from ther long spurs to the east of Mount Langley, all of which bear remnants of ancientr erosion surfaces, that the original fault escarpment must have stood at least fourr or five miles east of Mount Whitney's summit.r

r r

r Stream erosion on the eastern front of the range was supplemented at leastr twice by glacial erosion, most vigorously at the heads of the canyons and gulches,r less so toward their lower ends. Capacious cirques were developed on the northerly and easterly sides of the peaks, and as the curving cirque walls recededr under the combined attacks of quarrying glaciers and rock-splitting frosts, theyr bit deeper and deeper into the body of the Muir Crest, destroying the old preglacialr slopes and spurs, carrying away even the main divide, as in the stretchr between Mount Whitney and the Whitney Pass, where only the western sloper now remains. In some places, as to the south of Mount Le Conte, the divide,r attacked from both sides, was transformed to a narrow, pinnacled comb-ridge;r elsewhere, as between Mount Whitney and Mount Russell, it was reduced by ther headward quarrying of opposing glaciers to a low, frail rock-partition, and in ar r r few spots, as between Mount McAdie and Mount Mallory, the divide wasr demolished altogether and replaced by a smoothly concave saddle or col.r

r r

r A very massive, full-bodied mountain preglacial Mount Whitney must haver been, else it would have been reduced, like its smaller neighbor, Mount Russell,r to an attenuated alpine crag. To judge from its present outlines, its entire easternr half has been cut away by cirque glaciers. Those glaciers were small but doubtlessr
r
r
r r

r r  r

r r r

r r Wasting blocks of aplite. summit of Mount Whitney. By François Matthesr

r

r r long-lived, by reason of their unusually favorable locations, and they probably carried on their destructive work not only during each glacial stage but alsor for long periods during each interglacial stage and throughout most of the postglacialr interval. They have vanished only quite recently, and even today frostr sapping at the base of Whitney's cliff is promoted by lingering snowdrifts.rr r

r From the north side of the mountain a broad slice was removed by the widening of the glacial canyon that lies between it and Mount Russell, and on ther west side the lower preglacial slope was destroyed by the glacial widening ofr r r Whitney Canyon. The southeast side lost a small slice as a result of the incisionr of a narrow cleft, the northernmost of the series of clefts that gash the crestliner at intervals for more than a mile to the south of Mount Whitney. These clefts—r the breathtaking "windows" that afford occasional peeps to the eastward fromr the trail—are not glacial features, but have been etched out, so to speak, by frostr action seconded by snow avalanches along vertical zones in which the granite asr r

r

r r

r r  r

r r r

r r House on Mount Whitney and frost-heaved blocks of aplite. By François Matthesr

r r

r r a result of ancient faulting movements is sheared into thin, fragile plates. Onlyr on its southwest side Mount Whitney still retains its preglacial slope approximately intact and there connects with the equally unglaciated western slope ofr the main divide.rr r

r One of the most astounding features of Mount Whitney is that, although situated in the center of a district from which glaciers formerly radiated in allr directions, its own summit platform and the upper portions of its sides have remained unglaciated. Not the slightest evidence of glacial action, whether in ther r r form of polish, striae, or moraines, is to be found on the summit platform; andr as for the canyons at the immediate base of the mountain, these, it is clear fromr the moderate height to which their walls appear smoothed by lengthwise glacialr corrasion, were never filled with ice to more than one-half of their depth. Ther effects of glacial corrasion which they exhibit are, of course, only those producedr by the later glaciers, but it is manifest from the height and the gradients of ther older moraines on the sides of Whitney Canyon that the earlier glaciers, therer as in other parts of the Sierra Nevada, had no greater depth in the cirques andr upper canyons than the later glaciers.r

r r

r A similar dearth of glacial ice prevailed throughout the entire extent of ther Muir Crest, as is shown by the low “ice lines” in all its canyons and by its numerous unglaciated summits and spurs. This state of things, which must haver contrasted with the superabundance of glacial ice in the upper San Joaquin andr upper Tuolumne basins, was due in part to the position of the Muir Crest closer to the southern limit of glaciation in the Sierra Nevada, which coincides approximately with the southern limit of the High Sierra, properly speaking; and inr part, also, to the fact that the Muir Crest was then, as now, robbed of its rightful share of snow by the Great Western Divide, upon which the snow clouds,r driven up by southwesterly winds, unload the bulk of their white burden.r

r r

r The sides of Mount Whitney, in so far as they rise above the level of ther ancient glaciers, are furrowed by parallel or converging gullies, as much as 50r or even 100 feet in depth. Where these are spaced at close intervals, they arer separated only by sharp, craggy rock-ribs, and the cliffs have a distinctly flutedr appearance in consequence. These gullies, it is now realized, have been worn,r not by streams of water, but by avalanchess of snow shod with rocks. They are,r indeed, characteristic forms of avalanche sculpture that have not until recentlyr been recognized as such in this country. The bottoms of these gullies are smoothlyr concave, as a result of the rasping action of frequent avalanches, and remindr one of coal chutes such as are used for the unloading of coal cars or coal trucksr by gravity. The term “snow chutes” (or perhaps “avalanche chutes”) thereforer seems appropriate for them.r

r r

r Snow chutes are numerous on both the north and west sides of Mount Whitney, but those on the west side are developed on the grandest scale. Still morer perfect, though perhaps less deep, are the snow chutes on the north side of Mountr Hitchcock and in the cirque at the head of Whitney Canyon. The Mount Whitney district is, in fact, remarkably rich in avalanche sculpture, far richer thanr r r the Great Western Divide and many other parts of the high Sierra, the principalr reason being that its granitic rocks have a fairly regular joint structure. In manyr alpine regions where avalanches are active in winter, snow chutes are only imperfectly developed or entirely absent, because the rock structure is too irregular.r

r r

r That the snow chutes in the sides of Mount Whitney were carved chieflyr during the Ice Age, while the canyons were being glaciated, is evident from ther fact that they end invariably at or close to the “ice line,” which marks the upperr limit of glacial corrasion on the canyon walls. Avalanches have occurred, ofr course, through all of postglacial time and are active in winter even now, but allr of this postglacial avalanching has added but little to the depth of the chutes,r r
r
r r

r r Milestone Basin with Mount Whitney in the distance. By Walter L. Huberr r

r r r

r r

r

r

r r r as is demonstrated by the small size of the rock piles that lie beneath them.r These rock piles obviously contain but a small fraction of the total amount ofr material that has been carved out of the deep chutes.rr r

r The snow conditions that prevail on the summit platform of Mount Whitney, and that have prevailed there throughout all glacial times, are intimatelyr related to the development of the snow chutes in its sides. The avalanches arer composed today, and doubtless have always been composed, in large part of snowr blown from the summit platform by the winter gales. Because of its simple configuration,r unaccidented by ridges, pinnacles, or ravines, that platform is wind-sweptr throughout and in every direction. As a consequence the greater part ofr the snow that falls upon it is blown off by the winds while still in a powderyr state. As westerly gales are most prevalent the bulk is flung out to eastward inr great "snow banners," such as Muir described many years ago, and swirls downr in the "wind shadow" of the peak; but considerable portions of it are blownr also in other directions and accumulate in massive cornices at the edges of ther platform. It is the breaking down of these overhanging, unstable cornices thatr gives rise to the avalanches.r

r r

r Those who have observed Mount Whitney in winter say that its summit isr never more than thinly mantled with snow. Sometimes it is even partly barer when the valleys at lower levels are smothered beneath heavy loads of snow.r The same is true of all the tabular summits of the Sierra Nevada. What is more,r there is good reason to believe that closely similar conditions prevailed on themr during glacial times, for the climate then was not more snowy but colder. It isr entirely possible, even, that those lofty summits then bore less snow than theyr bear today, for because of the more intense cold the winter gales were more violent, and the zone of maximum snowfall, which today lies, according to the bestr data available, fully 3000 to 4000 feet below the level of the main peaks, thenr probably lay lower still, so that the peaks rose high into regions of relativelyr scant precipitation.r

r r

r The summit of Mount Whitney not only has escaped glaciation, but, whatr may seem more astonishing, it has escaped stream erosion also, during all ofr glacial, interglacial, and postglacial times. Not a single streamworn gully cutsr its surface, nor is there any more than the merest trace of a rainwater rill. Ther reason is that heavy showers are rare at its high altitude. Even in midsummerr the precipitation consists in large part of snow pellets—*graupel* is the technicalr term—and the snowdrifts waste away chiefly by direct evaporation under ther r r intense radiant heat of the sun, as is attested by their deeply pitted surfaces.r

r r

r The small amount of meltwater that issues from the snowdrifts, nevertheless, is a source of considerable destructive energy. Congealing night after nightr in the crevices of the rock, it loosens up the joint blocks and in the course of timer splits them into smaller and smaller fragments. The results are familiar to everyr mountaineer who has visited any of the tabular summits of the Sierra Nevada.r They are all encumbered with frost-riven and frost-heaved blocks that maker progress excessively wearisome. This type of intense frost work on unglaciatedr surfaces at high altitudes (and in high latitudes too) has been termed *nivation*,r because it is dependent upon the presence of snowfields and snowdrifts. Ther top of Mount Whitney, accordingly, is properly described as a nivated summit.r

r r

r It is a pertinent question at what rate the process of nivation works. Howr fast, or rather, how slowly is it reducing Mount Whitney in height? No observational data are at hand on which a quantitative estimate may be based, but thisr much can be said without fear of contradiction, that the nivation process worksr in general far more slowly than either stream-and-rain erosion or glacial erosion.r Much depends on the character of the rock. In thin-bedded or slaty rocks thatr break up into shingle and small flaky fragments, an auxiliary process known asr *solifluction* (literally soil-flow) sets in, that operates to remove the frost-splitr material. It consists of a sluggish flowlike movement that is particularly activer in masses of fine material permeated and lubricated with water, causing themr to gravitate down slope in tonguelike bodies that push the coarser shingle up onr edge. But in the granitic rocks of the Sierra Nevada, which break up for ther most part into large and heavy blocks, or locally into loose sand through whichr water passes as through a sieve, solifluction is not effective as a transportingr agent, and as a consequence the frost-split material remains largely in place.r Reduction by nivation there is necessarily very slow.r

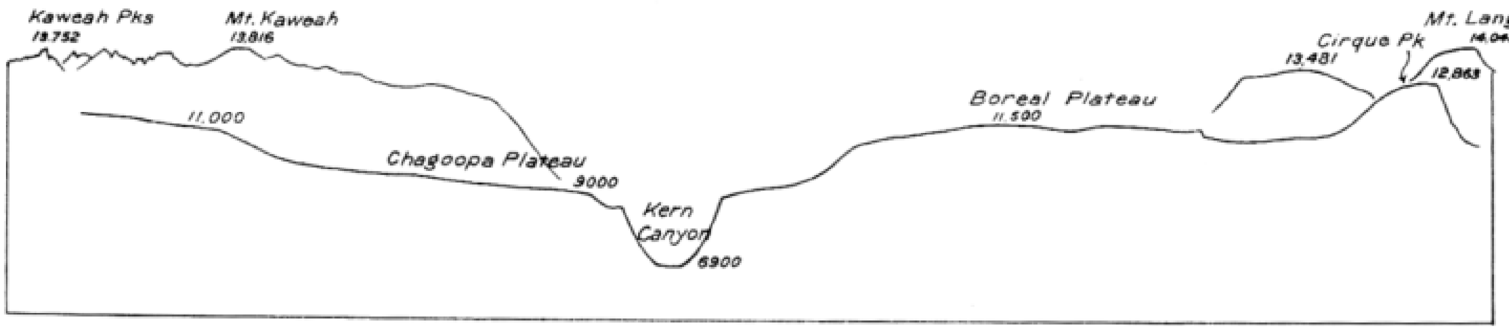
r r

r It happens that the summit of Mount Whitney is composed in large part ofr a fine-grained, siliceous type of granite known as aplite—the kind of rock whichr ordinarily occurs only in narrow dikes (veins, as they are commonly but erroneously called). This rock breaks up characteristically into large angular slabs andr weathers down to sand far more slowly than the coarse-grained granite roundabout. It follows that on Mount Whitney solifluction is wholly inoperative andr nivation works even more slowly than on some of the other tabular peaks of ther Sierra Nevada. How slowly, you ask? Perhaps as slowly as three or four feet inr 250,000 years, to judge from the rate at which certain dikes of aplite whoser r r glacial history is definitely known appear to have been reduced by weathering.r As the Ice Age and all of postglacial time together aggregate in round numbersr one million years, it would follow that Mount Whitney has suffered a reductionr of only 12 or 16 feet since the Ice Age began. The total reduction which Mountr Whitney has suffered by erosion of all kinds since it was a lowland hill, considering the climatic conditions and the vegetational cover that existed in preglacialr times, probably amounts to several hundred feet.r

r r

r Remains the question, how old is Mount Whitney? How many millions ofr years have elapsed since it was a lowland hill? Again, only a rough estimate isr r r r r r

r r



r

r

r r r
r r Figure 14.—Simplified east-west profile across the Upper Kern Basin showing remnants ofr r four ancient landscapes (erosion surfaces) at different levels above the Kern Canyon. Verticalr r scale exaggerated. Courtesy University of California Pressr

r

r
r r possible, only an indication of the order of magnitude of the interval, based onr the data that are now at hand concerning the evolution of the upper Kern Basinr and the Muir Crest.rr r

r The best method of approach is by evaluating the duration of each of ther successive cycles of erosion that have left their impress on the region (seer Fig. 14).r Without going into a full discussion of all the factors that must be considered, it may be pointed out that the Kern Canyon has been produced by streamr and glacial erosion since the last great uplift of the range. It is therefore presumably about one million years old. The broad rock-benches of the Chagoopar cycle, by comparison, must have required 10 to 15 times as long an interval forr their development—in round numbers, 10 to 15 million years. The still morer maturely developed landscape of the Boreal Plateau cycle, then, may have required fully 20 million years, and at least another five to ten million years isr to be assigned to the cycle that followed the initial uplift. The total length ofr time that has elapsed since the lowland stage, when Whitney Hill was only 1500r feet high, therefore appears to be of the order of 35 to 45 million years.r

r r

r *Reprinted from* Sierra Club Bulletin, *1937, pages 1-18.*r

r r r

r [1]Seer footnote on page 97,r and Appendix.—Ed.r

r r r

r [2]The small peak that bears Muir's name at present seems hardly commensurate in importancer among the features of the Sierra Nevada with the greatness of the man whose love for the "Ranger of Light" inspired the movement for the conservation of its scenic treasures.r

r r

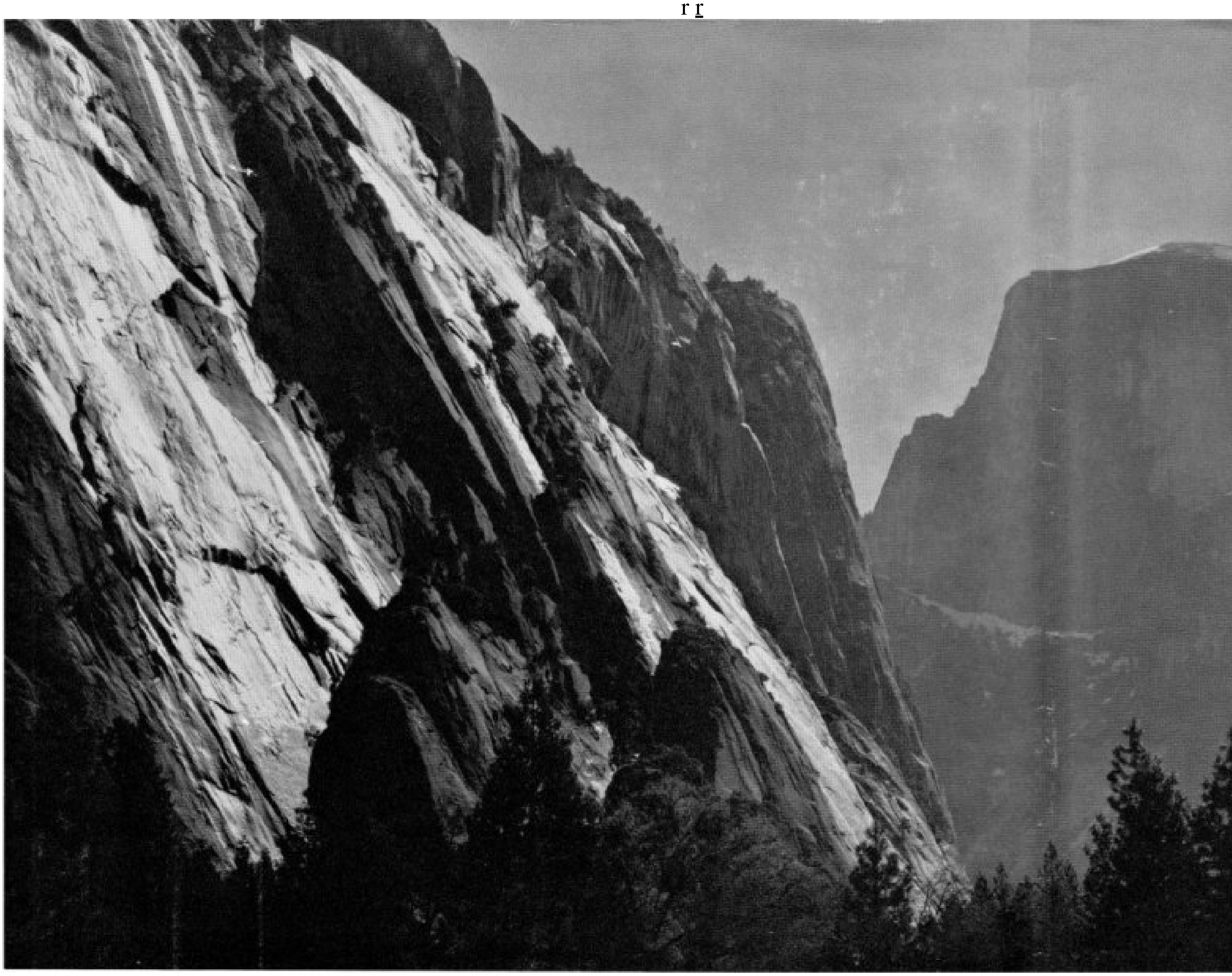
r [3]"The Geomorphogeny of the Upper Kern Basin," by Andrew C. Lawson, inr *University of California Publications, Bulletin of the Department of Geology*, 1904, 3:15, pp. 305—330.r

r r

r [4]Since this essay was originally written, the higher part of Mount Young has been given ther name Mount Hale.—Ed.r

r r r r r r

r r



oyal
hes,r
r
ington
umn,r
l Half
me,r
emite.r
Ansel
amsr
r

r
r r r
r r r

r r r r r r
r r

r r

r **r Next: John Muir Glacial Theory •r Contentsr • Previous: Avalanche Sculpturer** r

r r r

r

r r

r

r r

r http://www.yosemite.ca.us/library/matthes/mount_whitney.htmlr

r r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r John Muir and the Glacial Theory of Yosemite >r

r r

r

r r r

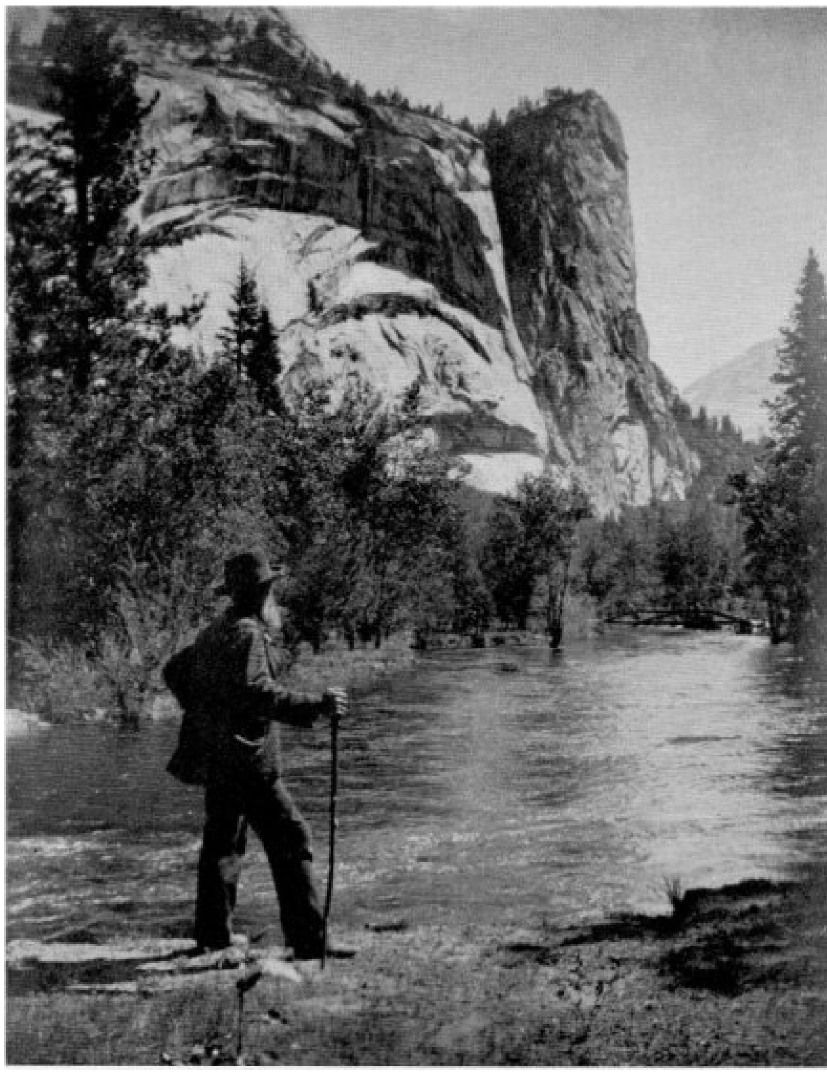
r **r Next: Appendix: Geologic Time •r Contentsr • Previous: Mount Whitneyr** r

r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

r r r r

r r  r

r r r
r r John Muir, Washington Column. Yosemiter

r
r r r r

JOHN MUIR AND THE GLACIAL THEORY OF YOSEMITE

r r r

r r John Muir'sr r name, it need hardly be said, will forever be associated withr the Yosemite Valley which he loved so well. It will also be remembered—shouldr be remembered—as the name of the humble nature lover who dared oppose ther dictum of one of the foremost geologists of his time. The theory of that scientist,r then widely accepted, was that the Yosemite had come into existence suddenlyr as the result of a violent convulsion of the earth, its bottom dropping out, so tor speak, and leaving the sheer walls standing. Nothing but a catastrophic happening of this sort, it was believed, could have given the chasm its extraordinaryr shape. Yet Muir boldly advanced the unorthodox idea that the Yosemite hadr been gouged out primarily by a mighty glacier of the Ice Age, and that it hadr been elaborated little by little in the course of thousands of years.r

r r

r In the controversy that ensued, Muir's theory was treated rather roughly byr his opponents. Scientific controversies in those days were not conducted in ther gentlemanly manner that now prevails. His views were assailed, ridiculed, andr belittled as the wild fantasies of an ignorant shepherd. It seems appropriate,r then, on this occasion to show where Muir's theory now stands, and to appraiser its scientific worth as impartially and as dispassionately as may be, in the lightr of the findings of modern geologic research.r

r r

r Mine was the privilege for several years, under the auspices of the Unitedr States Geological Survey, to study the complex problem of the Yosemite's moder of origin. Systematically and in detail I covered the very ground that Muirr studied with so much zest. I did so, however, without the guidance of the charmingly intimate accounts of his discoveries which Muir wrote in letters to hisr r r friends, for those letters then were not yet published. My findings, therefore,r were independently arrived at. Moreover, they were tested out by comparativer studies in all of the other Yosemite-like valleys of the Sierra Nevada.r

r r

r The results may be summed up as follows: In neither the Yosemite nor inr any other valley of its type is there evidence of any dislocation of the earth'sr crust. In every one of these valleys, on the other hand, there is abundant proofr of powerful glacial action such as Muir had recognized. To be sure, the glaciersr did not reach down to the foothills, nor did they excavate the canyons in theirr entirety, as Muir supposed. The Ice Age, it is now clear, was preceded in ther Sierra Nevada by long periods of canyon cutting by the streams in consequencer of successive uplifts of the range. But let no one cite these recently determinedr facts to Muir's discredit, for geologic science in the sixties and seventies of lastr century had not advanced to the point where any man, however expert, couldr have detected and proved them. Whatever shortcomings may be found today inr Muir's geologic interpretations, they are to be attributed primarily to the limitations of the science of his day. To one thoroughly at home in the geologic problems of the Yosemite region it is now certain, upon reading Muir's letters andr other writings, that he was more intimately familiar with the facts on the groundr and was more nearly right in their interpretation, than any professional geologist of his time.*r

r r

r On this centennial of his birth, then, it will be a source of satisfaction to hisr friends and admirers to learn that, far from being in error, Muir was probablyr as nearly right in his glacial theory of the Yosemite as any scientist in the earlyr seventies could have been.r

r r

r *Written for a broadcast, April 17, 1938. Reprinted from* Sierra Club Bulletin, *1938, pages 9-10.*r

r r

r *See especially,r r John Muir's Studies in the Sierra. The Sierra Club, San Francisco, 1960. 142 pages.r Introduction by William E. Colby; Foreword by John P. Buwalda.r

r r r
r r

---

r r

r **Next: Appendix: Geologic Time •r Contentsr • Previous: Mount Whitneyr** r

r r r

r

r r

r

r r

r r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r Appendix: *Major Divisions of Geologic Time in Use by the U.S. Geological Survey* >r

r r

r

r r r

r **Next: End Paper •r Contentsr • Previous: John Muir Glacial Theoryr** r

r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

r r r

APPENDIX

r r

Major Divisions of Geologic Time in Use by the U.S. Geological Survey

r r r

Era	Period or System	Epoch or Series	Approx. no. of million years ago.[1]	Approx. length in millions of years[1]
Cenozoic	Quaternary	Recent Pleistocene	0–1	1
	Tertiary	Pliocene	1–12	11
		Miocene	12–28	16
		Oligocene	28–40	12
		Eocene Paleocene	40–60	20
Mesozoic	Cretaceous		60–130	70
	Jurassic		130–155	25
	Triassic		155–185	30
Paleozoic	Permian		185–210	25
	Pennsylvanian (Upper Carboniferous)		210–235[2]	25
	Mississippian (Lower Carboniferous)		235–265[2]	30
	Devonian		265–320	55
	Silurian		320–360	40
	Ordovician		360–440	80
	Cambrian		440–520	80
Proterozoic	Pre-Cambrian		520–2100+	1600+

r r

r [1]Report of the National Research Council, Committee on the Measurement of Geologic Time, 1949–50.r

r r

r [2]Estimate of J. P. Marble, Chairman of Committee on Measurement of Geologic Time, March 17, 1954.r

r r r

r r

r SOME OTHER PUBLICATIONS ON THE SIERRA NEVADAr BY FRANÇOIS E. MATTHESr

r r

r Superintendent of Documents, Government Printing Office.r Washington 25, D.C.:r

r r

r r The Geologic History of Yosemite Valley. Professional Paper 160, U. S. Geological Survey. 1930.r

r

r Reconnaissance of the geomorphology and glacial geology of the San Joaquinr Basin, Sierra Nevada. California. Professional Paper 329, U.S. Geologicalr Survey, 1960.*r

r

r r Glacial reconnaissance of Sequoia National Park, California. (To be published by the U. S. Geological Survey.)*r

r r

r The University of California Press. Berkeley 4, California:r

r r

r *Sequoia National Park: a geological album*. 1950.*r

r

r *The Incomparable Valley: a geologic interpretation of the Yosemite*. 1950.*r

r

r * Posthumous works, edited by Fritiof Fryxell.r

r r r
r r

r r

r **Next: End Paper •r Contentsr • Previous: John Muir Glacial Theoryr** r

r r r

r

r r

r

r r

r r r r r r r r r r r r r

r

r r

r Yosemite > Library >r François Matthes >r End Paper >r

r r

r

r r r

r **r Contentsr • Previous: Appendix: Geologic Timer** r

r r r

François Matthes and the Marks of Time: Yosemite and the High Sierra by François E. Matthes (1962)

r r r r r

---

r r r

END PAPER

r r r

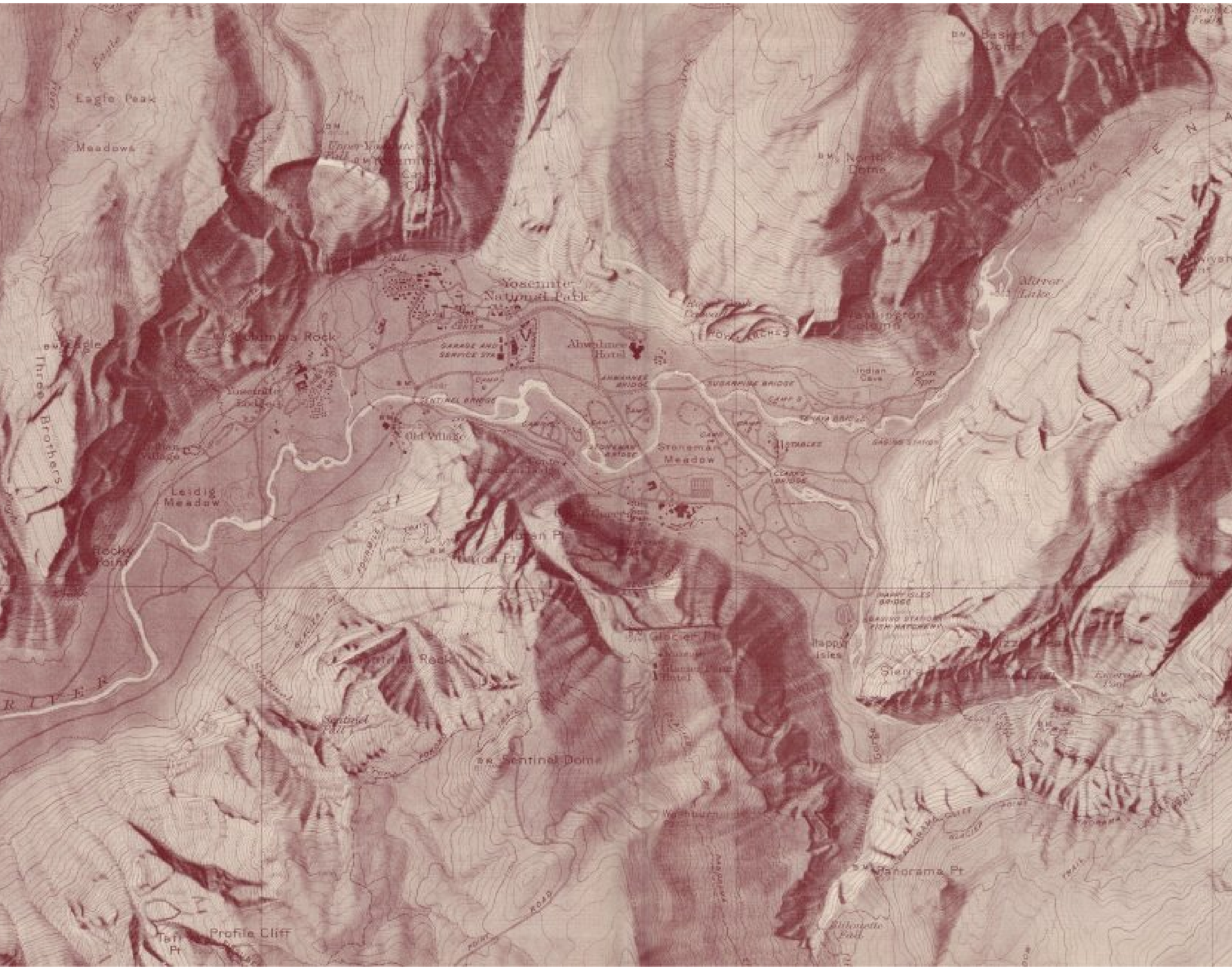
r r The end paperr r is a portion of a map of Yosemite Valley. Ther topography is by François Matthes and stands as one of ther most beautiful topographic maps ever published. Matthes urgedr for many years that the United States Geological Survey shouldr publish shaded topographic maps and left his own version ofr shading with the Survey upon his retirement. The portion herewithr is an approximation of what he had hoped for and is reproducedr in one color from the U.S.G.S. sheet, which is in fiver colors.r

r r

r *Source:* U.S. Geological Survey, Map of Yosemite Valley, Yosemite Nationalr Park, California, surveyed in 1905–1906 in coöperation with the State ofr California and partly revised in 1934 and 1946. The shading was added inr 1946, and the source sheet is one that was reprinted in 1949 with corrections.r The scale is 1:24,000 (1 inch equals 2,000 feet) and North is up.r

r r r r r r

r r



r
r r r
r r r

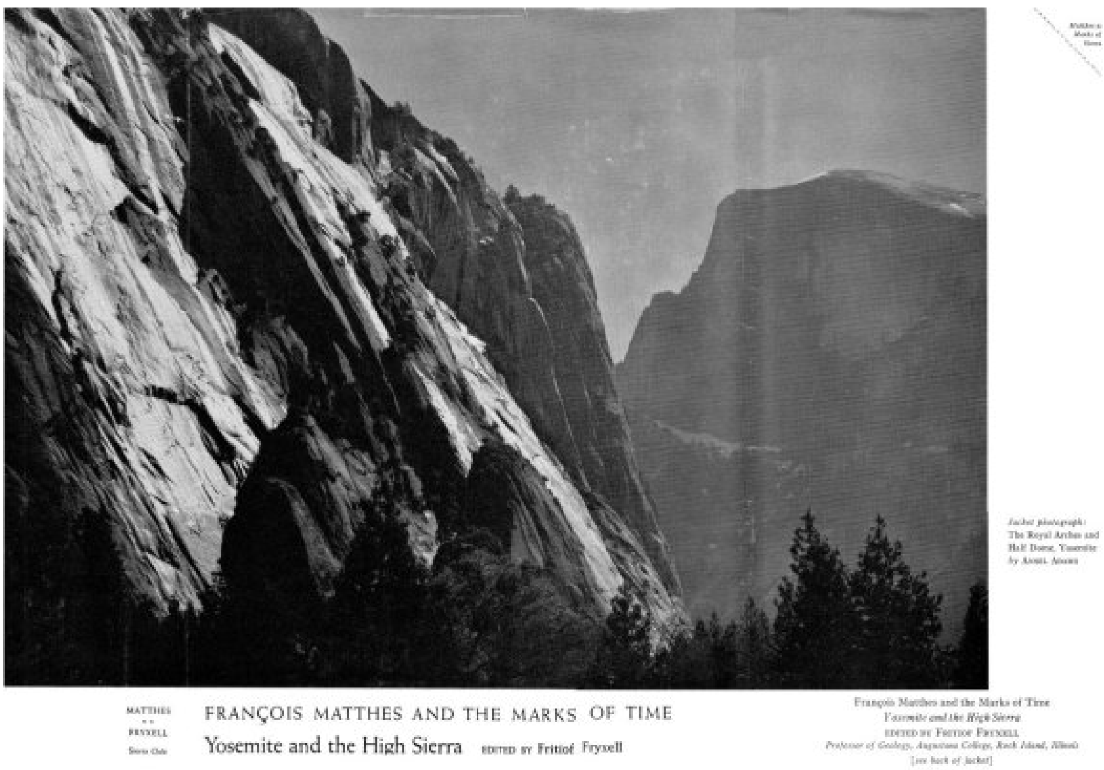
r r r r r r

---

r r r

Dust Jacket

r r



r r r

r r r

r r *Dust jacket*r

r r

r François Matthes “interpreted the beautyr
r of the Western American landscape to the mindr
r as well as eyes of all who love mountains.”r
r —Robert Gordon Sproulr

r r

r **r François Matthes and the Marks of Time:r**
r Yosemite and the High Sierrar
r Edited by Fritiof Fryxellr r

r r

r “As an interpreter of the western scene,” Professor Fryxell writes, “Matthesr was without peer among contemporary American geologists.” And his workr fascinated nongeologists, too. One wrote, of a friend and himself, “We have bothr carriedr r Professional Paper 160 [about Yosemite]r in our knapsacks when everyr ounce of weight was precious.”r

r r

r Matthes first came to Yosemite in 1903. The first of his “Little Studiesr in the Sierra” appeared in the *Sierra Club Bulletin* in 1910, his last, in 1948.r Others were drawn upon for his books; still others are first published here.r

r r

r It is appropriate that Professor Fryxell, who has completed three ofr Matthes' books on the Sierra Nevada posthumously, and who also traveledr with Matthes on some of his explorations, should complete the present workr and preface it with a beautifully and sympathetically presented biography ofr a very special kind of scientist.r

r r

r It was the unique gift of François Matthes to make geology a living subject.r A detective of the high-mountain wilderness and an artist in the way he presentsr his story, he gives nothing away prematurely, but asks the reader and himselfr questions: Could the range have formed because the mountain lifted or becauser the valley dropped? If the valley dropped, then should we not find two or threer kinds of evidence? Lets go out and look.r

r r

r After a certain amount of suspense, we find the evidence, and he lets usr discover it for ourselves—again and again on field trips through these pagesr with Matthes. The man who is not a geologist to begin with ends the trip withr the makings of a geologist in him—and he will love the transformation and hisr new appreciation of the old mountains he thought he knew.r

r r

r *r Illustrated with many photographs by Ansel Adams and including photographs,r sketches, diagrams, and topography by François Matthes. Designed by Markr Robertson.r* r

r r r
r r

---

r r

r **r Contentsr • Previous: Appendix: Geologic Timer** r

r r r

r

r r

r

r r

r http://www.yosemite.ca.us/library/matthes/end_paper.htmlr

r r r r r r

---

r r r r r r

r

r r

r r r

r

r r

r **r Next: Title Pager** r

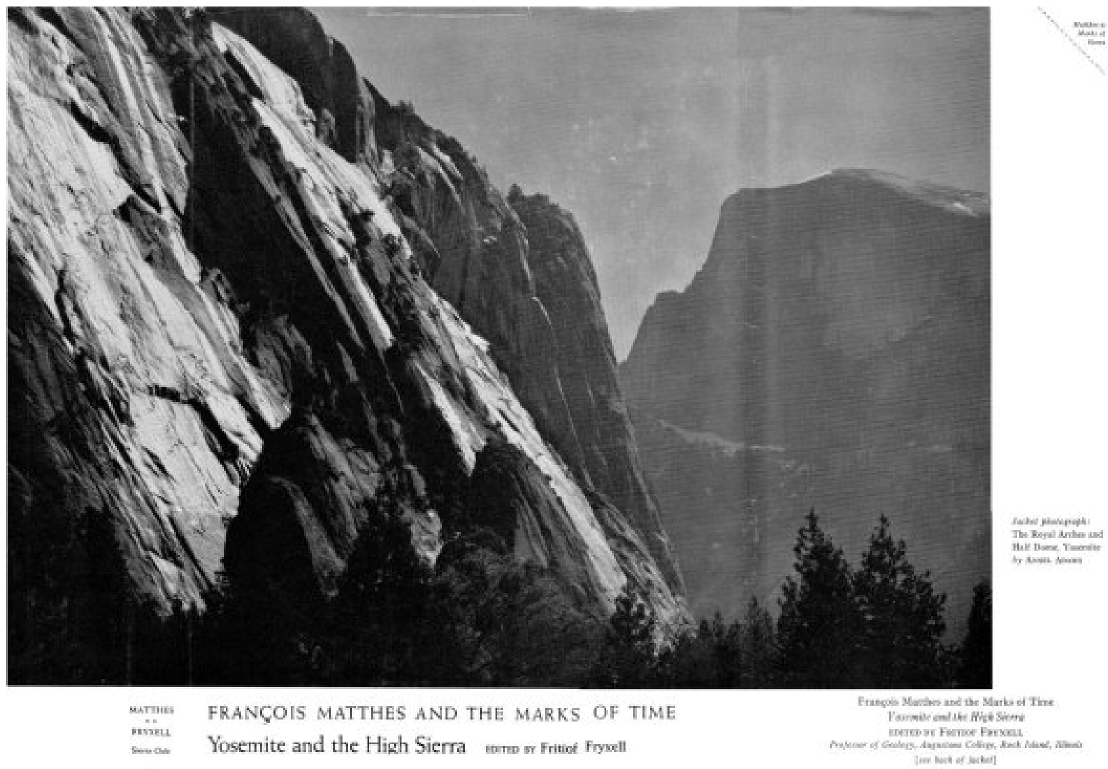
r r

---

r r

François Matthes and the Marks of Time: Yosemite and the High Sierra (1962) by François E. Matthes

r r r



r r r

r r r

r r *Dust jacket*r

r r r

r
- Title page and front matter

r
- Preface

r
- Contents

r
- François Emile Matthes

r
- The Winds of the Yosemite Valley

r
- The Striped Rock Floor of the Little Yosemite Valley

rr r r

r r

About the Author

r r

r  r

r *r François E. Matthesr*
r (photograph byr
r Ernest A. Bachrach)r r

r r

r François Matthes (pronounced *france-wah mat-hes*)r was born in Amsterdam March 16, 1874 and spent much of his youth in Switzerland,r where he became interested in mountains and glaciers, then Frankfurt, Germany.r He came to the US in 1891 to study at Massachusetts Institute of Technology (MIT) and graduated as a Civil Engineer.r Geology and glaciology was his hobby and became his work.r Matthes joined the U.S. Geological Survey (USGS) in 1896,r where he mapped and surveyed several National Parks, including Yosemite.r In the 1920s he set out to determine ifr r John Muir’s Yosemite glacier theories were correct.r Matthes found that glaciers were a major force in creating Yosemite Valley and other features and published his findings asr *Geologic History of the Yosemite Valley*r USGS Professional Paper 160 (1930).r Matthes also published several popular articles inr r *Yosemite Nature Notes*.r Although Matthes never received an earned Doctorate,r he received an honorary LL.D. degree in 1947 from University of Californiar for his life-long accomplishments.r

r r

r Matthes died June 21, 1948,r while he was working on a popular book interpreting Yosemite geology.r Matthes widow, Edith Lovell Matthes, and a colleague,r Dr. Fritiof Fryxell,r edited the unpublished manuscript and published it asr *The Incomparable Valley: A Geologic Interpretation of the Yosemite*r (1950).r They also edited this book,r *François Matthes and the Marks of Time* (1962),r a selection of articles that appeared inr *Sierra Club Bulletin* and elsewhere.r

r r

r
- r r Donald E. McHenry,r "Francois E. Matthes Honored—Retires,"r *Yosemite Nature Notes* 27(2):54-55,57 (February 1948) [PDF]r

r
- r r Donald E. McHenry,r "Francois Emile Matthes" [obituary],r *Yosemite Nature Notes* 27(7):97-98 (July 1948) [PDF]r

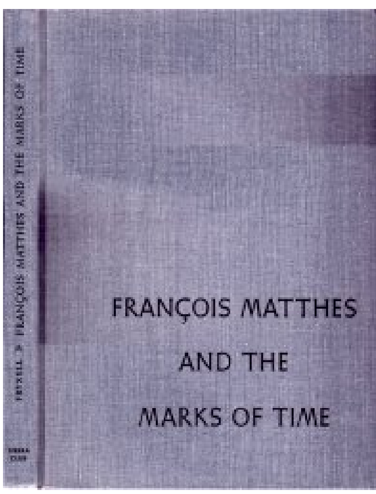
rr r r

---

r r

Bibliographical Information

r r r r

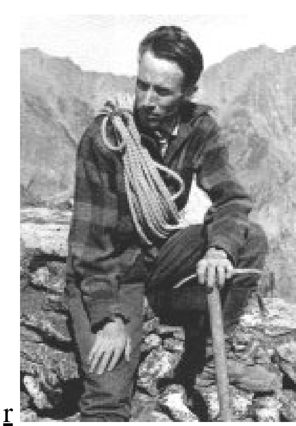
r r 

r

r r r

r r *Cover*r

r r

r r 
r

r r r

r *r Dr. Fritiof Fryxellr r (editor) climbing in ther r Grand Teton range,r r Wyomingr* r

r r

r François E. Matthes (1874-1948),r *François Matthes and the Marks of Time: Yosemite and the High Sierra*r (San Francisco: Sierra Club, 1962),r Edited by Fritiof Fryxell (1900-1986).r Copyright 1962 by the Sierra Club.r LCCN 62011763.r 189 pages. Illustrated. 26 cm. Bound in charcoal cloth board.r Library of Congress call number QE89.M3.r

r r

r
- r r Keith A. Trexler,r "Francois Matthes—the Master Interpreter" [review of *François Matthes and the Marks of Time*], *Yosemite Nature Notes* 40(6):148 [PDF]

r
- r Another review of this book appears inr E. H. Brown, *The Geographical Journal* 128(4):537 (Dec. 1962).r

rr r

r r r
r

---

r r

r **Next: Title Pager** r

r r r r r

r

r r

r

r r

r http://www.yosemite.ca.us/library/matthes/r

r r r r