A BIOGRAPHY OF CLARENCE EDWARD DUTTON (1841-1912), 19TH CENTURY GEOLOGIST AND GEOGRAPHER

Robert Stewart Anderson
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PREFACE 2017

It has now been 40 years and 4 months since I finished writing this biography of Clarence Edward Dutton, my Masters thesis at Stanford. This has been on my shelf, and in the stacks at Stanford ever since, read by the few to whom I lent it, or who tripped across it while perusing the stacks.

Since then no other biography of Dutton has been written. Stephen J. Pyne produced his tome on G.K. Gilbert about the same time I finished Dutton. So the hole in the history of American geology that this thesis was intended to fill remains open. I apologize for not making this available sooner. Dutton's story deserves to be told. With Gilbert and Powell, Dutton helped to open the geological and geomorphic story of the American West.

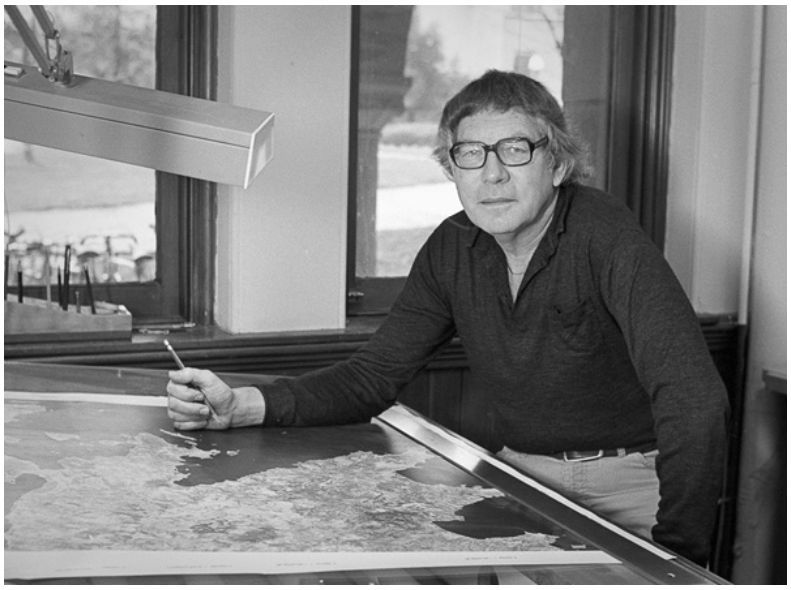
While I have spent 30 years as a teacher and a researcher of geomorphology, and therefore know much better than I did in 1977 the context for Dutton's research, I have not delved back into this thesis to update it, nor have I corrected those impressions I had and interpretations I made at the time of writing. That would have taken too much time – and it is the sense of not having the time to do it right that has prevented me from getting this out.

That and the fact that this was a 115 page type-written manuscript. I did manage in 1987 to have it converted to an electronic document. It was graciously transcribed into a Word document while I was at Caltech as a postdoc… but I have since lost the little 3.5 inch floppy disk. Believe me, I have looked. So this winter, 2017, I scanned it using optical character recognition technology. I have swept through it to root out the misspellings, and corrected a few grammatical glitches, but have otherwise made no changes.

While the original preface remains intact, let me expand on it to tell a little of the story of how this came to be. After all, it was a Masters thesis in the geology department at Stanford. My pursuit of this as a topic of a Masters study was allowed by a confluence of several circumstances, and involved several important people.

First, let me amplify my gratitude to Tjeerd (Jerry) van Andel and the Stanford geology faculty. Jerry was well known for his course in marine geology. While I was not interested in the pursuit of that topic for my own research, time as a graduate student should be used to take good courses from good professors. His lived up to its reputation. It was well known that Jerry was available at all times, except for the hour

before his lectures. This was a time in which he would be giving the lecture to himself, closed behind his office door. He would then burst into the lecture room, and proceed to give the lecture again to the students, timed to the minute. So we all learned about the field of marine geology, the use of marine sediments to tell the tales of the oceans, and of the history of climate that is archived in those sediments (his 1982 book *Science at Sea: Tales of an Old Ocean* is still available). As a final project in that class the students were given a choice between i) writing an NSF-style proposal to perform marine geological research, and ii) taking a modern research article published within the last year, tracing its ancestry to set its intellectual context, and projecting its importance into the future. I chose the latter, as I basically get seasick in anything larger than a rowboat. I began tracing the history of a particular article backward. With Jerry's library at my disposal, and with his recommendations for books to read, by the time the fall term ended, I was in the middle of the 19th century. I took an incomplete. Over the winter break I continued to read more broadly about the middle of the 19th century, including Bernard Devoto's trilogy (his *1846, the Year of Decision*, is a beautiful window into the events in the rest of the century), and Wallace Stegner's *Beyond the 100th Meridian* and *Angle of Repose* (see below). Upon my return, I made use of the Stanford stacks to read the biographies of important scientists at the time. I focused on biographies written by members of the National Academy of Sciences, who apparently ask members of the academy to write biographies of recently deceased members. I found that the biography of Dutton was cursory, just a few pages long. When I told Jerry where I was stuck, he suggested out of the blue that perhaps I could turn a study of Dutton into a Masters thesis. I jumped at the chance. Given that this was well outside of the norm for topics in geology, and that I was not formally trained as a historian, I think it highly likely that Jerry had to go to bat for me in faculty meetings to allow this to happen. For that I am eternally grateful. The Stanford faculty also had at the time Arvid Johnson, to whom I am indebted for his teaching of the application of math and physics to earth surface problems. He also shared a passion, as it turns out, for the history of science in this era. The faculty also included Bernard Hallet, a freshly minted PhD from Ron Shreve's tutelage at UCLA, who inspired my fascination with patterns in Nature, and with glacial and periglacial processes and landforms (and who would ultimately become my PhD advisor at the University of Washington years later). I owe all of these faculty members for their teaching, for their flexibility, and for their recognition that this was an opportunity worth allowing a young geologist to pursue.



Tjeerd van Andel. Photo by Chuck Painter, on Stanford website illustrating a memorial essay, upon his death in 2010.

Second, while my contact with Wallace Stegner was short, his encouragement to continue mining the vein of Dutton's story that he had first tapped in the 1930s was important. I already admired Wallace Stegner for his *Angle of Repose*, a historical novel set all over the west of North America that I still recommend everyone read. I had read it the winter before I chose to work on Dutton. And his biography of John Wesley Powell in *Beyond the 100th Meridian* has stood the test of time. Stegner was retired from teaching writing at Stanford, but lived in a house in the hills above Palo Alto, essentially beside the San Andreas fault. To my astonishment, he responded to my request to meet, to talk about Dutton and the resources he had arrayed upon writing his own Ph.D. dissertation at the University of Iowa in the 1930s. We met for tea at his house, he a very well known author, me a 24 year old geology student. He showed me his writing room, really a separate building (I recall it being hexagonal?), the walls lined with books to the ceiling, the windows letting in a redwood glow, and a big central table cluttered with papers and opened books. He told me of having been in touch with Dutton's relatives, and learning about the fire that had destroyed the collections of his letters. He told me of having typed out his own copy of Dutton's *Tertiary History of the Grand Canyon*, his most famous monograph, from the University of Iowa stacks. There was no Xerox machine at the time, and he couldn't afford to buy a copy – even then. It was the depression, after all. But the most interesting part of the conversation occurred when the topic veered to Dutton's role as the head of the Irrigation Survey.

I had wondered aloud at what Dutton was like as a person. I had found no personal letters, no letters either to or from his wife or children. Stegner allowed as how Oliver, the protagonist in his *Angle of Repose* was based upon a real person named Arthur Foote, who for some portion of his career was an employee in the Irrigation Survey. The book was based upon a set of letters Stegner had stumbled across in the stacks of the Stanford manuscript collection. The letters were sent from Mary Hallock Foote, a

woman of New York society written to her friends back east as she traveled the West in her long marriage. (I note that these letters have since been published in 1992 as *A Victorian Gentlewoman in the Far West*: *The Reminiscences of Mary Hallock Foote*). Perhaps in one of her letters, Stegner thought, she describes a meeting between Dutton and her husband Arthur. Soon I too was rooting through the letters; if I recall they were still in a shoebox in the stacks. I found that indeed Dutton was supposed to have had dinner with them in the field (in Idaho I believe), but that something had diverted his travel plans. They came within a couple hours of meeting. We were robbed of a description of Dutton from the eyes of a remarkably perceptive woman.

So it is that I owe so much to both Jerry van Andel and Wallace Stegner in promoting and encouraging this brief biography of Clarence Edward Dutton. Let this serve as a jump-start for someone else to carry on a more formal and expanded study of this interesting, artful, and important character. We owe much to him, and to the generation of geologists with whom he so closely teamed. *Boulder, Colorado 2017*

PREFACE 1977

This thesis is an outgrowth of what was to be a paper in marine geology. I found I was more interested in the history and philosophy of geology, and through the generosity of Professor Tjeerd H. Van Andel I obtained permission to pursue that interest. This led to an absorption in the past, and in particular in the late 19th century. It was an exciting era in Western American geology. I liked the smell of the old reports, and the sound of the old geologists.

I chose Dutton for several reasons. First, no major biography had been written on the man. Second, I enjoyed his writing style. Third, I felt he was a most important figure in Western American geology. Dutton did not consider himself worthy of fame. He did not save correspondence, pictures, or manuscripts. What letters his family saved were lost, and have not been recovered. Yet some of the geologists with whom Dutton corresponded saved his letters. It becomes a matter of the educated guess and coincidence that these letters are found.

I spent one hectic but productive week in Washington, D.C., both at the National Archives and at the Smithsonian Archives. I greatly appreciate the help of Bill Deiss at the Smithsonian and of Richard Crawford at the National Archives. I must thank the Shell Fund of the Stanford University Geology Department for supporting my trip to Washington.

Since that trip I have found three more collections of letters: one in Edinburgh, Scotland, another in Austin, Texas, and a third at the USGS field records library in Denver, Colorado. Dr. Gordon Craig of the University of Edinburgh was kind enough to send copies of the Scottish collection, correspondence between Dutton and Archibald Geikie.

For his encouragement and insight I thank Professor T. H. Van Andel. His enthusiasm for the project never wavered. *Stanford, California 1977*

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INTRODUCTION

A new generation of scientists was born with the passing of Halley's comet in 1835, and taken away with its next pass in 1910. Endowed with a natural curiosity and nurtured by the feast of a frontier awaiting exploration, many of this generation grew fat on the various courses of natural philosophy. Along with Clarence Edward Dutton, who was born more or less at the center of mass of this group -- twenty miles north of Yale, and on May 15, 1841 -- perhaps a dozen men found in geology the challenge to match their energies, both creative and physical. Within four years on either side were born Clarence King, George Wheeler, Othniel Charles Marsh, Grove Karl Gilbert, and Thomas Chrowder Chamberlain; within eight, John Wesley Powell, and William Henry Holmes (and in Europe, Archibald Geikie); within thirteen, Ferdinand Hayden and William Morris Davis. The science was still young, its growth having been for the most part in Europe. In its adolescence, geology was to be exposed to the American West, and it grew from the experience into a full-fledged science, with its own societies, its own publications. The lessons of that period were hard to learn; it took no small time to dispel the old myths about mountains and volcanoes, about faults, folds and a contracting Earth.

The discoveries were as geographical as they were geological, as much exploration as science. This duality was expressed in the writing and in the personalities of the Western geologists. Some stuck almost exclusively to the scientific viewpoint. Their works helped define the geologic principles and the scientific methods. Others saw as well the geographical purpose. The Western scene was not known. Myth told stories of the Great American Desert; painting portrayed a lush sylvan landscape. The role of revealing the truth fell on the geologist. Even the survey leaders of the day had radically differing visions and definitions of the role of the scientist. King would dwell on the economic resources of the nation: gold, copper, mercury, coal, lead. Powell laid emphasis on the geological and topographic map. He held out hope for land reform in an agrarian West, in which water was the principal resource. Powell's goals were as much political and social as they were scientific.

Dutton's geologic paths crossed all of these, and were bent at times by the crossings. His works are digestions of huge tracts of land. He would cover a 2° atlas sheet in a summer, and write a monograph on it in the following year. “The Tertiary History of the Grand Canyon”, “Hawaiian Volcanoes," and , “Mt. Taylor and the Zuni Plateau" were all done in this way. His first work was on the High Plateaus of Utah, a work that took him three field seasons; but never again would he spend as much time in one field, although in the Cascades a decade later he intended to. His geologic ambitions embraced large themes: western mountains, the problems of physical geology, volcanism. But the forces that molded his career were not as simple as one man's ambitions. Upon leaving Yale he began a military career that lasted four decades. His geologic career was a fifteen-year subset of these, one of the longest special details from the U. S. Army on record. Within geology he worked closely with Major Powell, his pier in some senses, his pawn in others.

Clarence Edward Dutton (1841-1912)

In Gilbert and Dutton, Powell had two left hand men (he lost his right arm in the Civil War). As a trio they both studied the Colorado Plateau in the 1870's, and ran the United States Geological Survey (U.S.G.S.) in the 1880's. As administrative work, much of their effort is undocumented. As geologic work, some aspects of their writings are not now understood, the geographical purposes overlooked. It was much through their writings that geology was given in its adolescence valuable exposure to the American West. Yet as important a product of that process was the exposure of the American West to the nation and to the world.

CHAPTER 1. 1841-1860

SOME GEOLOGICAL HIGHLIGHTS [1]

The year 1841 was the third of the “Wilkes Expedition,” as the First United States Exploring Expedition to the South Seas has become known. One of the naturalists on the two sloop, one brig expedition, a young Yale graduate named James Dwight Dana, was tasting his first field experiences. One of the major stops in 1840 was the Sandwich Islands, as the Hawaiian chain was then known; and in 1841 a part of the expedition marched from the Columbia to San Francisco Bay. The expedition’s legacy consists of two things: Dana's reports, which came out (in very limited editions, for the government thought this would enhance their value) over a period of twelve years; and the discovery of the Antarctic continent. Land had been sighted on January 19th, 1840, and Commander Wilkes sailed along the coast on the Australian side for some 300 miles.

Back in New Haven, Benjamin Silliman, Jr., was coming of age by beginning to share the responsibilities of editing his father's journal, formally titled the *American Journal of Science and Art*. As the first such journal for the diffusion of scientific knowledge in the United States, it had become affectionately dubbed *Silliman's Journal*. James Dana returned from the Wilkes Expedition in 1842 and married the daughter of the elder Silliman, becoming the brother-in-law of Benjamin, Jr. He would later take on his own share of the editorial duties, making the editors Silliman, Silliman, and Dana. Through the course of five more decades the various permutations of Sillimans and Danas were all explored as editorial staffs, the century ending with Dana's son, Edward S., as sole editor. So it was always to this scientific family that contributors sent their mail, mail concerning anything from the observation of a meteorite to the apparent bending of a stream by Coriolis forces.

Across the Atlantic a well-endowed and scientifically minded Englishman had died twelve years earlier -- a man named Smithson. His will read thus: “…to the United States of America, to found in Washington, under the name the Smithsonian Institute, an establishment for the increase and diffusion of knowledge among men." Mystery revolved about the small document; for years investigators sought for a motive among his correspondence, but none was ever found. He apparently knew no Americans of note, and, moreover, was disposed rather toward aristocracy than toward democracy. The money, some 105,000 pounds, was transferred to the United States Treasury upon the death of his one surviving cousin in 1838.

The seven years that followed witnessed a grand and formal squabble over the eleven word definition of the Institute. In 1846 the Smithsonian Institute was finally established. Before the end of the year, Professor Henry, then of Princeton University, was persuaded to take charge as Secretary. Until then, Henry had been studying electricity and magnetism, publishing his numerous papers in Silliman's Journal and in the Transactions of the American Philosophical Society, still the only major scientific society to claim a national membership.

Again in England, a second generation of geologists was coming into its prime. Charles Lyell had published Principles of Geology in 1832. Adam Sedgwick and Roderick Murchison were working their way toward each other across the Cambrian and Silurian sections of Wales. The British had already begun to take their scientific expeditions seriously; the HMS Beagle, with the young Darwin aboard, sailed in the 1830's.

In France and Switzerland, papers in the 30's prefaced the Ice Age debate. First proposed by Carpentier, the concept of an earlier and more extensive glaciation was extrapolated by a close friend, Louis Agassiz. It marked a shift in interest for Agassiz, until then submerged in a study of fishes, both living and fossilized. In 1840 he published his classic, ”Etudes sur les Glaciers”, and in the following field season began systematic observation of the Aar glacier. He made headquarters in the Hotel des Neuchatelois, located under a comer of a large boulder in the medial moraine, with blankets on the ice floor, and another draped in front to damp the chilled winds. The setup worked well until the action of periodic frosts caused the boulder to split. The hotel was relocated in a considerably less comfortable tent.

Agassiz remained in Switzerland until 1846, when, to the great advantage of the scientific corps of the United States, he emigrated to America. His diverse studies found enthusiastic and general support, and he settled into a teaching position at Harvard. His future became irrevocably an American one when in 1849 he married a prominent lady about Boston.

The United States benefitted thrice from the Revolution of 1848 in Switzerland. Arnold Guyot and Leo Lesquereaux followed Agassiz's emigration by two years, the Academy at Neuchatel having been closed by the revolutionary economy. Guyot, who had been a colleague of Agassiz at the Academy, and had worked extensively on the glacial drift problem, became a prominent physical geographer and educator, teaching primarily at Princeton. Lesquereaux became well known for his extensive paleobotanical reports for Owen, for Hayden, and for Whitney.

In the United States there was nothing comparable to the Paris School of Mines, or to the Academy of Neuchatel in Switzerland. The Sheffield Scientific School at Yale, and the Lawrence Academy at Harvard were not yet founded. These and various other universities along the eastern seaboard had chairs in geology, but only a couple universities were truly dedicated to anything but the classical education, which included almost no science at all.

Only two schools were attempting to break from the mold: Eatons’ Rensselaer school in Troy, and Maclure's School of Industries in New Harmony, Illinois [2]. Amos Eaton, a graduate of Williams College, convinced the wealthy Stephen Van Rensselaer of New York State to endow a school devoted to the instruction of persons “who may choose to apply themselves in the application of science to the common purposes of life." In 1825 the Rensselaer School was founded in Troy, New York, with Amos Eaton senior instructor. The curriculum soon expanded to include a summer field course along the Erie Canal, in accordance with the school's maxim -- “learn by doing." Perhaps the

best-known graduate of that period is James Hall, who completed the two year course in 1832. He stayed on as a teaching assistant through 1835, and later became a full professor of chemistry. By 1841, Hall held a significant position within the New York State Survey.

The other scientifically oriented school in the United States was a less formal one, more experimental in its stance. In cooperation with the renowned educator, Robert Owen of Scotland, William Maclure founded his School of Industries in New Harmony, Illinois. Far in advance of its day, this school offered not only a solid scientific background but also ran a printing press to promote the diffusion of scientific knowledge. Maclure, a Scot, had come to the U. S. in 1796 and by 1809 had traversed the states many times, compiling notes to be published in a large work entitled “Observation on the Geology of the United States”. Other instructors in the school were Troost, trained in Paris, and Say, a pioneer paleontologist. The most celebrated student of geology at New Harmony was the fourth son of Robert Owen, David Dale Owen. He led, in 1839, a large federally sponsored tri-state survey of Iowa, Illinois, and Wisconsin.

But as Dutton went through school, the major scientific exploration of the western territories stayed in the hands of the military [3]. The discovery of gold in California late in the 1840's was followed by twenty years of attempts to establish a route for a western railroad to the Pacific. Military party after military party was sent out with special instruction to reconnoiter this or that route, discover what types of difficulties plagued each, what elevations and grades would be encountered. The Stevenson expedition, the Macomb, the Williamson, the Ives, and of course Fremont's escapades were among the many. All were well-documented journeys, and many came up with the most extraordinary reports. But the geologic chapters were necessarily sketchy. The information was drawn in passing from those points that happened to lie along the route of a proposed rail: more a catalogue of sights seen, thoughts stimulated. No attention was paid to the integrity of the geologic systems. By the fifties most states had their own geologic surveys, many being run by graduates of the Rensselaer and New Harmony schools. In these surveys many of the new generation of geologists were to find their initial training. But, as Dutton completed his education, California was the only state in the West.

DUTTON'S YOUTH -- AN AUTOGIOGRAPHICAL SKETCH

Little is known of the youthful Dutton. His father was a shoe and boot dealer in Wallingford Connecticut; his aunts and grandmothers were notoriously pious. Although Clarence dabbled in science from an early age, spilling sulfuric acid on his clothes and collecting dirty rock specimens from the hills around Wallingford, his educational course never deviated from the classical. In a letter written thirty years later, Dutton details the chronology of his education.

> When I was twelve years old I went to a boarding school in Ellington Conn. It was a “rum” place I assure you. Holiness to the Lord was blazoned all over it. Before I

had been there eight months I knew by heart the Sermon on the Mount, the Books of James and Corinthians and Timothy, and the lamentations of Jeremiah and Isaiah and could tell every morning just what the principal of the school was going to pray about and I could also tell from his prayers just what boys were going to get fustigated after breakfast. Incidentally I also learned something of Latin Grammar, Greek Grammar, German and Algebra. I stayed there until I was 14 and would have stayed there longer had I not fallen desperately and madly in love with a girl about four years older than myself. My cruel cruel mother tore us asunder and would not let me return. At 15 I entered Yale College and graduated about the middle of my class in the year 1860. After graduating the question arose what was I to do? My friends thought I ought to become a minister and insisted that I should go to the Theological school. I tried it two weeks. There was an evident wont of harmony between myself and good old Noah. Porter Fisher and Tim Dwight and I had to dismiss them. You see if I hadn't they would have dismissed me. I managed however to put in a couple of good years to good advantage in studying mathematics and physics hoping that I might become a teacher and professor of those branches. I believe I should have succeeded but in 1862 my brother who had graduated with high honor at West Point was in the engineers and had just been appointed a colonel of a Conn. Regiment -- offered me the position of adjutant which I accepted. I have been in the Army ever since ...[4]

There seems an evident “wont of harmony" between this and other information scattered about concerning Dutton's youth. The letter was intended as an autobiographical sketch to aid a potential biographer, Marcus Benjamin, working for Appleton’s Cyclopedia -- in lining up the facts of Dutton’s life. Dutton simplified the picture somewhat. He makes it sound as if he had always intended to become a scientist. From the mineral collection he claims to have established by the age of two, to the two years devoted to scientific study after graduation from Yale, he glosses over his record, stringing the various beads on a scientific string. He skips mention of the year his parents detained him from entering Yale, though this may have been connected with the “cruel cruel mother” episode.

YALE [5]

The Yale curriculum in the 1850's was a classical one. The courses taken then and the books read sound as different from those of today a does the tuition: $45 for Dutton's senior year. Scientific studies had made few inroads into the regular course of Greek, Latin, rhetoric and mathematics. Only in the junior year was “natural philosophy" introduced: some basic physics, followed by a taste of astronomy, but only twice a week instead of five times, and all under one professor.

The first term of the senior year was the most scientific. It included the continuation of the astronomy course, a six week set of lectures in chemistry -- by Professor Silliman, Jr. -- and another six week series in geology and mineralogy by Professor Dana. But that was about it. The second term of the senior year had only a single course in meteorology and astronomy, taught again by the natural philosopher; and the third term

had no science at all, only the classical courses of political philosophy, theology, and the history of philosophy. Dutton, in his four years at Yale, had contact with only three scientists. The natural philosopher, Professor Olmstead, died in 1859 and was replaced by an interim tutor for Dutton's senior course. The other was Silliman. No formal contact with Professor Dana was gained, as Dana was for some reason on leave that year. His course of lectures was given instead by Silliman.

When C. E. arrived in the fall of 1856, his brother Arthur had just completed the one-year term of the Scientific School's engineering course, and was on his way to West Point. Following if anything a literary leaning, C. E. stuck to the academic curriculum, immersing himself in Homer's *Iliad*, Euclid, Latin Prose Composition, Euripides, Xenophon, and the like. Though he was well respected, he was a bit less flashy with his grades than a classmate of his, O. C. Marsh. Dutton's final average was 2.58, good enough to rank him 88th in a class of 110 seniors [6]. But in other ways, C. E. stood out.

Both he and Marsh were active members of the Chess Club, a group of fifteen who consistently rivaled over the checkered board, at times blindfolded. (Though such boastful statements should be suspected, Dutton claimed at a later date to be able to play nine games simultaneously, all blindfolded. But he quit the hobby in 1890, finding it robbed him of his sleep.)

Physically the young Dutton excelled in both gymnastics and crew. He was a short person, standing around 5'7", and in his youth had a trim build. Though the gymnasium at Yale was not constructed until 1860, he went, as did most students, to various private clubs in the town for indoor exercise. Crew in the 1850's had become extremely popular among gentlemanly recreations. The Yale boathouse, located on the Mill River as it enters the New Haven Harbor, sported the equipment for a dozen shells, mostly six oar, a few eight, and all but two owned by various clubs in the Junior and senior classes. The other two were the rudiments of what was known as the “Yale Navy", the boats in which Yale crews vied against those of Harvard in a fierce set of aquatic battles that escalated in the 1850's. The scene in New Haven Harbor must have been impressive: a dozen shells, with flags bow and stem, rowed all by teams of men distinguishable by their gaudy uniforms. Dutton (in the Veruna Club, which owned a 33 foot shell pulling six oars) could be seen on such days strutting about in a white shirt with red-trimmed blue collar, cuffs, and shield, the shield being inscribed “60, Veruna, Yale", a black belt, white pants, and to top it all off, a straw hat. The story exists of his having rowed number 7 in the first match against Harvard, but the official records do not support it. The first race against Harvard had been ten years earlier, and in a six-man shell.

Chess, crew, and gymnastics did not define the young man, C. E. Dutton. His interest in classical studies was, if we are to let his grades tell the story, somewhat less than sustained. Upon graduation, however, in June of 1860, Dutton received two awards quite indicative of his intellectual range. The second of two senior prizes for mathematics, yielding $10, went to Dutton for best solution of mathematical problems. And he was given the Yale Literary Medal for an essay written earlier in the school year, on “Charles Kingsley, the Novelist" [7].

In the essay he heaps praise on Kingsley for the Christian ethics infused in his novels. Though he was quickly to loose his religious leanings, there are other aspects of the essay which are clearly precursors of his later writings. Stylistically, the Dutton of the Grand Canyon and Hawaii monographs is evident in the Latin words, the turns of phrase, the long sentences, the inverted modifiers. His fascination with the history of his subject is clear, in this case the history of the novel. That literary form, evolving under the pens of Dickens, Thackeray, and Twain, had been handed down through Scott, Fielding, Smollet, and Richardson; and Dutton had read them all. He would read throughout his life, enjoying the voluminous and the humorous writers of the day, grabbing phrases here and characters there, many to be used in his correspondence, and no doubt in his conversation. After graduation, he found quickly that religion was not his career. His fascination with Kingsley had been more for the literary experience than for the religious insights. According to his son, his disposition would become distinctly agnostic in later life [8]. Science became his religion.

CHAPTER 2. 1860- 1875

BEGINNINGS OF A MILITARY CAREER

There are yet more generalities in Dutton's 1886 autobiographical statement. After rejecting the theological course, he claims to have taken a direct path toward science, and indeed toward a professorship. But if his fascination with science had any manifestation during this period, it must have been entangled in his attachment to his older brother Arthur. In 1861, Arthur graduated from West Point with honors. Under his tutelage, Clarence spent the four years after graduation from Yale studying military science. It becomes ambiguous whether C. E. was aspiring to scientific or to military heights. These purposes cross for the rest of his life. In a letter Dutton sent to the President of Yale College, Mr. Woolsey, we learn of the extent of his military aspirations.

> My dear Sir: Oct. 28th, 1861 Allow me for a moment to remind you of my name and connection with Yale College in the class of 1860. Though I am well aware that you have little cause to remember me with much interest I cannot help asking a favor of you on the ground of my relationship to you as a collegian and an alumnus. I am about to apply through some of my friends to Gov. Buckingham for the commission of Lieutenant Colonel of one of the regiments now being recruited in Connecticut and I desire to secure your influence on my behalf. I hope that you will not think that in aspiring to this position I have nor calculated the amount of responsibility it would impose and compared it with my capacity to discharge it. Not only this but I have also taken pains to learn the opinions of others upon this subject who were best acquainted with my qualifications and competent to judge them. I do not find that I overestimate.

My attention was first turned to the study of military science immediately after graduating by a protracted visit to West Point. My object was to secure a commission in the regular army of which some hopes were held out by my brother who was then a distinguished cadet in the Military Academy. For six months I applied myself to the exclusion of every other purpose in acquiring some qualifications which might put me on a footing with West Point graduates and when the new administration was inaugurated I made an application for Lieutenancy hoping that unlike many others I was not without a recommendation. I very soon learned that I was deficient in the only qualification recognized in Washington. Though unsuccessful the first time my application was repeated until I was convinced that it was quite useless. Just at that time I had a good many reasons for not wishing to enter the volunteer service and so the matter rested. Some time ago, my brother now a member of the U. S. Corps of Engineers invited me to come and stay with him as long as I chose and I have now been occupied for many weeks in studying military science in books and in the field. As my brother belongs to a staff corps and the highest in the army and as he has from the nature of his duties been stationed usually at the headquarters of a general officer I have had many opportunities to catch the highest inspiration of military life and imbibe the truest military ideas. It is therefore with a conviction of my own fitness that I make application for a Lieutenant Colonelcy. If after all my painstaking and enthusiasm I am still mistaken then it must be owing to a material lack of aptness to comprehend and apply what passes under my observation.

But I think sir that I understand the wants of the service and the spirit of discipline and I long for the opportunity to carry out these ideas. At least I may be excused for saying with some warmth that if I do not know my duty better than these gay birds whose plumage adorns Pennsylvania Avenue and places of resort and if knowing I could not discharge it better I would never apply for a Corporal's guard. Now, perhaps you would have thought it more modest had I applied for a Major's commission. As there is very little difference in the duties of the two I would of course prefer the Lieutenant Colonelcy …

If upon consideration you think you could recommend me to the Gov. and would do so you cannot imagine how greatly obliged I should be for your kindness. Should you think best to do so could you do so immediately. [9]

Although the extent of Woolsey's efforts on Dutton's behalf is not known, it is certain that Dutton was never appointed to a Lieutenant Colonelcy.

THE CIVIL WAR

With the outbreak of the Civil War in April, 1861, Arthur's duties gradually increased until on September 5, 18.62, he was given command of the 21st Connecticut Infantry Regiment. Upon Arthur's request, Clarence was appointed the adjutant at a rank of Ist Lieutenant, and the brothers remained together through the year 1863. The regiment marched down the Blue Ridge, encountering the Confederates in various skirmishes.

Clarence sustained substantial injury (later complicated with enteric fever) in the Battle of Fredricksburg, but was able to continue service before 1863 was out 10.
In December of that year, he accepted the opportunity to compete for a position in the Ordnance Corps. His own description of the War experience, drawn again from the autobiographical sketch, was this:

> During the war I saw a great deal of service in the field and pretty rough service too. In the year 1863 the enlargement of the regular Army was authorized. The ordnance Corps needed more officers and not liking to take from West Point only what the engineers had left it obtained authority to admit candidates upon competitive examinations. There was a stiff examination and quite a large number of competitors. I was one of the lucky ones.

He fails to mention that four months later he married Emiline Babcock of New Haven. (His personal life he never puts to paper.) A secondary source hints that she played piano well, and another that Mrs. Powell enjoyed her company greatly; but that is the extent of our knowledge of the lady. Nor is there mention that in the middle of 1864 Clarence lost his brother Arthur, who was mortally wounded while on reconnaissance near Bermuda Hundred.

Just why Clarence jumped at the opportunity to become an Ordnance Officer is obscure. His son later said he believed it to be out of a love of math that his father applied, the accounting of men, mules, and munitions being under ordnance Corps jurisdiction [11]. On the other hand the exam's occurrence between a major injury and a marriage might be thought to imply the action of forces beyond a mere love of math. Yet for three years he had clearly pursued the opportunity to become an officer in the Army -- not necessarily an Ordnance officer, just an officer -- and the opportunity had presented itself. He sheds no further light on the matter himself. Never is there reference to his liking or disliking the job, which he held off and on for three and a half decades.

The years 1864 and 1865 record a set of transfers, from arsenal to arsenal, across the northern states, leaving him assigned to the Watervliet Arsenal, in West Troy, New York, at the end of the war.

The set of men who were soon to take up the geology and geography of the American West bore the effects of the Civil War variously. Powell is of course the most obvious example. Before a year was out he had lost part of his arm in the Battle of Shilo. He attained the rank of Major during the war, a name by which he was later called by even his best friends (though Dutton at times called him “Professor” in reference to a short teaching experience at Illinois Wesleyan after the war). Gilbert did not see action in the war. His height -- he stood 6'3" until a disease in 1909 left him slumped to 6' 1½" -- and lanky build barred him thrice from attempts to enter through the draft. The University of Rochester had refined his mind over his body, leaving him to take his only and unsuccessfully stabs at teaching, not, as his biographer W. M. Davis has said, as the

beginning of a career, but as payment of the intellectual debt incurred in his own education.

William Henry Holmes, born in 1846, was too young to participate in the conflict. Clarence King, who graduated from the Sheffield School at Yale just as Lincoln called for volunteers, did not serve in any “Thou shall not kill" quite literally and without exception. He went west to work with Whitney, then in charge of the new California Survey.

Drs. Hayden and Newberry saw service as part of the medical corps. Newberry, having received extensive medical training in Cleveland and in Paris, was Secretary of the Western Department of the U. S. Sanitary Commission, the Civil War's Red Cross. Hayden was an active field surgeon.

THREE MORE ARSENALS

With the end of the conflict Dutton set about his previous tack toward science. Whatever vestiges remained of a theological career had evaporated in the war. While stationed for five years at the Watervliet Arsenal, he divided his time neatly between scientific pursuits: steel and geology. The weekdays were spent in close partnership with Alexander Holley, the great American engineer, who was at the time attempting to smooth out the new Bessemer Steel process at the foundry up river. Dutton's work with Holley was a close one. As he tells an audience at a memorial meeting for the man in 1882, this allowed him to reveal a different side of the man than would otherwise have been seen. His description of Holley falls back, as do many of his descriptions, on the classical background of his Yale education. He wraps his memorial around an analogy to a great epic.

"But we know him the best perhaps through his relation to the Bessemer process -- that great epic or drama of the modem arts. And in that epic we will all concede that he played the part of Achilles or Aeneas. When I knew him most intimately and was most closely associated with him, the Bessemer process was in its dark days. Those who are familiar with the history of the early development of that process cannot fail to recall the vast multiplicity of difficulties which stood in the way of the development of its details -- how they rose up on every hand, how they met the engineer at every step. The art had no precedents whatever. Everything connected with it had to be created anew. It was from the period of 1866 to 1869 that those great difficulties presented themselves most numerously, and were battled with most successfully. There was many and many a time when Holley became almost discouraged, his whole soul was wrapped up in the enterprise, for which he seemed to live. Everything else for the time being was thrown away, and as disappointment after disappointment came over him, he would frequently break out to me, in moments of confidence, in a feeling almost bordering on despair. Probably very few of those who knew Holley can associate him with any such frame of mind… He too had trials which were bitter to suffer, and (sic) he surmounted them and conquered like a true hero." [12]

As his close associate over those years, Dutton cultivated his mastery of the science of chemistry. By 1869 he had gained sufficient confidence in his scientific prowess to present to the A.A.A.S. his first paper -- on the Chemistry of Bessemer Process -- at a meeting held in Troy. It was well accepted and almost a full session was spent in its discussion [13].

When a set of vacancies on the board of trustees of RPI opened in 1869, it was to Holley and to Dutton that invitations were extended. Though neither were graduates of the institute, their membership was considered a great boon to the college. As trustees, their principal contribution was as two of a trio appointed to evaluate the course of study at RPI. The other, E. Thompson Gale, was a graduate of RPI and a native of Troy. With Holley as chairman, they delved into the problem of education in a technological society. They asked for independent appraisals by such dignitaries as Professor Henry of the Smithsonian [14]. Is the course of study too mathematical? Is it too heavy in the natural sciences? Is it too theoretical? Is there anything missing? The compilation of recommendations ran some forty pages. It was a major document in Rensselaer history, expressing thoughts on the same innovative level as those of the original founder, Eaton, thirty five years earlier. The report anticipated the criticisms leveled against technical education which evolved over the next century, concluding that the lack of a liberal or literary training to parallel the scientific and engineering development was “an intolerable blemish if not an absolute unsoundness of the Institute." [15] The report was presented to the trustees in October 1870, just as Dutton was transferred to the Frankford Arsenal near Philadelphia.

But the Institute was not ready to broaden its scope. The faculty chopped the proposed expansions and additions to where RPI even narrowed its path. The trustees resolved, nonetheless, to search for a broadly educated professor of mechanical engineering. It seems Dutton was selected, and a petition to the Secretary of War was drawn up to secure his detail. In March 1871, the answer returned was negative, and Dutton's ambitions to become a professor were forever extinguished. He remained a trustee of RPI for six more years, but attended no meetings after his residence in Troy was terminated in 1870.

It was not only to the study of steel and iron manufacture that Dutton turned his attention in Troy. Twice a week he went to Albany to see R. P. Whitfield's and James Hall's paleontological laboratory, and on Sundays he and Whitfield went “fossil hunting and geologizing" in the hills about the Hudson valley. Just what inspired this new interest in geology is not known, though it was in all probability his simple proximity to these men so enthusiastically entrenched in its study. He began his lifelong attempt to keep up with the literature of geology, writing to Secretary Henry at the Smithsonian to solicit lists of publications, submitting requests for purchases, always asking for the latest Smithsonian annual reports well before they were published.

Dutton spent thirteen months stationed at the Frankford Arsenal where he claims to have maintained his interest in both geology and steel. His assignment there was to

experimental study “in connection with the manufacture and service of gunpowder for heavy cannon." He presented several papers on the subject to scientific societies.

Upon his transfer to the Washington Arsenal late in 1871, he quickly immersed himself in the town's rich scientific community, multiplying yearly under the nourishment of the various Western surveys.

"The appropriations for Ordnance being much reduced I had little to do except study. All opportunity to prosecute the study of iron and steel were now nearly gone, and refusing to be idle I took up geology with increased zeal. I began the microscopic study of rocks, making a machine for grinding the slices, and studying mineralogy." [16]

Before two months had passed he was elected a member of the newly formed Philosophical Society of Washington, of which Professor Henry was president. Dutton's first two papers, preserved for us only as titles, reflect his previous meddlings in science: “On the Measurement of the Pressure Developed by the Explosion of Gunpowder in Firearms", presented in April, 1872, and a month later, “An Account of Some Recent Experiments on Different Kinds of Gunpowder at Fort Monroe".

That year and two more he spent in the accumulation of a familiarity with both the literature and the men of geology. He devoured all the reports he could lay his hands on. He cultivated his friendships with men of the surveys, and became especially well acquainted with Major Powell. By his second year in Washington, the Lieutenant was presenting papers on geology to the society; his favorite themes were the most general of theories. Mallet's contractional theory is discussed, if not attacked (again all we have is titles), as is geologic time, and volcanism. By 1874 even glacial geological theory was brought up, a subject, it is said, that took up an entire meeting of discussion.

This range of interests allowed his easy society with the Washington group, many of whom valued the broad approach to science and geography. Professors Henry and Baird of the Smithsonian took great interest in Dutton. (With Baird he pursued a large correspondence concerning the expansion of his personal stamp collection -- but we hear only vague rumors of this hobby after 1874.) [17]

FIRST GEOLOGIC WRITINGS

Dutton's first geological article was published in 1871 after its presentation to the American Philosophical Society. The title is “On the Causes of Regional Subsidences and Elevations". It is clear that the original concept of subsidence had been previously advocated by both Babbage and Herschel in the 1840's, but in a presidential address to the American Philosophical Society, delivered by James Hall in 1857, is a more obvious precursor. In the thoughts of James Hall we are surely looking at the roots of Dutton's geologic conceptualization. Hall believed there was a clear-cut causative relationship between depositional belts and mountain systems.

"It is original deposition that not only gives direction to the mountain chains, but amount of deposition that determines their elevation; or, if you will reduce it to the simplest

terms, we may state that elevation is due to deposition, and there can be no great degree of elevation without a corresponding amount of previous deposition of sediments. Now I conceive this to be the simplest system of mountain making that can be proposed, and it can be shown to be applicable not only to the Appalachian chain but to other mountain ranges of the continent." [18]

Hall continues to expand this concept into one of the formation of continental masses, claiming that the history of geology is a gradual progression from an ocean basin to a continent, evidence being secured from the evolution of life from marine to terrestrial.

Dutton was profoundly influenced by Hall's thought. He begins early in his search for processes to tie together the phenomena of physical geology. The 1871 paper calls on the newly developed theories and data concerning metamorphism. In his close reading of the geologic literature Dutton had been struck by the possible consequences of the newly discovered change in volume connected with metamorphism. Could this not be the source for the forces needed to elevate the surface? If the minerals expand, elevation would result; if they contract, subsidence would result. He tacks in mid-article to address the problem of volcanic eruptions. If a combination of metamorphic processes softens and lightens the underlying rock, it should conform to the laws of fluid equilibrium and rise eventually to the surface.

> "Putting the problem into another form, the heavier overlying mass would sink into the lighter semi liquid beneath, and drive it upwards. If these views be correct then we ought to expect that volcanic regions will be confined to those areas which have recently been regions of marked elevation. And we find this to be the case." [19]

He has introduced what will remain principal themes throughout his geologic writings. Although they are muddled a bit here in his freshman attempt to tie the package together with a neat little bow, two themes of volcanism and isostasy will gradually separate.

His thoughts were not always original; he often found cause to espouse someone else's views, seeing their possible application to what he considered the fundamental problems of geology. He saw connections that others did not, a function of his wide reading of the geologic literature. He felt the need to plug these ideas into his developing notions -- his refined preconceptions -- of the broad conflicts in geology. And he wrote well. Never would a barrier be placed before his expression, either in speech or in writing.

Only titles are preserved for our scrutiny in the Bulletin of the Philosophical Society of Washington, but several of his early papers were published elsewhere. One bearing the same themes as his 1871 paper is found in the American Journal of Science under the title of “Criticism of the Contractional Hypothesis" [20]. Lieutenant Dutton calls upon his mastery of the mathematical discipline and applies to geology those results already attained by William Thompson (Lord Kelvin) in his studies of heat The contractional hypothesis was that model of the Earth which likened its crust with the skin of a

withering apple. This sprung from the concept of an initially molten Earth, since some unknown time in the past cooling gradually from the outside inward. The crust was a cooled slab floating in the still molten interior. But as materials cool they shrink, and so it was thought with the interior. Its shrinkage would withdraw support from the solidifying crust, and the crust would then buckle into the folds now visible in the rocks on the surface.

Dutton, in this article, shows how little experimental and theoretical support the hypothesis had, even when granted the most generous of assumptions. Not only does the hypothesis fail this numerical test, but, when subjected to simple deductive arguments, looses credibility doubly. For should it not be expected that the plications (or crenulations, or corrugations, or fold belts, or mountain chains) be evenly distributed over the shrinking surface? This is clearly not the case. The Earth's plications are primarily north-south, and, moreover, there are vast areas not in the least affected by the supposed contraction. In short, the analogy to the withered apple fails.

Dutton supports what he terms a “reactional hypothesis" -- one in which the groups of facts are explained by a reaction of the interior to the disturbances produced by external changes. The dynamics of his system are to be those driven by surficial processes -- erosion and deposition -- changes we can observe, not hidden at mysterious depths.

But he was not concerned with the surficial processes themselves. Others were studying them. His concern was more with the deep-seated effects, the coupling device through the interior. Though it may be that no rigorous check could then be made of his various proposals, he vehemently believed that the contractional hypothesis, whose proponents argued for an interior triggering mechanism for surficial disturbances, could be invalidated with experimental and theoretical considerations. It was his long-standing purpose to demonstrate that the contractional hypothesis not only failed but was not needed to explain Earth's tectonics; and he hoped to prove this by proposing other mechanisms.

CHAPTER 3. 1875-1890 A GEOLOGIC CAREER

The plain of Dutton's youth has been crossed. He is 34 and we face the mountainous landscape of his geologic career. The works themselves are not only larger, but are densely forested with the language of his youth and classical education cultivated. In the fifteen years Captain Dutton (he was promoted in June, 1874) spent in the field he produced five major reports. This is cited in biographical sketches as a feat of extraordinary energy and talent; but seldom do we get more than a cursory monograph by monograph synopsis: overall, three works on the Plateau country, one on Hawaii, and one on the Charleston earthquake of August 31st 1886. What were the forces that shaped these works? It is by no means obvious at first glance what ties these all together, short of one man's pen. What major decisions did he make, and by what decisions of others was his career bent? Where does the Captain fit into the geologic development of the last half of the nineteenth century? What were his principal contributions?

The imagination of the scientific public had been captured by the Western surveys, of which there were four by 1872: their leaders, King, Hayden, Wheeler, and Powell. Not only were men employed in the field doing the active exploration, but more were needed in the Washington offices to identify fossil specimens and examine thin sections. Powell's was the last of these surveys to become a federally supported operation, having previously been funded by Joseph Henry's Smithsonian Institute for the period including both Grand Canyon trips of 1869 and 1872. The Department of Interior was then persuaded to support him, and the official title of the Powell Survey became the Second Division of the Geographical and Geological Exploration of the Territories. Ferdinand V. Hayden had the first division, which since its birth in 1867 had grown considerably from the Land Office authorized survey of the new state of Nebraska to include large chunks of Wyoming and Colorado.

The other two surveys, under Clarence King and Lieutenant George Wheeler, differed in that they were run under the auspices of the War Department. King's was the first of the great national surveys. He proposed in 1867 to survey a hundred mile swath of country along the 40th parallel, from the Rockies to the Sierras -- the route of the Central Pacific Railroad. The army explorations of Lt. Wheeler were expanded in scope in 1871 when he took on his first geologist, the young G. K. Gilbert, fresh from his tutelage under J. S. Newberry of the Ohio Survey. Wheeler's was the fastest moving and by far the most military of the surveys, its title the Geographical Surveys West of the 100th Meridian. His field season of 1871 was more than a marathon, more than 200 marathons; he boasted of having covered 6237 miles.[21]

By 1874 and 1875 a rivalry between the surveys had become intense. Overlaps were common. There are stories of a slight skirmish between one of Hayden's and one of Wheeler's parties among the mountains of central Colorado. And letters between the heads of the surveys were somewhat less than polite, in their formal way asking for clarification of boundaries.

WITH THE POWELL SURVEY

Dutton's switch from the Ordnance Corps to the Powell Survey was a gradual one, and one in which he minimalized his own role. Acquaintance with Powell had grown into a close friendship, and Powell saw in his industrious friend a supply of creative energy untapped. Dutton's account of the switch is this, again from the autobiographical sketch:

> In 1875 he proposed to me that I should go into the field as a geologist. I took the ground that I would never ask for any duty nor refuse any -- would go if ordered and would be very much pleased to do so but would have no part in soliciting an order. Accordingly, Powell secured the services of Prof. Henry and together they secured by detail for a season's work in the West [22].

This was to be Dutton's policy throughout his career; his was a passive way. Decisions were left to others -- to Powell and the military hierarchy. It worked both good and evil in his career, according to the disposition and whim of his superiors.

As the year 1874 had witnessed a decline in Wheeler's popularity in Congress, the direct military involvement in the Western surveys was clearly on the wane. The Secretary of War was pleased to see a civilian survey take on a military career man. [23]

Gilbert had two summers earlier resigned from the Wheeler survey in favor of the more scientifically oriented and thorough Powell survey, a defection over which Wheeler harbored great bitterness. Other important men in the Powell parties included A. H. Thompson, who was Powell's brother-in-law (they married sisters), and Frederick Dellenbaugh, who had also been along on the Grand Canyon voyages. It is amusing to imagine the lanky Gilbert with his new associate, the short, stocky Dutton -- a Don Quixote and Sancho Panza of the Western exploration; or Dutton with Powell, the two of them being so short (Powell was 5' 61/2"). But they were together little in the field. Dutton was assigned the study of the great tract of land called the High Plateaus of Utah. Gilbert was by then working in the Henry Mountains. And Powell was wrapping up his study of the Uintas, only once, in 1877, to return to the fields of the West. His was an administrative career from the mid-seventies on. There is little known of Dutton's first field season. His field notebooks have not been preserved -- none of them -- and while all the parties of interest (except perhaps the wives) were in the West, there was little need for correspondence. Wallace Stegner, who wrote his thesis at Iowa University in 1935 on C. E. Dutton as a nature writer, was able to record this about the Captain's first field experience: As for the “habit of command” acquired in the army, it came close to making his field work difficult, to say the least, for according to F. S. Dellenbaugh (in a letter to Stegner, Feb. 18, 1935) Dutton took with him to the western surveys the distinction between officer and man that prevailed in the service, and as a result had one of two sharp arguments with his men. Foreseeing difficulties, Professor Thompson led him aside and pointed out that the half wild rugged frontiersmen who composed his party were too independent to submit to army discipline. After this advice Dutton like a wise man threw aside his artillery training and almost immediately was the best liked and most respected man in camp. [24]

It must have been a startling trip, as it is for all those seeing for the first time the vast expanses among the plateaus of central Utah. But it must have been more so then, when the nearest train station was in Green River, Wyoming, or in Salt Lake City. After the train, it was all done on horses, with mules behind and beside, and with men especially hired to pack and to cook and to hunt. Some surveys employed an odometer, a cart with one wheel, a larger version of the ones now used on trails in the forest service, or in measuring cross-country race courses. The photographer, if there was one -- and there usually was, for it was photographs which became the gifts with which congressmen could be swayed -- would require at least one mule's entire energies to cart about his darkroom, his dry plates, his chemicals, and his cameras. It was no small outfit, and demanded of the party's leader a knack for organization, and of the party a sense of the team.

Dutton had no doubt read all there was about the region before embarking on the season's adventure, but there simply was not much to read. A couple of the Pacific

Railroad surveys had made tracks across the area's perimeter two decades earlier. The geologist along on the Macomb and Ives Expeditions, John Strong Newberry, had put his observations to paper in their reports. [25] Gilbert had been through the area in the marathon of 1871 with Wheeler, his report likewise embodied in the larger report of that year's expedition. In conversations with Powell, Dutton could glean all that was to be made public in his book Report on the Exploration of the Colorado River of the West, to come out by the end of 1875. There was certainly not much in the literature of Europe to aid in his readiness for the Plateau country. But he went with a mastery of the hand specimen and a familiarity with the fossil record, as it had by then been uncovered -- through the works of Marsh, Cope, Guyot, Lesquereaux, Agassiz, Meek, Hall, and Whitfield to mention a few.

At the end of the field season, Dutton returned to his position at the Washington Arsenal, within easy reach of the Washington scientific society. There he readied another assault on the contraction hypothesis, refining and expanding his arguments and alternatives, to be published in the spring of 1876. In May of that spring, however, one month before the next field season was to begin, the Captain was ordered to take charge of the Ordnance Department of the Platte, based at an arsenal in Omaha, Nebraska. By then the Captain had formed solid expectations of another special assignment with the Powell Survey, but again found the formalities difficult to handle. His superior was General Crook, who at the time of Dutton's arrival was gathering his forces in Fetterman for an indian campaign. (It was a big summer in the indian business, and the campaign was to become known as the "Starvation March".) Arrangements, however, were finally made, to the Captain's great glee: "Everything is lovely *et pundit anser in altitudinum.* I hope you get $300,000 in the Sundry Civil." [26]

This second season enhanced Dutton's feel for the country, and yielded almost enough material for the completion of his High Plateaus report. Dutton wrote a letter to Powell, who stayed that season in Washington, from East Fork Canyon in central Utah, a place to which Dutton had come only after falling quite ill while traveling toward the Henry's with Gilbert. On the 17th of September, 1876, Dutton sat under an awning of pack covers and bedding to keep out of the rain, which had halted or made miserable his field excursions for three days running. He had before him a fragment of a rock he called a trachyte (what we would now call a dacite), but his particular specimen was peculiar in that it contained fossils. We cannot know his location exactly without his field notes; we cannot check him. But it is the speculation the rocks inspired which interests us here. Of the rocks in the canyon he wrote.

> I consider this section an unequivocal instance of sedimentary beds metamorphosing into trachyte and the proof to my mind is as clear as anything in geology. And when you come to think of it, it ought not to be considered to be very marvelous. Whatever may be the locus of trachyte before it is erupted it must be in situ somewhere and why not here? I find myself drifting toward the idea that metamorphic and igneous rocks represent merely different (though unknown) conditions in the operation of the same process -- that metamorphism and volcanism are the same process acting under slightly varied conditions. In

> one locus and of one bed the same force may give us a gneiss in others a trap in others a trachyte or even a basalt. Granitic rocks are seldom erupted but almost always remain in situ. The porphyritic trappeau series are probably as often found in situ as in eruptive beds while trachytes rhyolites and basalts are almost always erupted and as far as I know this is the only case where one of these has been discovered in its original seat and so identified.[27]

Such was the knowledge of volcanic and igneous rocks and processes in 1876. Dutton wished desperately to define the connections between the three classes of rocks: metamorphic, sedimentary, and igneous. His synthesis was at times premature, at times based on poor observation, or on poor experimental data, but the speculations themselves are well constructed, and benefited the science.

For some reason, Dutton did not allow Major Powell to pull the necessary strings to secure a winter detail in Washington -- a location immensely more suited to the writing of a scientific report. Powell's offer was never acknowledged, and Captain Dutton stayed the winter of 1876-77 in Omaha.

The winter's writing deemed a third field season necessary for the tightening up of the High Plateaus report. Dutton, in his intellectual isolation, relied heavily upon his friends in the East to send him copies of the most recent reports. Powell's Uinta report had come out that year, and the other surveys were turning out their annual reports as usual. He engaged, through his correspondence with Powell, in a tug-of-war for the photographer Jack Hiller's services in the coming season. And he occupied the remainder of his idle time giving lectures in the larger towns about -- Kansas City, St. Joe, Leavenworth -- "sounding loudly the gong of the 2nd Division of the United States Geographical and Geological Survey." Powell, in Washington, began consciously developing support for the consolidation of the surveys. In a letter to Captain Dutton only four days before his third season of special detail began, Major Powell wrote these lines:

> The continuation of my work in the future I am satisfied will depend very largely on the success with which I ally it to the industries of the country. I have a very fair prospect of having my work greatly enlarged next year mainly on the grounds of what I have done in the classification of the lands. I am desirous this summer of pushing this side of the investigation to the utmost and I beg a favor of you. It is this: that you will make an especial study of "Irrigation", and the extent of land that can be reached by irrigation of the Sevier and San Pete Rivers. I know that this is not the line of investigation which you desire to follow and if I am asking too much I know you will not allow me to impose upon you. I only make the request because I am satisfied that there will be a conflict next year for the continuation and consolidation of the various surveys. You will do me a favor also by writing as full notes as possible on all the areas covered with timber which you visit. Prof. Thompson will talk more fully with you on this subject. Mr. Gilbert will devote his entire field season to the study of irrigation and I shall do the same. Thompson you know has already

done much in that direction; so with what we have already and what we can do this summer, I expect to make a very good showing for Utah Territory. [28]

Professor Thompson reached the Captain in Omaha before the letter, bearing both this news and that of Jack Hiller's assignment to other tasks for the summer. A disappointed reply nevertheless expresses the desire to comply with the Major's requests, "though the subject (of irrigation) is a novel one to me." The Captain knew absolutely nothing about irrigation.

As the 1877 season progressed, Dutton did gain access to Hillers for a few precious and rambling weeks. They photographed scenes and structures Dutton had remembered from up to two years previously. As Hillers went on to join Gilbert, Dutton was left to tidy up the details of the High Plateaus study. He left a full and hurried month of October for the investigation of the Sevier and San Pete drainages.

Upon returning to Omaha in late October, having missed the Major by only two days at Green River Station, the Captain set about drafting his reports on the High Plateaus and on the Irrigation of the Sevier drainage. A letter written to Powell soon thereafter emphasizes his desire "to complete these in time to prepare myself for the study of mining and smelting in the Wasatch next summer. In the winter or spring I shall have to visit Washington and hope there to have a long discussion with you." [29]

This is odd. Never before, nor ever after is Dutton mentioned in connection with mining or smelting. His wish to study the process -- which, it is true, was considerably more aligned with his previous studies of steel, more so than even volcanism -- was buried in the confusion and the duties of the next year. His duties as a citizen and as a friend of Powell simply did not include a study of mining processes.

The winter of 1877-78 was an important one for the Powell Survey, by then known as the Geographical and Geological Survey of the Rocky Mountain Region. Before December Powell had made the necessary arrangements to secure a more sustained detail for the Captain, and the New Year found him across the street from the Major in Washington, at 909 M St., NW. (The Powells occupied 910 M St. for several decades; it was a well-known address among scientists.) Major Powell was quite explicit in his need for the Captain's support in Washington. In a letter written to Dutton soon after his return from the field, he wrote:

> I hope Captain that you have decided to spend the winter with us. Can you not come at once and work up your results here? I believe you can work better here than in Omaha and I think it would be pleasanter for you. Let me tell you Captain that all your friends in Washington would be exceedingly pleased to have you back. In addition to what I have said above I ought further to state Captain that I have special reasons why I wish you here this winter. I need your advice and assistance in carrying out my general plans and the more so as your friend Mr. Hewitt is this year a member of the appropriations committee ...[30]

Dutton procrastinated, as was his custom, in becoming involved in soliciting an order, stating that February was soon enough for him, but dropped sufficient hints about the necessary steps so that Powell found it easy enough to arrange the whole matter himself. By December 1st the Captain was in possession of orders from the Secretary of War to report to the Secretary of the Interior, his special detail having been granted “in order that he may complete a final report upon the extinct volcanoes in Utah Territory.”

Dutton's removal to Washington poses a biographer's nightmare. Once again, all the men of significance to this study are in the same place. The correspondence dwindles to a few formalized notes to lithographic companies and an occasional request for permission to travel on business. The events of the next year and a half must be patched together from publication dates, from studies made of President Hayes’ Washington, and from the few letters that managed to escape the bounds of the city.

The Captain apparently did not go to the field in 1878, but stayed in Washington, engaged both in the writing of reports and in lobbying for Powell's support in Congress. In the spring of 1878 Congress had investigated the rivalry between the Western surveys, but few conclusions were made; a special instruction was sent to the National Academy of Sciences, then headed by O. C. Marsh, to investigate the alternatives more thoroughly. Powell, it seems, was in healthy favor among the members of the Academy. O. C. Marsh in particular was an ally, this time on the same side of the checkered board as his old chess club acquaintance, C. E. Dutton.

During the winter of 1877-78 Dutton wrote at least one letter to an academic friend in Cincinnati who had easy access to the Cincinnati press: Professor Wetherly of the University of Cincinnati. Dutton spells out the Major's plan for survey consolidation, delineates the opposition views, and hopes that by laying the matter so clearly before the professor, his support could be counted upon. It is an artfully composed letter, and deserves to be quoted in full.

> "During the coming winter an effort will be made to consolidate and reorganize the Scientific Survey of the Government. The matter was taken into consideration by the National Academy of Sciences at its last meeting in New York and a carefully drawn report was almost unanimously adopted by that body and will be presented to Congress at the opening of the session. The general tenor of the report recommended that the surveys be placed under the Interior Department and should be required to coordinate their work to the needs and requirements of our public land system.
>
> You are well aware how imperfect and of how little real utility are the present surveys of the public lands under the administration of the General Land Office and how valueless they are for any purpose except providing a perfunctory and nominal survey under which titles to homesteads, mines, etc., etc., can be acquired. For geographical or scientific purposes or even for the establishment of permanent divisions or parcels of land they are practically useless. It was thought that by introducing good topographical methods of survey by triangulation and an economic

survey upon scientific principles every good and permanent purpose of a survey whether for the acquisition of titles by settlers the proper subdivision of lands and all geographical and geological purposes could be met. Above all for the interest of scientific men the basis of a scientific survey could be laid in the introduction of such methods and by the creation of a permanent organized scientific survey with a legal status.

The plan of the Academy was that the Coast Survey be transferred to the Interior Department and vested with a trigonometrical survey of the public domain; that a bureau of economic survey -- including geology and physical geography in its widest significance be also created; and that both of these bureaus should coordinate their work to the requirements of our public lands system.

This would involve a radical change in the official relations of the present surentific surveys. At present they have no legal standing or establishment. They are annually legislated into existence on an appropriation bill and expire on the 30th of every June. They are perfectly autonomous and have no official responsibility except a fiscal one and even the president has no lawful authority to interfere with them. The proposed plan contemplates a legal establishment for them under statue and creates lawful purposes for which they may exist and transforms them from purely personal affairs into vital parts of the Government. This plan will meet with much opposition. It will I think be chiefly opposed by the Engineers of the Army who have always (apparently) entertained the idea that general scientific surveys of the public domain were the proper function of their own bureau and have always been opposed to any measure enlarging the scope of the Coast Survey. They will also oppose it probably in the interest of Lieut. Wheeler whose survey would be supplanted by the proposed measure.

Dr. Hayden may also oppose it in the fear that if a consolidated scientific survey were established he might fail to be appointed as the sole head of it or might be curtailed in the exercise of unlimited discretion in the management of any appropriation which might be made for it.

It may be safely said I think that personal considerations are of no moment whatever in this connection. The existence of three independent surveys has shown itself to be a state of affairs which will not much longer be tolerated. Each being governed solely by the views of its proprietor there is no concert of action, no common method of work, and there is much duplication. There has also been a large amount of disagreement and quarreling and members of Congress have made up their minds I believe that there shall be either one survey or there shall be none. It was for the purpose of finding a solution of the difficulty that the matter was referred by Congress to the National Academy. I for one am persuaded that the solution they suggest is not only wise but admirable in every respect. Indeed there are but two possible. Either the surveys should be transferred to the War Department and be divorce entirely from the Land system and become more than ever the personal property of Lieut. Wheeler or they should be consolidated and made tributary to the

practical wants of the Land system under the Interior Department. I have the best of reasons that the present state of affairs will be broken up by Congress this winter.

The question therefore is not one of person but of measures and it is very plainly the duty of Congress to consider now which of three persons it will gratify but what is for the public interest? It is pretty evident moreover that Congressmen are beginning to take that view of it.

Maj. Powell earnestly supports the plan of the Academy. He renounces all claim or desire or effort to be the head to the united survey and would merely ask for a subordinate position under it secured to him by executive appointment. This is certainly wise on his part. The administrative duties of such a position would render it impossible for him to acquire the only thing he really covets and that is a standing among men of science resting upon his own personal contributions to it. All his friends applaud his wisdom in this matter and think it the true course for him to take. As for Dr. Hayden if he should desire the directorship, and the President after taking the advice of the scientific men of the country should choose to appoint him I do not see how any objection could be raised against it effectually.

I have writing this letter for the following purpose. It may be thought desirable for the gentlemen who are pushing this matter to have it discussed during the winter in the newspapers. A calm judicial discussion as a question of public policy and quite free from personal considerations could only add strength and conviction to the measure. I believe you have access to the Cincinnati papers and I will ask you if you will not take pains to look into the matter and if upon reflection your views should coincide with my own you will not undertake to furnish some of those papers with communications or editorials upon the subject. Provided however that it should seem advisable to agitate the question in a public manner. It has not yet been decided to do so, but such action may seem before long desirable …[31]

It was a complicated plan, and involved much of the scientific society in conflict, much of the Congress in debate. During the year 1878 Dutton was no doubt employed in the more direct encounters with the Congressional opposition, and worked with the Major in preparation of legislation to embody the plan. The principal weapons used in the legislative battles were the reports and publications of the various surveys, accompanied by as many photographs as could be mustered. Powell had his own two reports on the Colorado River and the Uintas, as well as that of Gilbert’s on the Henry's, and the Report on the Arid Region of the U.S. This included the several irrigation reports from the field season of 1877, and was rushed through to publication by August of 1878. It was in such demand that a second edition was ordered and published before summer of 1879. The report is a landmark in the history of the West. Not only was it the first time the arid region had been so thoroughly analyzed, but, remarkably, it included legislation which the writers deemed necessary to allow efficient allocation and use of the arid lands. It was a work aimed directly at the Congress, and each member was supplied with numerous copies.

The section written by Dutton (other large sections were written by Gilbert, Thompson, and Powell) was confined to the Sevier drainage. It is an interesting account, bringing together the human and natural histories of the area. In twenty pages he covers a broad spectrum of problems. The reader is given the feeling of watching the scientist pose and attack questions as they appear to him in the field. Dutton spends a good deal of time describing the chemistry of the caliche or hard pan which affects the farming of such a region; and he introduced the need for a set of catch basins, or what he calls the "tank system", in order to maintain reliable water sources in dry years.

The Arid Regions report, and the struggle for consolidation into which it was thrown as ammunition, took precedence over the completion of the High Plateaus report. Yet the High Plateaus work was a product of the Powell survey, not of the U.S.G.S. For Dutton it was the culmination of three seasons in the field and another two years in Washington -- fitful years, chopped up by interruptions. He managed in the heat of the congressional battle to establish a correspondence with European geologists concerning the volcanics of Europe. Among these letters is one to M. Daubree of France asking is any French geologists had managed to update Pouletts Scrope's classic work on the Massif Central and Puy du Dom areas. [32] (Having come out in second edition two full decades earlier, The Geology and Extinct Volcanoes of Central France had not included such distinctions between volcanics as could later be recognized with advanced mineralogical and petrological techniques. New classifications had evolved.)

"REPORT ON THE GEOLOGY OF THE HIGH PLATEAUS OF UTAH"

Although Dutton clearly intended the work to be a volcanic treatise, the bulk of it remains a geographical overview of Central Utah. The first two chapters provide the topographic and structural setting. The third, fourth, and fifth contain his volcanic statements: General Discussion, Classification of the Volcanic Rocks, and Speculations Concerning the Causes of Volcanic Action. The next chapter addresses the stratigraphy, and the remaining seven treat one plateau apiece (The Wasatch, Tushar, Markagunt, Sevier and Paunsagunt, Fish Lake, and Aquarius), with a short interlude for the Sevier Valley alluvial conglomerates. The title leads one to expect a geographical synthesis, and this one gets. But the nuggets of the volcanic discussion gets buried. The stratigraphic and plateau-by-plateau treatments which follow become a protracted anti-climax to the bold speculations of the fifth chapter. They detract from the power of the work, though they were necessary for the geographical purpose imposed by the nature of the Western surveys.

We cannot now appreciate Dutton's contributions to volcanology without knowledge of the geologic literature of the mid-19th century. Dutton refers specifically to Richthofen's work, "The Natural System of Volcanic Rocks", a paper read before the California Academy of Sciences in 1867 (and later printed in its Memoir 1). There is much in Richthofen's analysis with which Dutton disagrees.

Richthofen suggests a classification with five types of volcanic rocks, from rhyolite to basalt, and straightens out some confusion over the existing nomenclature. He goes on, however, to define a chronological sequence, saying that in general the andesites will

be found to follow the propylites, and the trachytes the andesites, the rhyolites the trachytes, with the basalts last. So there was a trachyte epoch, and a rhyolite epoch, and so on, all these within the Tertiary, and preceded by the porphyritic and granitic ages of the pre-Tertiary. In his eagerness to synthesize, Richthofen mixed an age and a compositional scheme of classification, thus protracting the confusion. In the High Plateaus report we find an excellent example of the growth of a concept in science. The mind when turned loose to speculate is not an infallible tool; it sputters along with a good insight here, one off the track there. Dutton's report had the potential to move the study of volcanology toward a more stable foundation. His classification scheme was chemical and mineralogical. This improved upon Richthofen's by not requiring a parallel chronological classification. All rocks can be extravasated in all ages. That volcanic rocks varied closely in space and in time had to be explained. For this Dutton invented hypotheses which sought to establish a relationship between the various types of magmas. First, through reliance upon a world wide average of the chemical composition of volcanic rocks, Dutton deduced that basalt was the "synthetic" melt, the underpinning to the continents. This was a major contribution in itself. Secondly, he hints at a theory of magmatic differentiation, though by great misfortune his conjectures were based on a set of bad experimental results for the fusion temperatures of various volcanic rocks.

In his speculations on the causes of volcanic action, Dutton reveals his bias. He addresses the processes of volcanology, and discusses a correction between his conclusions and those in the current literature concerning the evolution of the Earth. The contractional hypothesis is again attacked, for it does not explain the multiplicity of volcanic action. If the crust were to cool, its density would increase and it would sink. And volcanic eruptions, if they started, would have no reason to quit until the whole of the crust was submerged. No, there must be a local mechanism by which rocks are heated and turned into volcanic magmas. Magmas, in other words, are not primordial; they are secondary. Other hypotheses suggested that small chambers containing the magmas were bubbles left behind the cooling front as it descended into the depths, but again, what was there to stop an eruption once it started? Dutton's mechanism, which he admitted had no energy source at the present state of knowledge, required the local heating of rocks (or perhaps a local release of pressure, though he preferred the first). Moreover, this conjecture was supported by logical eruptive mechanism; that volcanic eruptions were periodic, or episodic, could be explained by the accumulated melt surpassing a threshold pressure. Subsequent eruptions would drain the chamber periodically. It was for the distribution of the High Plateaus report that Dutton began a long-standing correspondence with Archibald Geikie of Scotland. [33] Misspelling his name "Geike" for the first two letters, Dutton requested that his colleague send him a list of various people in Great Britain to whom it would be wise to send a copy of the report. In characteristic humor, he says: "Very likely after you have seen it your opinion will be that the most suitable list may be obtained from among the junk dealers and ragmen."

When Geikie sent Dutton his newly published report on the Carboniferous Volcanic Rocks of Scotland, Dutton moaned, wishing he had seen the paper before writing his own:

> How I wish I could write such a paper. It makes me feel very sea-sick: for it brings forcibly before my mind the fact that the work I am about to publish must come under the scrutiny of men who can write such papers and whose unerring judgment fills me with fear and trembling. It is the feeling of the amateur who listens to the performance of the master. I am especially pleased to see how much you have made out of what an American geologist would probably consider a very small and contracted field. It is a capital example of what patient toil and research with careful comparison of facts may accomplish and is a lesson to us all who in this country are content to get what we call the cream of the country and throw the rest away. [34]

His respect for Geikie could not have been greater, and he long wished to meet the man. It was to him that Dutton wrote his most candid letters, those most free from the Victorian formalities. He spelled out the state of the Survey, its organization and its mood. He spilled forth his own ambitions and frustrations. And he allowed his humor full reign. When Geikie proposed to review the High Plateaus for Nature Magazine, Dutton wrote back "lay on Macduff." [35]

THE COSMOS CLUB [36]

Before the legislation calling for the consolidation of the surveys had passed through Congress, the scientific community of Washington gave birth to yet another society, adding to the National Academy of Sciences (1863) and the Philosophical Society of Washington (187 2). The first meeting was called at 910 M St. on November 18th 1878. Within a month the club had obtained the use of several rooms in the Corcoran building, and had voted, upon the suggestion of Colonel Mallery, to call itself the Cosmos Club of Washington City.

Many of the first members were of a group who regularly met in what was called the "adjourned meeting" of the Philosophical Society of Washington, held at a beer saloon on D street near 10th. The Philosophical Society held its fortnightly meetings in the old Ford Theatre, which, since the assassination of President Lincoln there in 1865, had been used as an annex to the Surgeon General's Office, and as a depository for the growing Medical Library. It seems the place was rather stuffy, the walls of dusty books and portraits of bloody anatomies being none too conducive to a social atmosphere. Of the group of men who regularly met over beer to help digest the readings of formal papers, many were just beginning their scientific careers. In the first list of 59 members were Gilbert, Dutton, Powell, and Holmes, all by then associated in the study of arid regions.

As in these men the love of science did not diminish the love of good fellowship, the time was ripe for a social club. According to Dutton, it was upon his suggestion that the first meeting was called. It was to be fashioned after the Century Club of New York, and the Scientific Club of London, but an essential difference was sought: membership in the Cosmos Club would not hinge on previously attained fame. High standards were kept, higher perhaps for the non-scientific than the scientific members. The result was that a young generation of scientists, including almost all of the Western geologists, received an excellent and receptive forum for informal gatherings, not only among

scientists, but among artists and writers. Intellectual exchange, it can be imagined, centered around many a game of billiards.

1879-1882 FIRST YEARS WITH THE U.S.G.S.

The legislation forming the United States Geological Survey was signed March 3rd 1879, but this was only a partial victory for Powell's cause. Before passing, the major provisions for land reform in the arid regions has been struck from the bill, and land was to continue to be parceled in square miles and quarter miles, paying no heed to water access. The lessons of the Arid Regions Report had not been learned. True to his intentions, Powell did not seek any position of authority within the newly formed organization, and instead threw his support behind King of the 40th Parallel Survey. King was appointed the first Director, much to the chagrin of Hayden, thirteen years King's senior.

There was much work left to be finished from the four discontinued surveys, and King delegated the responsibilities to those who would best know, the geologists of the various parties. Arnold Hauge was placed in charge of the Pacific Slope Division; G. K. Gilbert of the Great Basin; J. W. Powell of the Plateau Country; and S. F. Emmons of the Rocky Mountains' eastern ranges. T. C. Chamberlain resigned as chair of Geology at Beloit College to take up the study of the glacial phenomena north of a line from Denver to New York. But all this was second to the Economic Geology Division under Raphael Pumpelly. King emphasized this segment of the work in order to procure immediate results which could later operate in the securing of larger appropriations. [37]

For Dutton the first summer with the U.S.G.S. was spent in again pushing the High Plateaus report toward publication. Gilbert continued his study of the Lake Bonneville problem, while topographic crews under Remshawe and Bodfish carried on what Gilbert had started in the summer of 1878 -- the accurate mapping of the region north of the Grand Canyon. Most of Powell's energies were spent in the organization of the new Bureau of American Ethnology (B.A.E.), of which he had been given charge upon its creation in 1879.

By spring of 1880, Dutton was free from the office work once again. His High Plateaus was published, and he had in his possession the set of completed topographic maps of the north rim of the Grand Canyon. It had taken five years to complete the High Plateaus study, but within two more he would turn out the Tertiary History of the Grand Canyon District, an even larger and much more famous work. How could he have done all the necessary work in one field season's ramblings? He dissolves this mystery in the preface to his monograph:

> During the seasons spent in the study of the High Plateaus I have found the temptation irresistible to wander far outside the limits of my prescribed field; and whither should the errant geologist tum his footsteps so eagerly as towards the wonderland of the south? And so, when the early snows and biting winds of autumn drove us out of the lofty volcanic regions of the north, the remaining weeks of each year were spent in rapid excursions through the milder regions which lie beyond the

> foot of the great stairway of terraces which leads down from the heights of the Markagunt. [38]

Only the 1880 season was spent wholly in the Grand Canyon district. In another letter to Geikie, written only a few days before leaving for the field, Dutton reveals the intent of the summer's study. With less funding than had been hoped (his coverage of which revealed an intimate entanglement in the congressional combats), he planned to tackle a "very limited tract about mid-length of the canon and on the north side of it. It is a basaltic field chiefly; with about 120 cones still standing." [39] He was referring to the Uinkaret Plateau. The study was to be another volcanic one, but it grew again in scope to include a huge area of canyonland. For the latter half of the 1880 season, both the geologist and the artist in Dutton rejoiced in the company of William Henry Holmes, whose illustrations had already earned him great respect among the scientific community. The assignment was a perfect one for Holmes, whose path in life steered between the pursuits of science and art. Following the completion of his formal education, Holmes had attempted to enter various art schools. He found instead short periods of work with E. F. Andrews and Caroline Ransome, developing thereby his basic skills of representation. Through a circuitous set of circumstances -- which included the sketching of a stuffed tropical bird in the Smithsonian -- he was granted an introduction to Fielding B. Meek, then engaged in collection of fossils from various Western surveys. This led to his incorporation in the Hayden Survey, with which he spent several seasons in the field, and from which he gained his geologic expertise. By 1878 Holmes's status was one of a full geologist, but after the 1879 survey consolidation he was without a job. He immediately embarked for Europe and a ramble about the capitals of the continent with Frank Duvenak and other American painters. It was from this pursuit that Holmes was summoned in the summer of 1880, clearly at the request of Captain Dutton. [40]

By mid-August the Captain had seen a full month in the field and had just moved camp to near Mt. Trumbull when Holmes was due to arrive. It was thought only hospitable to send the artist some method of conveyance, and Mr. John Smith was dispatched with a wagon, bearing these instructions for Holmes:

> You will have a rather hard and dry as well as hot ride, but Mt. Trumbull is not a bad place. Take with you for your ride of two days as many "goodies"_ as you like and make whatever you think fit for fighting the misery of the desert you will have to cross. Put in as much fruit as you can conveniently carry and remember that what you cannot eat on the way will find plenty of eager mouths yawning for it at the journey's end; perhaps the best fruit you could bring would be pommes de terre God bless them with smiles all over their faces. I will gladly pay the bill. [41]

But Mr. Smith met en route with Holmes, who had already hired a driver, and the mouths at Mt. Trumbull remained unsatiated.

Two and a half months were spent about the rims and the plateaus north of the Grand Canyon. Holmes preserves the basic itinerary in his "Random Records of a Lifetime

Devoted to Science and Art", but little about Dutton is disclosed. Holmes spent a good deal of time poking about the many indian sites in the area, an inclination which would lead him into involvement with the B.A.E., of which he took charge upon Powell's retirement in 1902. It was his primary engagement, however, in these two months, to capture on paper the beauty and the precision of the Grand Canyon panoramas. His diary of the latter half of September speaks for his intense energies:

Sept. 18th: Made a lone march to DeMotte Park, center of Kaibab Plateau. Pass the Paiute camp, entered the plateau canyons and soon reached the shallow grassy swales of the upland. From a barren sage plain we passed into a region of pines and lovely aspens, of grass and flowers. Chilly evening. Bodfish and party in camp.

Sept. 19th: Left camp for a point on the eastern brink of plateau. Three hours through aspen groves and grassy swales; saw deer and grouse. Camped on a promontory that overlooks the vast, red desert of the Marble Canyon -- altogether a scene long to be remembered. The Paria Plateau, Navaho, Henry, and LaDalle mountains, the latter 200 miles away, the Echo Cliffs, and the marvelous canyon are all in view.

Sept. 20th: Made panoramic sketches and returned to camp in the park.

Sept. 21st: Made sketches of aspens. In the afternoon whole party went down to Thompson's Springs.

Sept. 22nd: Rode down swale five miles and came out of woods upon the brink of the most marvelous canyon, the bottom of which could hardly be seen and the side walls of which were wonderfully carved and colored.

Sept. 23rd: From Thompson's Springs by way of Sedge Pool to Point Zed. Splendid views of the canyon on the one hand and of the beautiful woods on the other. Stone enclosures and pottery observed.

Sept. 24th: Sketched with greatest pleasure from sunrise until half past three marvelous buttes and most interesting geology. Returned to Sedge Pool 12 miles.

Sept. 25th: Passed through forest and parks to Thompson's Springs to Milk Springs and afterwards with two men and a cook hurried on to Point Sublime. Arrive before sunset and had glance at the grandest, the most extraordinary panoramas in the wide world.

Sept. 26th, 27th, 28th: Sketched from sunrise to sunset except while at meals and until nine o'clock the morning after.

Sept. 29th: Returned to the park. [42]

Upon returning to Washington at the end of October, Holmes found himself in charge not only of the Atlas for Dutton's monograph, but of all the illustrations for the entire Survey. His was a busy winter, compounded by being given charge of all of Hayden's uncompleted reports.

Dutton occupied the winter of 1880-81 in the preparation of the Grand Canyon monograph. It would take him through the next winter to complete it, though a shorter version was submitted for inclusion in the U.S.G.S. Director's 2nd Annual Report.

The Director of the Survey was by then Major Powell, Clarence King having resigned in March of 1881. For half a year King had wished to free himself from the economic restrictions placed on the head of the Survey, which stated that no economic interests could be maintained by that person in the work carried out by the Survey. Yet he stayed in office, withholding his resignation until the administration changed. Hayes would probably replace King with Hayden; with Garfield there was no such fear, and Powell was quickly appointed. [43] The Major, then, found himself in charge of both the Bureau of American Ethnology and the United States Geologic Survey, a dual command he maintained for thirteen years. And King turned his head toward the riches and society of the booming West. He already owned large ranches in the West. He became the manager of the mining interests of the Shaw's of Boston, the owners of the best gold mines in America. He took on the directorship of the Atkinson, Topeka, and Santa Fe Railroad, by then the largest and richest railway combination in the West.

"THE TERTIARY HISTORY OF THE GRAND CANYON DISTRICT -- A MONOGRAPH"

The Tertiary History was and would be different from every other work Dutton was to write. The study itself was an inherited one: Powell had intended to write it years before, but had abandoned it to pursue larger schemes in Washington. Hoping one day to write a synthesis of the Plateau Country and its lessons, the trio of Powell, Gilbert, and Dutton had seen their works as part of a whole: Explorations of the Colorado River of the West, the Uintas report, Henry Mountains, Lake Bonneville, High Plateaus, and Tertiary History of the Grand Canyon. [44] The synthesis was never written.

Dutton begins his monograph by describing the terraces, that giant staircase of cliffs and deserted platforms which step down from the High Plateaus to the north. Those grand truncations of the Mesozoic section he characterizes most vividly in the Vermillion and White Cliffs. In so doing, he introduces erosion, the hero of the work. Carefully assuring the reader of the former continuity of the beds, he presents the Grand Denudation of the Miocene. This proposition is to be turned over and over in the following 200 pages, slowly amassing an "unassailable" defense in concordant facts.

Leaning heavily on a simple model of erosion, the Captain infers the geologic history. The district suffers repeated elevation and quiescence, repeated moist and arid climates. Cliffs slowly retreat in the arid quiescence, the single trunk river saws through the strata in an arid uplift. The elevations are regional but locally variable, and adjustments being made along the many great faults and monoclines of the district. The volcanism on the Uinkaret Plateau follows also the repetition of activity. (He spends very little time discussing volcanism itself, those 160 cones he had written Geikie about.)

The erosional processes invoked were those already defined by Gilbert and Powell. The Captain firmly adheres to the concept of antecedent drainage, as proposed by Powell in the Uinta report. He even uses the same verbiage; the Colorado River" "saws" its way through the strata as unknown subterranean forces uplifted the section. Dutton quotes a full section of Gilbert's "Land Sculpture" chapter in the Henry Mountains Report that

discusses the variables of erosion. The consequences of an arid climate he reiterates: lack of vegetation, and soil enhance transportation by rare flash floods; normal chemical weathering is decreased; cliffs form in the mechanically resistant beds. And Dutton borrows from Powell's concepts to describe the recession of these cliffs.

The work is a drawing together of ideas, presented over the past six years, all debated and discussed by the three men in the field, in the Washington offices, and over billiards in the Cosmos Club. Geologically, it is a product of the trio.

As a demonstration of erosional processes, the *Tertiary History* is unmatched. But no new process is exposed. Dutton's conjectures are limited to details, to chronology. Erosion as a hero caught the Captain with less imagination than did the more speculative characters of volcanism and tectonics. But the story of the Grand Canyon had to be told -- the world must know.

The monograph is an intimate and intentional mingling of science and art. In Dutton's own words:

> I have in many places departed from the severe ascetic style which has become conventional in scientific monographs. Perhaps no apology is called for. Under ordinary circumstances the ascetic discipline is necessary. Give the imagination an inch and it is apt to take an ell, and the fundamental requirement of the scientific method -- accuracy of statement -- is imperiled. But in the Grand Canyon District there is no such danger. The stimulants which are demoralizing elsewhere are necessary here to exalt the mind sufficiently to comprehend the sublimity of the subjects. Their sublimity has in fact been hitherto underrated. Great as is the fame of the Grand Canyon of the Colorado, the half remains to be told. [45]

The canyon had been described earlier, even illustrated, but the images were distorted. The artists were of a European school, and too willing to immerse the canyon in sylvan glades. Sagebrush and sandstone became evergreen and granite. Holmes's sketches and panoramas, on the other hand, are all but photographic in their depiction of reality. Similarly avoiding the dreamy rendition, Dutton's succeed by their distance from the classic superlative. He abandons the God-fearing, the angelic, and the heavenly images for those of man and science. The Captain draws a sweeping architectural metaphor over the whole, resting all other descriptions on its foundation. The scene is one of towers, thrones and temples, of facades, entablatures, cloisters, naves and transepts. Many of the names given to these landforms, either in the writing or in the Atlas, have stuck. The metaphor is preserved. Following the descriptions of the terraces, the Captain rides into the Canyon District proper. Though occasionally lapsing into a diary account of an experience, the descriptions maintain an air of distillation, a more orderly arrangement of events and scenes than the rambles of the previous summer had given. He describes the plateaus from west to east: the Unikaret, the Kaibab, and then the Paria. He develops the scene using every aspect of the natural setting. Vegetation is described by its hindrance to travel in the forests of the Kaibab, by its sparseness if the mules and horses cannot get enough to eat. History sneaks in. The climate is illustrated

by emphasizing the rarity of a thunderstorm. He and Holmes stop and watch the changing light on the wall of an amphitheatre as the storm passes over. Even geology is slipped in the side door. The image of a lava flow pouring over the brink is emphasized by its blackness against the red and white walls. It becomes a route by which the river is reached, its broken surface providing the "admirable" and "precarious" footholds needed. It is one of two places the descent can be made and Powell's Colorado River world revealed. The Captain is forever curious. On the rims above he addresses any and all geological questions the country raises. The Kaibab Plateau, with its springs and parks, affords a discourse on both karst drainage and a previous river network. A consistent increase in the regional dip from one to three or four degrees just before cliff fronts raises the question of adjustment after unloading by erosion.

The flavor of the country is squeezed out, and the image of the Colorado Plateau and its marvelous chasm are corrected forever in science and literature. It is, I think, no coincidence that the monograph naturally falls open to Dutton's description of the panorama from Point Sublime. The purpose and inspiration of the task, and the quality of its performance can be no better illustrated than in this passage, written as if seated at the brink itself:

> The Grand Canyon of the Colorado is a great innovation in modem ideas of scenery, and in our conceptions of the grandeur, beauty, and power of nature. The lover of nature, whose perceptions have been trained in the Alps, in Italy, Germany, or New England, in the Appalachians or Cordilleras, in Scotland or Colorado, would enter this region with a shock, and dwell there for a time with a sense of oppression, and perhaps with horror. Whatsoever things he had learned to regard as beautiful and noble he would seldom or never see, and whatsoever he would see would appear to him as anything but beautiful and noble. Whatsoever might be bold and striking would at first seem only grotesque. The colors would be the very ones he had learned to shun as tawdry and bizarre. The tones and shades, modest and tender, subdued yet rich, in which his fancy had always taken special delight, would be the ones which are conspicuously absent. But time would bring a gradual change. Some day he would suddenly become conscious that outlines which at first seemed harsh and trivial have grace and meaning; that forms which seemed grotesque are full of dignity; that magnitudes which had added enormity to coarseness have become replete with strength and even majesty; that colors which had been esteemed unrefined immodest and glaring are as expressive tender, changeful, and capacious of effects as any others. Great innovations, whether in art or in literature, in science or in nature, seldom take the world by storm. They must be understood before they can be estimated, and must be cultivated before they can be understood.[46]

This accomplishment must be assigned the label of art and of literature. The two men, Dutton blocky and short, and Holmes thin and mustached, who chased about the good views in the summer of 1880 returned to Washington to write and illustrate a grand work. No other monograph has as its frontispiece a watercolor. Holmes’s drawings and paintings, transferred by woodcut, lithograph, and photoengravure to the printed page, give the work permanence. There are 42 plates and 23 atlas sheets in all to accompany

Dutton's 260 pages of prose -- a monumental output. Holmes had seen the country with the eyes of an artist and a scientist. Dutton had seen it with the eyes of a scientist and a nature writer. In no other work does he so fully indulge this latter inclination.

INCULCATION OF A DREAM

Late in the year 1881, shortly before the publications of the Tertiary History monograph, Dutton received a letter from James Dana that seems to have stimulated the maturation of his geologic ambitions[47]. Dana requested that Dutton undertake an areal synthesis of the volcanic geology of the Western U. S., to appear as a series of articles in his American Journal of Science. Dutton's response is interesting, if not a bit sad. Though he demurred, claiming no one had at that time sufficient knowledge of the subject to perform the task at all well, he admitted that his knowledge of the subject was probably the most extensive. But that extent included only a "fifth or sixth part" of the volcanic fields of the West. He had not seen Oregon; he had not been to Montana; and he had only glimpsed the volcanics of Nevada. The writer of such an overview must have a feel for the whole -- and the literature of the day was in such a chaotic state as not to permit the falling in of defects in one's personal knowledge by reading. In short, that scientist must get about and it is as much to this task as to any other that Dutton applied his energies from 1882 through 1886. Within six months of writing his reply to Dana, the Captain was climbing among the calderas of Hawaii; two years later he was in the Mt. Taylor volcanic field of northwestern New Mexico; and for two more he studied the Cascades of northern California and Oregon. The sad part is that his pursuit of synthesis ended there, without the publication of any of the Cascades work. He would write no overview, neither of the Plateau volcanics, nor of the Cascades volcanics, nor of the Western volcanics as a whole. Discussions with Powell following the completion of the Tertiary History monograph in early 1882 concerned the direction of Dutton's future studies. Happily, their ideas coincided, and Dutton took on the volcanic fields of the West. He would start with the Cascades. Yet to do geology one must have accurate topographic maps, and these were lacking. The topographer Gilbert Thompson was assigned the task of establishing a preliminary map of the Cascades in the field season of 1882, a task to be consistently plagued by the late summer forest fires that obscured the necessary long-range triangulations. Dutton was left with a year's time on his hands.

CASCADE STUDY DELAYED -- OFF TO HAWAII

He made the most of the delay. With Powell, Dutton figured this an excuse to visit an active volcanic field. Hawaii was chosen over Iceland for reasons of ease in transportation and of lack of previous study. The Hawaiian chain had last been visited for geologic purposes by Dana, forty years earlier on the Wilkes Expedition, and that stay had only lasted a month. Dana himself encouraged further study, and would publish the letters Dutton wrote him 43. Problems arose with the financial details of the trip. The justification for Dutton’s being sent to Hawaii would surely be called into question by Powell's flammable and highly vocal opposition. The Major checked with the Secretary of the Treasury, found that he would not be authorized in sending Dutton with Survey funds, and went instead to Professor Baird at the Smithsonian [49]. Powell's favor with the Smithsonian was as high as it had been a decade earlier, when that Institute had funded his early surveys, and Baird was swayed to support the scheme. The

Smithsonian gave Dutton $2000 (to which sum was added another $1000 when Dutton found the cost of living to be greatly inflated in the sugar booming Hawaiian islands).

The Captain came to port in Honolulu on June Ilth 1882, and bade farewell to the Alaska Commercial Company's ship only to realize that his trunk of clothes and scientific papers had not followed him onto the dock. The trunk was to see Australia before Dutton again saw its contents. The Captain's letters from the Hawaiian Islands bear the mark of a scientific Samuel Clemens. They are a mixture of humor, travelogue, and science. The reader is given a well-rounded picture of the place, a picture possible from neither a reporter nor a scientist. The Captain was at his delightful best. He complains pointedly about the sugar boom and draws an analogy with the mining booms of California's '49. His ire is reduced somewhat by his timely acquaintance with and accommodation by Mr. John A. Buck and his cousin, a Yale graduate. Dutton's consequent stay at one of the largest sugar plantations on the Islands, in the stimulating and incomparable society of these two worldly men, allowed his fascination with Hawaiian agricultural industry to gel. The information he thus gained was used on many a later occasion: in addresses given to the Smithsonian Institute on the Hawaiian Peoples, and in less formal "smoke talks" aboard pleasure cruises after this retirement. But, after all, the voyage had a scientific purpose, and through the generosity of these two comrades he obtained a guide, a cook, and the necessary animals -- all of much higher quality than generally available, and at much lower costs than those to which the normal tourists were flagrantly subjected. The remainder of his six-month tour he spent in the pursuit of geologic understanding of the Hawaiian volcanoes. Much of what he wrote in letters was later set to more formal paper in his "Hawaiian Volcanoes", published in the 4th Annual Report, 1882-83, of the Director of the U.S.G.S.

"HAWAIIAN VOLCANOES"

The report on the Hawaiian volcanoes carries on the light tone of the letters. Dutton fuses the descriptive and the interpretive, bringing both to the reader in his easiest of manners. By no means does the Captain stick to geology. The reader sees Hawaii in its flavorful whole. The account is spicy. The Captain pays as much attention to the wildlife, the people, the guides, and the pack animals as he does the geology. He hunts wild pigs. His pack animals chew their ropes, and stumble across the aa trails with lurching loads. Dutton lets down the reigns of formal science and is taken where his spritely whim wills. He writes to those who will probably never see the scene, and feels a need to lay it all out, unrestrained. He carries the reader along, as he did in the Grand Canyon, setting the experience in the present tense. On the approach to Kilauea Dutton remarks:

> After a few miles of pahoehoe we find ourselves in front of an ugly, ominous barrier, which scowls and bristles across the path as if to forbid a nearer approach to the Inferno beyond. [50]

We walk, talk, hunt and stumble along with the vandyked Captain and his Panaka guide. As in his letters, he does get down to the business of geology. We are conducted on a tour of the islands, visiting Kilauea, Mauna Loa, Mauna Kea, and Hualakai; and it

as a geologic tour foremost. Before we leave the Inferno of Kilauea, Dutton has found the opportunity to define a new term. Dissatisfied with the overworked images of craters and pits, he apologetically introduces the "caldera" in reference to the much more limited class of phenomena of which Kilauea is the type. The word's quick incorporation in the geologic literature is testimony of its need. Geographic description comprises the bulk of the work. Dutton brings in a historical account when tradition will provide it, or when a reference to something Dana had seen forty years earlier may be compared. But nestled among the geographically titled chapters is one called "The Volcanic Problem". Dutton brings all the accumulated geological insight together in one place. He interrupts the geographical adventure by a lecture, an essay, not as punishment for the reckless fun of the whole, but as a teacher would point out the moral of a fairy tale read in class. The work would have seemed complete without it. The volcanic chapter is a ramble in itself. We see the Captain turning over the fundamentals of what makes a volcano tick. The search is for a source of heat. He raises one hypothesis to scrutiny, brings to bear all the available logical evidence, rejects it as unfit. He sits at his Washington desk, with a sample of Hawaiian pahoehoe before him, perhaps a paperweight on a stack of illustrations and pictures of the Hawaiian volcanoes. The analogy with a geyser tempts him. The huge volumes of steam in eruptions, and the vesicles in the specimen before him are tempting evidence. But no, the analogy fails. It leaks under the weight of the evidence. He votes against the geyser model. Then how about a chemical agent, for instance the oxidation of a primordially unoxidized interior: a combustion? But the evidence crushes this one too. And certainly the contractional hypothesis with its various volcanic models could not be called upon. The scientist was frustrated. There is a fourth hypothesis that cuts the Gordian knot instead of untying it. It assumes that as a result of causes hitherto undiscovered heat is generated within some localities within the earth and that such local increments of heat produce all the phenomena of volcanism. It is a simple appeal to mystery. It is a chain with its primary links missing. It is an arch without a keystone. And yet it may be true. Indeed I, for one, am strongly imbued with the hope that science will some day, not very far distant, close the missing link or put the keystone, yet unquarried, in its proper place [51].

One other hypothesis remains: the release of pressure can cause melting. But what is there to cause a release of pressure, other than the process of denudation? Certainly no correspondence can be verified between the two phenomena of volcanoes and erosion. If anything, the tables should be turned, and the height of a volcano should attract erosive agents. What then, he asks, turning over the piece of pahoehoe before him, do the Hawaiian volcanoes have to say about the process of volcanism? One great fact remains supported: Darwin's observation that volcanoes are each occupants of rising platforms. The erosional history of the Hawaiian Islands clearly implies recent uplift. But general uplifts are as solemn a mystery as are the processes of volcanoes. They require either an addition of mass to the pile, or an expansion of the existing mass. Here, he thinks, the two mechanisms could be tied together. Dutton redoubles his appeal to the mystery source of heat. Not only would the heat be employed to melt the potential lavas, but it could provide a general expansion and uplift. It seemed to work. But this left unsolved the mystery of the source of heat. Twenty-three years later he would think he had found it.

AN ABORTED VACATION

The field season of 1883 was forfeited for the completion of the Hawaiian report. (Of the fifteen summers Dutton worked on geologic detail from the Army, five were spent in the writing of reports in the office in Washington.) It was his young assistant, a petrologist named Mr. J. S. Diller, who was employed to begin the geological reconnaissance of the Cascades, following closely the topographers G. Thompson and Kerr. Diller was accompanied by an ensign from the Navy, E. E. Hayden, their joint assignment to pay close attention to the petrological nature of the volcanics in the Cascade field. Though Dutton stayed behind in a hot Washington office at Powell's request, he did hope to get abroad to Great Britain and Europe late in the fall of 1883, for a brief vacation. He counted on meeting his foreign correspondents and colleagues, among them Archibald Geikie, by then the Director General of the Survey of Great Britain. By October the Captain's family was already in Dresden, awaiting his arrival; but he never came. In a letter written on Halloween, and signed "Very Cordially but Ruefully Yours", he sends his regrets to his Scotch friend. He was tied up in the administrative details of the Survey, though he does not reveal the intricacies of the confinement. Only by metaphor did he intimate the drudgery of the whole mess: "No geologic news here. All is quiet along the Potomac". The wheels tum regularly and slowly. The grist comes out about as usual." His disenchantment with the gears of the Survey would grow. Though he never puts it in personal terms, nor assigns the maladies to the failings of any one person, he clearly felt bound up in the machinery of running a major governmental bureau.

FURTHER DELAY -- ON TO THE ZUNI PLATEAU

Even the summer of 1884 did not allow Dutton to begin his study of the Cascades. The extensive forest fires continued to hamper Thompson's and Kerr's attempts to complete detailed base maps. Diller resumed his geologic reconnaissance, though clearly his work was considered a mere outline of the massive assault on the geologic questions posed by the region to be undertaken later. He began to focus his attention on the phenomena of the Shasta region of northern California. Dutton had another summer to fill. Powell suggested the Captain take advantage of the newly completed Atkinson, Topeka, and Santa Fe Railroad to study further the volcanic fields around the southeastern border of the Plateau Country. Dutton replied: Fully concurring with you that it is desirable to prosecute work vigorously upon the volcanic phenomena of the regional belt extending from the San Francisco Mountains through the Mogollons and Mt. Taylor district and northward to the Sierra Abajo and La Sal, I would propose subject to your approval to undertake it beginning this summer in the Mt. Taylor region and San Francisco Mountains. The work in the Cascades will "keep" for a couple of years while the topographic survey and mapping progress, while the very inviting and now accessible region of New Mexico &c. are so very unique and inviting that they may be readily plundered and pretty nearly gutted by misc. investigators at any time. But this may be premature and I have not fully a plan of operations [52]. In returning to the Plateau Country he was returning to the intellectual company of Powell and Gilbert. His appreciation is stated in the first page of the Mt. Taylor report, an eminently quotable work: In daily intercourse with Powell and Gilbert, and with a bond of affection and mutual confidence which made the study in a peculiar sense a labor of love, this geological wonderland was the never-ending theme of discussion; all observations and

experiences were common stock, and ideas were interchanged, amplified, and developed by mutual criticism and suggestion. The extent of my indebtedness to them I do not know. Neither do they. I only know that it is enormous, and if a full liquidation were demanded, it would bring me to bankruptcy [53].

Dutton left for Fort Wingate, on the AT&SF Railroad in northwestern New Mexico, on July lst 1884. His intended course of study was first to entail a month in the Mt. Taylor region -- just to the east of Fort Wingate, and 60 miles west of the Rio Grande River. He then planned to go to the San Francisco -- 150 miles to the southwest along the physiographic boundary of the Colorado Plateau, and on the political border between New Mexico and Arizona. As the season progressed, however, his attention was distracted by the Zuni Plateau on which Fort Wingate was located. After six weeks in the Mt. Taylor area, he decided to devote the remainder of the field season to the study of the heavily wooded hills that comprise the Zuni uplift. The study of the San Francisco Mountains was postponed indefinitely. In his own words: It has always been my desire to discuss only such geological fields as present a series of facts which can be grouped together into a definite, easily comprehensible whole, and to avoid a subject which has, so to speak, neither head nor tail to it. Both of these fields have form, consistency, and unity. They are individualized features and each teaches us a lesson worth learning. [54]

Each had its own lesson, and they both fit on a two degree atlas sheet -- Mt. Taylor on the east side, and the Zuni Plateau on the west. Captain Dutton maintained discretionary authority to redeem his projects in the field, an authority he often used. This time he used the freedom to maintain a geographic unity to the work, feeling that the San Francisco Mountains were part of a larger, more complicated, less accessible, and potentially less fruitful region. He preferred "to do one district wholly and well rather than to attempt to do two in part and badly."

But the fieldwork ran anything but smoothly; he was not immune to annoying delays.

> This time the trouble is with my men. My best packer has left me to take a position as chief packer to the Military Department. My second packer a most competent and excellent man has been for three days not exactly drunk but "unco fu." I have though it best to ignore it as I cannot replace him. Lastly my cook after being drunk once and duly warned got drunk again and has not been seen for two days. I will cook myself rather than keep him. So I am hung up here until I get new men - or at least a cook. Dodge and I can pack as well as anybody but neither of us want to cook nor yet pack for that matter. My outfit is pretty shabby (sic) and I am a good deal ashamed of it. [55]

The summer ended with a visit from Professors Tyler and Mosely from Britain, a tour -- apparently given jointly by Dutton, Thompson, Powell, and Gilbert -- of the Grand Canyon area, the whole in the grip of a chilly early winter. They returned to Washington in November, and Dutton sat down quickly to write up his report on the season's accomplishments. He wished to be free to go to the Cascades in the next summer. The topographic mapping had progressed well in the 1884 season.

“MOUNT TAYLOR AND THE ZUNI PLATEAU”

Dutton treats the Mt. Taylor volcanic field and the Zuni Plateau as separate phenomena. After two chapters on general physiographic and geologic features follow one chapter each on the Zuni Plateau and the Mt. Taylor region. The last of the five chapters deals almost exclusively with the lessons of the Zuni Plateau, as Dutton felt these were perhaps the most "worth learning".

Yet his treatment of the Mt. Taylor volcanics is not without its insights. The region is first set in its volcanic perspective. Dutton recognizes the peculiar absence of volcanics within the Plateau Country itself, and notes that (with one significant gap in the Uintas) they ring the Plateau: The Flattops of northwestern Colorado, the San Juans, the Jemez, Mt. Taylor, the Mogollon, the San Francisco Mountains, and more. The lesson of the Mt. Taylor field is basalt floods, as in the Snake River plain, but are the accumulations of sheets centered in numberless plugs and necks, the remains of previous volcanoes? These odd additions to the landscape, with their beautiful columnar symmetries, are the intriguing sights of the area. Mt. Taylor itself is not that instructive.

Clearly the thrust of the report is toward the lessons taught and the thoughts stimulated by the Zuni uplift. The subject becomes the Western mountain range. Dutton capsulizes the essential differences between plicated (or Appalachian-Jura) mountains and what the geologist studying western North America would call a mountain range. In so doing he reiterates and expounds the distinction made ten years earlier by Gilbert in his Wheeler report. The description, both morphologic and genetic, of the western mountain range is a principal contribution to geology in general. Dutton gives the concept's evolution:

> Within the past twelve or fifteen years it has become a widely accepted view among the geologists of Europe and America that the forces which have elevated mountains are derived from the strains set up in the outer envelopes of the earth by secular cooling and shrinkage of its interior. But it should be borne in mind that geological science has flourished most in those countries where the best known and most thoroughly studied mountains and ridges are greatly plicated. To the European geologist the Alps and the Jura have always been the most commanding and interesting of orographic structures. To the Briton the highlands of Scotland and Wales have been equally absorbing fields of research in which the solution of the problem of mountain building has been attempted. In America geology had its first and most rapid growth in the Appalachian region, and when it sought fresh fields in the Pacific Slope it first found them in the Coast Ranges and in the Sierra Nevada. All of these regions are more or less plicated, and it is not to be wondered at that an universal conviction should have grown up that plication and mountain building are only different names for one and the same thing, or that the process which built the mountains folded the strata at the same time. But as soon as the geologists penetrated the vast mountain belt which lies east of the Sierra and west of the Great Plains, and proceeded to a careful study of the forms there presented, a wholly different state of affairs was revealed. Not a trace of systematic plication has yet

been found there. The terms "anticlinal" and "synclinal" have almost dropped out of the vocabulary of the Western geologist. The strata are often flexed, but the type of the flexure is the monocline. [56]

The Western mountain range is a product of vertical tectonics rather than horizontal. It cannot be explained by the contractional hypothesis. In his broadest view the Captain describes the geology of the West as being "composed of many short, abrupt ranges looking upon the map like an army of caterpillars crawling northward. At length the army divides into two columns, one marching northwest, the other north-north east."[57] … hence the Great Basin's ranges, and the Rockies. If we carry the metaphor further, all these caterpillars must be genetically related. They are, Dutton claims. Some are in lower evolutionary stages than others, yes, but all have in common "the action of some unknown forces beneath which have pushed them up."

The Zuni Plateau is an embryonic mountain range, a mere cocoon. So also, says the Captain, are the San Raphael Swell of central Utah, the Nacimiento uplift of north central New Mexico, and the Black Hills of South Dakota. Only by the ravages of the hungry mantis of erosion are geologists allowed a look at the cores of these. The Park Ranges of Colorado, as described by Hayden's parties ten years earlier, are mere adolescents, having shouldered aside the shielding strata. The "granitic bosses" were driven to new heights and fresh exposures. The Wasatch, in Dutton's view, is the adult form of the process.

It is a simple distillation of the problem, too simple perhaps, but the emphasis is on the vertical tectonics, and this was correct. The mystery forces are still a mystery.

But the report is more than a work of geologic synthesis. Dutton has a geographic as well as geologic goal. The descriptive bulk of the work paints masterfully the picture of the field area. We travel again with the Captain. Viewing first our destination from the housetops of Albuquerque, we ride the newly completed railroad through the field area: first by Mt. Taylor on our right, and beyond to the plateau country of the Zuni "swell". Disembarking at Ft. Wingate, on the northwest edge of the swell, we take to horseback and track the base of the flexure, then up through to the older core, and finally back to Mt. Taylor itself.

The good views are always pointed out. If we behave, perhaps the Captain will take us there some day. The images drawn are vivid, penned in whatever language suits the scene best. Dutton despairs the poor choice of words at his disposal for such features as the plateaus present.

There is lava, too, in the valleys and passageways between the mesas, and these valley lavas are seen at once to be much younger than those on the tops of the tables. And by the way, what is a mesa? What is the special significance of the term? And why is it used instead of good Anglo Saxon? I will answer these questions by asking another. Did it ever occur to the reader how poverty- stricken the (I will not say English exactly, but) Anglo-American language is in sharp, crisp, definite topographic terms?

English writers seem to have gathered up a moderate number of them, but they got most of them from Scotland within the past thirty of forty years. They are not a part of our legitimate inheritance from the mother county. In truth, we have in this country some three or four words which are available for duty in expressing several scores of topographic characteristics. Anything that is hollow we call a valley, and anything that stands up above the surrounding land we call a hill or mountain. But the Spanish or Mexican, if you prefer, is rich in topographic terms which are delightfully expressive and definite. There is scarcely a feature of the land which repeats itself with similar characteristics that has not a pat name. And these terms are euphonious as well as precise: they designate things objective as happily and concisely as the Saxon designates things to the purpose. A "mesa" means primarily a table. Topographically it is applied to a broad, flat surface of high land, bounded by a cliff, the crest of which looks steeply down upon the country below. And the Plateau country is mesa, mesa everywhere - nothing but mesa. It is not at all necessary that the high tabular surface should be completely encircled, or irregularly but completely environed, by a descending cliff. One side may be cliff-bound, while the other dies away by a gentle, barely perceptible declivity into distant lowlands. Still it is a mesa. Or a few miles back of its crest line a second cliff may spring up to a higher flat beyond. Even so it is to the Mexican a mesa, though we might in this case call it a terrace. The Mexican sees but one side at a time, and if that answers to the general conception it is enough for him.[58]

The reader is struck at once with the tangibility of the author's mind. We watch Dutton think. His son, who for later writings transcribed as his father strolled about the office, smoking his ever present cigar, tells how field notes, maps, and references would all be chewed and digested as a whole before any word was put to paper. Everything was committed to memory. Then at once the work poured forth, paragraphs, pages at a time. The Captain did not plod from one page of notes to another, and the works read smooth by it. That freedom allows asides natural to a fertile mind, unnatural to a pile of notes. The reader is given glances at the language, at the history, the vegetation, the colors, even the imaginings stimulated by the panoramas.

EARTHQUAKES ON THE EAST COAST – PRECURSORS

While Dutton had been in New Mexico that summer and autumn of 1884, the eastern seaboard had suffered a number of large earthquake tremors. This stimulated general scientific interest in the understanding of seismicity, still thought to be a random process. On November 22nd a conference was held, with Dutton in the chair, its purpose to begin "the framing of a provisional plan for systematic observation of earthquakes." The first conference of its kind, it could be considered the birth of systematic seismology. Of the scientific men called, all or most had shown previously an interest in the field: Professor William Morris Davis of Harvard, Professor Rockwood of Princeton, Professor Cleveland Abbe of the Signal Corps, and Professor Paul of the Naval Observatory were principal participants. The mixture of the institutions involved was reminiscent of these from which the initial members of the National Academy of Sciences had been formed two decades earlier.

Powell's choice of Dutton for this particular study was an odd one. The Captain had not shown previous interest in the phenomenon of earthquakes. Yet a new breakdown of the U.S.G.S. into subject rather than areal divisions had found Dutton, predictably, at the head of the Volcanic Division. But under this division would fall the youthful category of seismology is less predictable. Apparently the division took on the scope of "natural catastrophes connected with earth processes." This, and the prevalent notion that earthquakes were tied intimately with volcanic activity, dictated Dutton's involvement in the organization of the new field of inquiry.

In the course of lively discussion, the minutes of which were typed (rather than hand written -- the typewriter, having been invented in 1873, had finally caught up with Dutton memorabilia), several committees were formed. And three bulletins were deemed necessary: one on the available instrumental designs for both precise and general seismometers; another a bibliography of earthquakes within the U.S.; and a third to be a digest of all scientifically observed quakes in the U.S., or, more ambitiously, in North America.[59]

Many questions were raised, and the enthusiasm of cooperation seemed high. The U.S.G.S. was to remain the organizational agency to coordinate the efforts of the many interested institutions and bureaus. But Dutton was not able that year to pursue with much rigor the questions and duties which arose. His next involvement with seismology was of another order, and in another year.

A PROPHESIED DECLINE – 1885

The momentum and confidence Dutton established gained him acceptance into the National Academy of Sciences, and gained his works international reputations. But along with the confidence were born the beginnings of the end. His attachment to the Survey's inner workings led him into bureaucratic entanglements; his services were to be solicited in the already brewing congressional battles. He feared the distance from the field that all this implied.

The dichotomy of health and eminent decline were the subject of another letter to Geikie in the winter of 1885. He refers to the renewed congressional interest in consolidating "into a single department all the various bureaus and isolated organizations engaged in work of a specifically scientific character." The gloomy forecast to follow stems from both his anger at his involvement in such congressional debates, and his more general dislike for organization. He was not a politician.

> I am not a believer in much organization for scientific work. Some organization is necessary but it should I think be a minimum. The scientific worker must be as untrammeled as possible. And scientific results depend upon the efficiency of the man who does the scientific work and all that organization _ought_ to do for him is to give him men money and room and let him alone otherwise. In point of fact an organization beyond the most necessary points merely restricts instead of helps -- clogs instead of expedites. "Organization" sounds well. Surely it is valuable in an

> army, a machine shop, a commercial house, a railroad. But what do you and I want of a big machine to control us when we are trying to reach geological results?
>
> Gov't science has and always must grow more and more perfunctory. It must grow more expensive and less efficient and that continually. Our survey is now at its zenith and I prophesy its decline. The "organization" is rapidly "perfecting" i.e. more clerks more rules more red tape, less freedom of movement less discretion on the part of the geologists and less out tum of scientific products. This is inevitable. It is the law of nature and can no more be stopped than the growth and decadence of the human body.[60]

It was Dutton's fate that his own zenith would correspond with that he saw in the U.S.G.S., and a twist of that fate that his prophecy would be so quickly realized, that his personal career would be so contorted by Powell's struggle over the next five years. But the immediate causes of the eventual death of Dutton's career had not been born in 1885. That day had not come. The bad winter of 1886, the crescendo of the next decade's drought, and the political and personal consequences of Powell's reactions to these natural events were still in the future.[61]

THE CASCADES – FINALLY

For three years Dutton had looked forward to beginning this new and larger project in the Cascades. He intended to spend a long while working out the Cascades geology. He had not spent two consecutive field seasons in an area since the summers of 1875-1877 in the High Plateaus of Utah. Yet it was an area larger even that he had imagined (and he never would set foot in the more northern Cascades of Washington State), with geologic intricacies and logistical complications sprouting round every redwood. Clearly, it would take years of work both in the field and in the office. Simply to outline his campaign took him two years. He let his imagination free to design and undertake projects no one else would have considered; his confidence was at a peak. He was 4fi Dutton left for the northern California field area in early June of 1885, in hopes of getting in a good season before the forest fires made further progress impossible. The railroad was by then completed between San Francisco and Portland, constructed with much difficulty across the dissected piedmont between the Cascades and the Pacific. The Captain -- this time with his young son, Clarence, Jr., along -- hopped off the train at the head of the Sacramento Valley, at Red Bluff, California. He quickly organized his field party, and proceeded to the volcanic area of Lassen Peak (he called it Lassens), where Diller had already started his second season of detailed work.

In that first short trek the Captain met with many of the country's idiosyncrasies. The pictures of the scenes and experiences detailed in his "My dear Major" letters mingled economic and religious allusions, practical and social comments. It was another country Powell had not closely known, and Dutton, as he had done in Hawaii, took the opportunity to color the Major's view of it.

> There are difficulties which I have never before examined. I am used to a country where grass is plentiful and water limited. Here water is abundant as in the

> Appalachians, and grass as scarce as possible and what little is to be had must be bought like the soul's salvation -- with a great price. There are very poor trails, I will almost say none at all, and the routes of travel must be by wagon roads which are usually very good or else through the pathless wilderness. If by wagon road we must pay toll at rates which would have shocked the old robber barons of Germany in the 12th century. If we leave the roads and take to the woods we flounder through a gigantic forest encumbered with scrub that is everywhere horse-high with fallen timber and ground covered with boulders. Ravines and canyons are many and deep, the ridges equally enormous and very steep. Between the roads and wilderness I think I prefer the latter for it only tries my patience and physical endurance while the tolls arouse a sense of burning indignation and tempt me to homicide and arson.[62]

To cover the large distances one simply had to use the roads. In another lashing, Dutton continues his treatment of the social state.

> The principal business in northern California seems to consist in all the people charging each other heavy tolls and supplying each other with work house meals at four bits -- every horse and mule being reckoned as one person. Wherever I go through a toll gate I have to beg the robber-in- charge not to shut the gate till I get through the next one for fear of smashing my hind wheels. If you have any poor relatives out of luck send ‘em out here to set up a toll gate or build a corduroy bridge over a fifty foot creek which they can do for a hundred dollars or less. They will soon be able to keep their daughters in a fashionable boarding school.[63]

In every sense the country seemed the antithesis of the Plateau Country: only from the heights could one obtain anything nearing a commanding view. Yet even these peaks were guarded in their lower slopes with a chaparral impenetrable by man horse or grizzly -- it is bull strong horse high and pig tight." Within the first month in the field, Dutton decided to climb Lassens; once again his account is worth quoting:

The view from Lassens of course is most commanding but I failed to reach the summit. I attempted it but met with a slight accident which might have been most serious. Riding with Diller and my boy to the base of the upper peak we dismounted and began the ascent. It was very early in the morning and the snow which covered everything was frozen hard. After ascending about 200 feet my shoes would not hold. I slipped and slid to the bottom lacerating my left hand and straining my arm and wrist. Diller and Clarence who were rougher shod went on and reached the summit. If I had slipped higher up the consequences would have been disastrous. Dust we are and to dust we shall return. But the sensation of being filed into dust sliding helplessly over a steep slope of frozen snow is not the most acceptable way of fulfilling this decree of nature.[64]

The season of 1885 was a frustrating one. The area flaunted its worst obstacles in the face of this short, but curious Captain, already confounded by the newness and inherent frustrations of working in a chaotic stratigraphy covered thickly with vegetation. It took him a good while to accustom his habits and expectations, but he accepted the challenge and pursued his dreams tenaciously.

In reconnaissance heading north from the Lassen area, in the summer of 1885, and more extensively in 1886, he formulated a plan for a major assault (and he did think of these things in military terms) on the geologic problems posed by the Cascades of northern California and Oregon. He rationalized the additional forces needed, hoping by the increased pace of the work to cover the field before economics made it profitable to mine the gold and the coal from the steep slopes of the Cascade hills. The geology should be surveyed before the people needed it, and before the people disturbed it. The multiplied effort would require a couple more assistants. (Already he was tossing about several names in his letters.) These men would lead parties to take on the cumbersome tasks of rooting out the detailed geology -- the hands, and knees men, so to speak -- while the Captain pursued the larger questions, the overview.

The winter of 1885-86 that separated his two field seasons in the Cascades was a bad one across the nation. It marked the demise of the great cattle herds; millions of cattle died in merciless blizzards. The Cascades were not immune to the snows, which continued through May. Mt. Lassen and Mt. Shasta stayed snow-bound until July, and the rivers "boomed" down congested valleys as never before in the memories of the Western settlers. But this did not hinder the Captain. The bad weather had its advantages. It wetted down the forests enough to delay the fires; fires; which the previous summer had started two months early would hold off until late in 1886, enhancing the views from the otherwise smoky summits.

The Captain had big hopes for the summer of 1886. Having briefly visited Crater Lake in southern Oregon the summer before, he planned to study the vicinity in detail; and he hoped to gain an overview of the Oregon Cascades. Upon the first goal he allowed his imagination full reign. The season before he had looked over the rim into the turquoise waters of Crater Lake a thousand feet below. This time he planned to reconnoiter the lake itself. He asked How deep is the lake? What sort of topography does the bottom have? Will it support my earlier conclusions that the mountain is an old volcano since blown its top, a caldera?

To answer these questions he set into action a grand scheme. Three boats were specially ordered to be built in Portland -- one big, to be used for sounding, and two small auxiliary skiffs. These were then transported in wagon frames, supported by huge slings to spare them the shocks of travel, across the 100 miles of rugged mountain roads to the rim of the lake, and finally lowered gently over the 1000 foot slopes to the water. For the purpose Dutton used his pull with the Military, and had at his disposal ten enlisted men from the Fort Vancouver barracks.

> A cradle was made of scantlings, to which the boat was lashed, and the tackle, made fast to trees, was used to hold back the boat, while the men urged it forward and downward over the great snow- banks, talus and ledges. The process was not without peril. Apart from the danger of working upon so steep a slope, the melting snow frequently detached large stones, which went crashing down, threatening the men and boat alike. The task however was accomplished without accident though

there were numerous narrow escapes. The lowering of the small boats was a much easier matter. Next followed the work of cutting a trail from the summit to the water, in order to reduce the severe labor of ascending and descending the cliff. To camp below was impossible; there was no room to lie down in a position approaching horizontality.[65]

The results of the following month of sounding revealed the deepest fresh water in the United States -- some 2000 feet of it. And a bottom topography uniform around 1800 feet, with three conical hills: one of which forms the island seen in the western comer of the lake, the other completely submerged. Simultaneously, the Captain had an accurate map of the mountain's stump surveyed, showing the dimensions of the lake basin to be 4 1/4 miles, almost elliptical.

Dutton planned to pursue the Crater Lake investigation still further should the opportunity arise, but of course it never did. The remaining eight weeks of the 1886 season he spent in a general reconnaissance, meandering across, and back, and across again the Cascade platform of Oregon, establishing for himself an areal view. He benefitted no doubt from his earlier talks with Diller, who had made essentially the same trip in 1882.

Dutton had the highest of praise for his assistant, Mr. Diller. The man was learning quickly, amassing the wealth of field experience needed to ask the correct questions of an area, to define his own problems. It is clear that the Captain felt superior in his own powers of observation and synthesis. In a rare moment of self-aggrandizement he heaps lavish praise upon his ability to restore a landscape to its pre-erosional form. A skill highly developed in the Plateau Country, he could fill in the chasms, restore the continuity of the beds, look back in time. Diller had never been exposed to the marvels of the canyon country; how could be he expected to have developed those skills as fully as had the Captain? [66]

Dutton was most intrigued by the Three Sisters peaks just northwest of Bend, Oregon. They presented a well-rounded classical problem: one including sedimentation, volcanism, erosion, glaciation, and volcanism again. The glaciation, moreover, was upon a larger scale than that to the south, around Lassen and Shasta. This was the result of an ice sheet, not individual alpine glaciers. The whole Cascade platform north of the Three Sisters was a glaciated one.

As Dutton turned one last time to cross the Cascades, headed toward Mt. Hood and a late season ascent, a major earthquake rocked the south Atlantic seaboard, centering near Charleston, South Carolina. The date: August 31st 1886. Dutton did not know of this until he reached Portland more than a week later. Nor could he have foreseen that he would never get another chance to climb the already snowed Mt. Hood.

"GEOLOGICAL SKETCH OF THE CASCADES" [67]

With Diller, the Captain formed a simple conceptual picture of the Cascades. He realized that a major early Tertiary hiatus, which seemed to be discontinuous across the

region, indicated that portions of the Cascades had been islands in that time. The islands of this "archipelago" were separated by sediment-laden straits. The first of these they dubbed Lassen Strait, separating the islands to the north and west from the mainland to the south and east. Dutton recognized the basic components of the Cascade system: the andesitic platform with later, more varied volcanics; some historic in age; the Great Basin to the east; and the great floods of basalt later to be called the Columbia River field; the piedmont to the west. He was toying with the concept of quite recent uplift, perhaps including the whole western verge of the continent.

But of the work Dutton did in the Cascades there is no formal paper. Only three short articles appear, in *Science* magazine, all accounts of a couple days' observations, experiences, and thoughts. The first is a concurrence with opinion that a lava flow near Feathers, on Lassen, was very recent (still steaming, scorched trees, fresh cinders). The second, entitled "Crater Lake, a Proposed National Reservation," was written before the 1886 season in which the detailed soundings were made. It merely lays out the caldera hypothesis and its one snag -- the apparent lack of "corpus delicti" in the form of large blocks near the base of the mountain. The third is a delightful re-evaluation of the "Submerged Tress of the Columbia River." In this Dutton boldly, but not without apology, differs in opinion from his predecessor, J. S. Newberry, whose 30 year old tracks with the Pacific Railroad surveys Dutton had crossed many times: in New Mexico, in Arizona, in California and Oregon. But the simple hypothesis of a landslide damming the Columbia River would not hold up to closer scrutiny. Dutton checked the types of trees, whose stumps protruded in the low water for a thirty-mile reach of river; he noted the drastic difference in the height of a stranded terrace in areas strewn and not strewn with the stumps. All evidence pointed toward a recent broad folding of the area, a picture that coincided with the behavior of the Columbia River in that section. Dutton interpreted the river to be chewing its way headward across this newly formed arch, an action that created the "Cascades" waterfall.

Other than the sixteen pages of annual reports from 1886 and 1887, from which we learn only the generalities of Dutton's knowledge, this is all we know he knew. It is a shame the Captain got no time to devote to the writing of this study, or to further pursue the field work, for Diller's writing is of a different caliber altogether. Diller's use of the language is much stiffer, his sentences short. Awe and fascination are not communicated. It is a science in its factual sense only. (And there are other senses.)

BACK TO WASHINGTON

Captain Dutton was catapulted into a study of the Charleston earthquake upon his return from the Cascades in fall of 1886. He was an obvious choice; his chairmanship of the conferences on systematic seismology had made him the expert As Dutton was in the Cascades on August 31st, the night of the quake, others at the time free were sent to investigate. W. J. McGee, officially in charge of the Potomac Division, was on the scene by September 3rd, and worked there for some time with a photographer (probably Hillers, for it is his photographs of the disaster which are now preserved in the National Archives), and for some time with Professor Mendenhall of the Signal Corps. Being too large a task for completion in the short time allotted, the collection of data was

handed over to a local resident, Mr. Sloan, who had shown particular interest, an ability to work in that "most enervating of climates," and had a good eye for pertinent facts.

All these reports were turned over to Captain Dutton upon his return from the Pacific slope. With his assistant, Mr. E. E. Hayden, he collected further data on tremors felt at long distances from the quake. In December, from Washington, Dutton provided Marcus Benjamin of *Appleton's Cyclopedia* with his classic autobiographical sketch. In it he concluded:

> ...and in 1885 (I) began the investigation of the Cascade and Coast Ranges of northern California and Oregon. This is the work on which I am now engaged -- except however for a brief interruption for the purpose of preparing a monograph on the Charleston Earthquake. [68]

But upon writing his annual report to Powell on July 1st 1887 he could foresee that he would miss a field season in the Cascades. He went so far as to solicit the aid of Professor Thomas Condon of Oregon University in an attempt to keep two parties in the field.69 Condon declined the offer, and Diller's was once again the only party in the Cascades. Dutton hoped to be done with the Charleston monograph in another three months. It took him a year.

"CHARLESTON EARTHQUAKE MONOGRAPH"[69]

Dutton was less than enthusiastic about the results of the investigation. At the time of the earthquake there was not a single seismograph operating in the United States. This may have been the last investigation performed under such a handicap. Yet one happy circumstance remained in the Captain's favor. The U.S. had standardized its clocks in 1883. Once every day a signal was telegraphed from an astronomical clock to every telegraph station in the country at an appointed hour, minute, and second. The U.S.G.S. circulated a plea in local newspapers throughout the nation for accurate reports of tremors felt that evening of August 31st. The deluge of replies piled high on the Captain's Washington desk, and ranged from Boston to Cuba, Washington to Michigan. After four months of expurgating those accounts clearly unreliable, Dutton was able to establish the speed of propagation of earthquake waves with unprecedented accuracy: 3.22 miles per second. This corresponds closely with that expected from a homogeneous, silicious solid earth. Dutton considered this conclusion the prime achievement of the work.

Most of the report, however, is descriptive. He includes detailed accounts of the catastrophe from the best available sources. Three of these accounts comprise the first chapter. In these the general reader -- and it is again to the general reader that the work is addressed -- gains an unequalled impression of that Tuesday evening in Charleston. The ground shook for nearly a minute, snapping off all but a few of the 14000 chimneys in the town, bringing down a rain of Carolina grey bricks; cornices fell; steeples tilted and rocked; masonry walls cracked and crumbled; fires started in the still air; in all 27 people were killed outright. The whole town slept outside that night. Tents of rugs, blankets, window shades, and planks were constructed in all the town's main squares,

away from the tilted walls which spilled debris into the littered streets at every aftershock. Another 56 persons died from the injuries and exposures of that night. Morning revealed the ruin. As Charleston occupied a small tongue of land between two rivers entering the Atlantic, many of the houses rested on artificially filled land. These were virtually destroyed. Since fires had earlier gutted most of the buildings along the main streets, construction was required to be of masonry inside the fire limits. The report praises wood framed houses as the best suited for earthquake country.

But these were all simple conclusions from the observations made by others who had been available when the quake occurred. Dutton's big task was the compilation of all the reports into a cohesive picture of the event. He documents first the chaotic nature of the ground motion: the usually instructive displacements of cemetery monuments were utterly bewildering; and personal recollections of the ground motions seemed at odds. He then proceeds to deduce from the notes taken by Sloan (and later field checked by himself) that there were two epicenters, one west of town, the other northwest, thus explaining the chaos of the Charleston observations.

Dutton's methods for establishing isoseismals on the large map, and for computing what he called the index circle on the epicentral map, were necessarily subjective; the instrumentation his earthquake committee had recommended would surely have helped. He made the best of the data at hand, but those conclusions based on subjective criteria quickly became antiquated.

In a characteristically professorial manner, Dutton closes the work with a twenty-page essay on the nature and mechanism of wave motion. Having stated in his preface that he would refrain from conjectures on the causes of earthquakes (a subject he would return to almost two decades later), he expounds for his general reader the full effects of such waves once generated. It is an artfully constructed essay: all in words, no equations. Starting with the simpler pictures of waves in gases and liquids, he gradually complicates the image, adding the notion of transverse waves in solids; then on to heterogeneous solids; then to discontinuous, heterogeneous solids -- leading the reader into the complexity of the problem as into the complexity of the ground motions themselves. He concludes with a reproduction of Sekiya's "wire diagrams" from an earthquake in Japan, a technique for visualizing the three dimensional record of a seismograph. A more fitting illustration could not have been chosen. Read today, and modified surprisingly little by the new physics, this essay might hold as an introductory lecture in seismology. But the Captain was not at all satisfied. He had lost not one, but two field seasons in the Cascades on this "short interruption" from the volcanic studies.

THE IRRIGATION SURVEY

The Captain's forced residence in Washington for the whole of 1887 was to prove a captivity in another sense. Working closely with Powell allowed the grip of the larger willed man to strengthen. The 50th Congress was voted in amidst a growing national concern over the land laws, and a concern in the West over the continuing drought. Big Bill Stewart of Nevada was elected, and by early spring of 1888 he had pushed through a bill authorizing an Irrigation Survey.[70]

The law called for designation of reservoir sites, cost estimates of water works, and the segregation of irrigable lands. Two amendments were tacked on to the original Joint Resolution of March 1888 before the appropriation rode through on the Civil Sundry Bill of October 2nd 1888. The first stated:

> ...and all the lands which may hereafter be designated or selected by such United States surveys, for sites for reservoirs, ditches, or canals for irrigation purposes and all lands made susceptible of irrigation by such reservoirs, ditches or canals are from this time henceforth hereby reserved from sale as the property of the United States, and shall not be subject after the passages of this act to entry, settlement or occupation until further provided by law...[71]

It was an awkward statement, one easily molded to various interpretations. Did this mean the lands designated thereafter were withdrawn from settlement? Or did it mean that all Western lands were withdrawn from settlement until such designations had been made? Those who were startled at the sweeping power of the survey tacked on the following amendment, essentially a safety valve:

> PROVIDED, That the President may at any time in his discretion by proclamation open any portion or all of the lands reserved by this provision to settlement under the homestead laws.

Powell divided the survey into three segments: hydrographic, engineering, and topographic. The hydrographic corps would gauge streams, determine the "duty" of the water (how much land a unit volume of water would irrigate in the given specific area), measure evaporation, and in some cases measure sediment load (for determination of the potential life of a reservoir). The engineering corps was required to form some definite project of works for the irrigation of each hydrographic district, estimate the cost of the works, and the amount of land such works would irrigate. Quite obviously, the engineering and hydrographic surveys were mutually dependent. The topographic teams were to complete the mapping of the Arid Region's watersheds as an aid to the engineering and hydrographic corps in computing watershed areas and in locating the water works approximately.

Powell turned first to Gilbert for his field coordinator. Gilbert was sorely tempted by the chance to get back into the West, especially with the opportunity to carry on work from an engineering point of view. But he was forced to decline the offer by pressures to get his Bonneville paper to press, and by domestic anxieties with an ailing wife. The job went to Dutton. The Captain was given charge of the engineering and hydrographic corps, while Professor Thompson was given the topographic assignment. The appropriations, $100,000 the first year, and $250,000 the second, were divided between Dutton and Thompson almost evenly, with a small contingency fund held in reserve.

The summer months of 1888, between the Joint Resolution and the Appropriation, Dutton spent in both finalizing his Charleston Earthquake monograph and in drawing up

a plan for his component of the irrigation work. On July lst, the end of the 1887-88 fiscal year, he was removed from his charge of the Volcanic Division, Diller replacing him in that spot. With this died the Captain's dream for a synthesis of Western volcanism. The division was renamed in honor of the only field area being studied -- the Cascades. Whether the Captain still hoped to return to the Cascades is not shown in his writing, though he did hope to be replaced in this irrigation work "as soon as a more qualified man" could field party of his own. There was no art in it at all, no sense of creation. It was administration.

The problems he would face were simultaneously immense and miniscule. The Land Office would claim never to have received orders to close off the lands to settlement; stream gauges would break, or malfunction, or never be recorded. Congress would boil over with dissatisfaction, and impatience. His crew chiefs would get drunk. And he would disagree with Powell -- about small points.

The Captain's first task was to establish a corps of hydrographic engineers. Neither were there trained men, nor established methods, nor standardized instruments for the chore. Dutton set out to solve these problems in his first winter. By early December, 1888, he had a group of fourteen young men in a camp on the Rio Grande in New Mexico. It was to be run by Professor Newell. The camp functioned as a training ground for field teams in the skills of gauging runoff, evaporation, and rainfall. Dutton's first letter to Powell in over two years, written while on a tour of the arid Southwest, praises the competence of the new recmits.72 He fears, though, for their health, these city boys out in the middle of the New Mexican winter, gauging streams of icy water. They must have seen a pretty rough winter, in that tented camp near Embudo.

In the spring of 1889 the dozen men who were deemed of sufficient talent were distributed in the various hydrographic basins of the Arid Region. Forty-eight gauging stations were set up. As the summer neared, Dutton established his engineering corps, with two supervising engineers -- Hall and Nettleton -- and four division engineers.

By July lst, at the close of the 1888-89 fiscal year, the engineering parties had hardly begun their work. And the set of data collected by the hydrographers was years from being a useful guide to stream characters. Only two reservoir sites had been designated: Bear Lake, near the Utah- Wyoming- Idaho comer; and Utah Lake near Provo. They were both natural reservoirs.

That summer things moved fast. Seven divisions of engineers were in the field, with Dutton racing about between them. It was an administrative rat race: June 15th Denver, June 18th Boise, June 19th Denver, July 10th San Francisco, July 24th Washington, September llth San Francisco, September 22nd Pocatello, September 29th Salt Lake City, and back to Washington. The Captain logged more miles on the railroad that year than he had in all his previous travels.

A large portion of his correspondence deals with a renegade division officer, Mr. Bridges, who not only bought the most expensive equipment possible, but went about

work in whatever drainage he wished. And he usually chose one smacking of potential private profit. He was relieved of his duties.

The fiscal year 1889-90 was a profitable one, in some senses. By March of 1890 the several teams of engineers had designated 142 reservoir sites, had fully surveyed 300 miles of canals (and another 100 partially), and had reported 30 million acres of land as irrigable (out of some 890 million in the Arid Region).

The work was huge. One major problem still nagged them: the General Land Office (G.L.O.) continued to issue patents for settlement claims. Whether under the Homestead Act of 1862, the Timber Culture Act of 1874, or the Desert Land Act of 1877, these were all illegal under the letter of the October 2nd 1888 law. But the Land Office claimed it had never received orders to close its doors, and indeed it received none officially until April of 1890. Before the reservoir sites designated by the engineers could be officially cleared as such, all titles to privately held parcels of land within the perimeter of the reservoir had to be checked in the records of the General Land Office. Both from the pre-existing patents, and from those which every day trickled in (through the G.L.O.'s reluctance to close its doors) the dozen clerks at Powell's disposal were swamped. At the time Dutton reported 142 reservoir sites as designated, only two had been cleared.

Congress was in a flap. And led no less by those senators who pushed the bill in the first place. This was not what they had intended. All that was called for was a quick survey to lay aside reservoir sites. At this rate the lands would be closed to settlement for years. (Only after the reservoir sites and the canal systems had been cleared, and the irrigable land designated, could the President open the lands again for settlement under the Homestead Law.) How can you expect the mass migration to the frontier to check itself in mid-flow? Should we not trust to the wisdom of the masses: manifest destiny manifested?

A committee to investigate the irrigation surveys was formed in January of 1890 with Bill Stewart in its chair. Hearings began: Powell was called in to make a statement, then engineers, then residents of the West, then Powell, and Powell again. On March 13th, the fifth day of the committee's meetings, Dutton was called in to make a statement as Chief Engineer of the Irrigation Survey.[73]

The principal questioners were Bill Stewart of Nevada, John Jones of Arkansas, and John Reagan -- a staunch Powell supporter -- of Texas. Questioning, led mainly by Stewart, quickly centered around the propriety of and the necessity for the topographic work being conducted under the auspices of the Irrigation Survey. Reagan tried to draw Dutton into stating the absolute necessity of the topographic maps for the prosecution of the engineering and hydrographic thirds of the work. Stewart, on his side, tried to belittle the importance of such maps, questioning their direct utility.

In response, the Captain came out strongly against the prosecution of the topographic work: It was the Director's (Powell's) idea originally to have a topographic map

constructed with a degree of accuracy which would be sufficient to enable engineers to dispense with costly and cumbersome parties of transit men and levelers, and to produce maps which, when taken in the hands of the engineer and carried into the field, would enable him to lay down his canal lines with as fair a degree of accuracy and certainty as if they were actually run by transit and level. That was his way of making an irrigation survey. I think that the Director was under a misapprehension as to the degree of accuracy in his maps which was attainable by the methods actually used by the topographers and under the requirements which were laid upon them. My belief is that no such degrees of accuracy as would be necessary for the engineer was at all attainable by the methods adopted by the topographers, and I am quite confident that the topographers think the same way themselves, with the possible exception of Professor Thompson. That was the Director's desire in having a topographic map made.

The engineer's side of the question, I suppose, would be this: that a topographic map cannot by any possibility be made with any such degree of accuracy as is required for the crudest and most general purposes of the engineer. In the next place, the requirements of the engineer are for a very large scale map, a map merely of a strip of ground a few hundred feet wide along the path of his traverse; also for a very detailed map, on a scale never less that 200 feet to the inch, and most generally 100 feet to the inch, sometimes 50 feet to the inch for dam-site purposes. This minute survey on a very large scale is to enable the engineer to take the map into his office and estimate quantities, as we say. Similarly, also the survey along the line of his traverse on a very large scale is necessary for precisely the same purpose as the railroad engineer makes it, in order to be able to estimate the quantity of excavations he has got to make and how to adjust his cuts and fills.[74]

Not only does the Captain take with him the hydrographic and engineering corps under his direction, but he sweeps from under Thompson, who is head of the topographic corps (and, remember, Powell's brother-in-law) all of his field parties. This first weakening of Powell's ranks was a big one; sides quickly formed. It was Powell and Thompson against the lot of them. Nettleton, one of Dutton's two supervising engineers, seconded the Captain's views in later testimony before the Irrigation Committee.

There are earlier signs of Dutton's dissent from Powell's plan. In the first winter of the Irrigation Survey, before any topographic work had been initiated under irrigation funding, and while the hydrographers were just establishing their New Mexico camp, the Captain expressed clearly his views to Powell. In the letter, started in Santa Fe and completed in Phoenix just after Christmas of 1888, the Captain reveals his inclination to read the law and its purposes more narrowly than the Major. Reservoir sites, he thought, should be selected quickly in order to put them out of reach of the speculators and squatters, either of which could easily make a killing in condemnation awards when the reservoirs were finally put under construction. The quickest method would not need a topographic map at all, but would merely rely upon the placement of crude monuments secured by quick triangulation.

A simple declaration filed with the register of the proper land office that all the land in a certain valley situated below the level of a certain monument is selected as a reservoir site would rigorously define the selection. A description of the monument and its situation with reference to neighboring natural objects would sufficiently maintain the record against the obliteration of the monument by accident or design. At a later period the location and description of the site could be more specifically described and platted by a topographic survey and a good map could be made of it.[75]

For the segregation of irrigable lands Dutton had an equally quick method: with the hydrographic information, decide upon the highest point water can be taken out of the stream, run a single line of level "as far as there is any sense in running it" -- either on one side or both -- identify the quarter sections through which the canal would cut, and declare them and all below them to irrigable land. The President could then reopen these lands to settlement in 160-acre parcels as designated in the Homestead Law. Dutton's plan had two levels to it: one rough, one accurate. And the accurate one could wait.

Although Powell realized that urgency was at a premium, he tended to compromise between haste and permanence heavily upon the side of permanence. Powell's goals were political ones. His hopes involved the reorganization of Western political structures into those based on hydrographic basins, as he advocated in an appearance before the Montana Constitutional Convention in 1889. The Major hoped to influence the course of settlement in the West; and with five territories teetering on statehood he could taste the opportunity. (The Dakotas, Idaho, Montana, and Wyoming all held constitutional conventions in 1889.) Powell's was a plan for governmental control of land settlement, a plan to take the common interest into account. His was a socialist rather than an individualist view. And to do all these things Powell needed a topographic map of the whole region, so that works far into the future could be planned, so that a comprehensive plan could be charted out rather than piecemealed together. But most of all he needed the time implied by the construction of such maps, for the West had yet to be convinced of the need for political reforms included in Powell's plan.[76]

Dutton's goals were never political, though he perhaps agreed with the socialist sense of Powell's Western vision. Their differences were practical rather than ideological. Dutton's nose was consistently rubbed in the everyday practicalities of a West run by speculators and land squatters. Less optimistic for total reform, he was happy with the power vested in the Irrigation Survey through Congress, and hoped to put it to its quickest use before Congress had second thoughts.

The difference in approach between Powell and Dutton boiled down to the necessity for a topographic map, and the Congressional flap crystalized around any available nucleus. Powell's request for the 1890-91 appropriation was $790,000. He boldly extended the area to be surveyed to include that land termed sub-humid. This was a strip from British America to Mexico along the 100th meridian, embracing those lands hardest hit by the continuing drought -- the transitional belt, not needing irrigation in normal years, but lost without it in the dry. In defense of the threefold expansion of his

Irrigation Survey budget Powell appeared before the Appropriation Committee on June 4th 1890.

The questioning went from condescending to picky, picky to vindictive. Captain Dutton's earlier testimony before the House Irrigation Committee was brought up as part of what was to become a mauling by Senator Moody of the Dakotas. Powell agreed that a topographic map was not necessary. "We could do it by the trial line method. We could gauge all the rivers and measure the catchment areas by different methods, but we do it in this manner because it is the cheapest and I think the best."[77]

Moody continued the attack, arguing solely in specifics -- the Jim River in the Dakotas; the associated artesian basin; numbers of wells already sunk, and how the level had not dropped. Why was there so little thought of the artesian system? he asked. All were questions Powell had answered in previous testimony before the House Irrigation Committee. The conclusion to the day's hearings is a sad testimony to the state of the nation in 1890. It demonstrates that the failure of the Irrigation Survey can in no way be blamed upon Captain Dutton, nor upon Major Powell. Ammunition had been found in Dutton's testimony, yes, but equally damaging was that evidence purely invented, purely personal. It had as much to do with the age of the congress as with acre-feet of water, as much with politics as with science:

Senator Moody. Let me explain one thing of which you remind me. I deprecated, and do now deprecate, this unfortunate controversy which apparently has sprung up with Major Powell. There is nothing personal in it. I have a great respect and regard for Major Powell personally; but the trouble is, he gave our scheme a black eye at the outset and declared that the artesian basins would not amount to anything. Now we know better, because we know the wells we have got and that we can irrigate thousands upon thousands of acres of land with those wells.

Mr Sayers. So you are now going to give him a black eye?

Senator Moody. No; but I do not want to put money in an agent's hands to spend who declares in advance that he cannot expend according to my belief the way it should be spent. Now I will employ some other agent. I will hunt up somebody else because I want him to have the faith that I have in it, or else I will take charge and spend that money myself if I cannot find someone who has faith in it. Now in regard to this question of topography and all that, why I can very well see that the Major has been pursuing this business for years and years and has got a great big scheme here covering millions upon millions of dollars, but that can wait. We want crops -- we do not want pictures -- and the Major is making pictures. We want results. Our people in the West are practical people and we cannot wait until this geological picture and topographical picture is perfected. These witnesses from his own office, the engineers who are executing this work come and state that these topographical maps, so far as this irrigation is concerned, amount to nothing; that they are no more help to them than any country map would be when you go into a country. It helps them to find the streams but they say to us this is an exact science they are following, and when they select a reservoir they

must know whether they can get water into it, and they can do it only by running levels, and that they cannot by making pictures... they say they had to make these maps, that these topographical maps do not do any good. They make maps of the reservoirs and of the country surrounding the reservoirs, and of the streams from which they propose to take the water to the land. In other words they have to make maps from the streams to the reservoirs and from the reservoirs to the land and of the ditches. Scientific men know as much about that as we do, that water will not run uphill. The geological maps that are being made are all well enough; we do not want to interfere with that. I started the proposition of having the geological survey, although I think a great deal has been expressed that is a great humbug; that is, that there is a great deal of humbug about it. But our people cannot wait for the development of these things; we are getting too old, most of us in this Congress, and we want results, and we would rather have the money expended on some other line."[78]

The appropriation for the Irrigation Survey was struck from the Sundry Civil Bill, by tenfold the largest item dropped. No more hydrographic work, no more engineering work. And a limit was imposed on the amount of topographic work to be done in the West: only one half of that money allocated to the U.S.G.S. for topographic purposes could be spent west of the 100th meridian. That made $166,000, approximately half of what Powell had marshaled for the previous year's topographic work in the West. The Irrigation Survey, both by Powell's and by Dutton's view, was scrapped. The clause reserving the arid lands from settlement was repealed, leaving only a few reservoir sites the result of two year's work.

CHAPTER 4. 1890-1901 A MILITARY CAREER RESUMED

The events that followed are unexplained. The facts sort themselves into some semblance of a time line, but the why's remain unanswered. For the first three years of his geologic career Dutton had been granted one-year details to the Powell survey. Starting in 1877, however, Powell had arranged for a series of four-year details, the maximum length allowed by the Army. The third of these would close in 1891, but with it the administration of the Ordnance Corps would change: in Dutton's view a change for the worse. Dutton received a promotion to Major in May 1890. We do not know why.

It may have been the last friendly act of the outgoing Chief of Ordnance; it may have been meant to induce Dutton to resign his geological duties, drawing him closer to the Corps as he drew away Powell. We do not know the extent of the rift between Powell and his left hand man. The emotions and intentions of Dutton in that summer are buried, apparently without correspondence.

It is clear that a bitter enemy of Dutton's was to succeed his friend as Chief of Ordnance, one who would take less than kindly to sustaining his special detail (already one of the longest in military history), especially in the light of the Congressional turmoil over the U.S.G.S. and its Irrigation Survey. If the Irrigation Survey folded, where was Dutton to go? In June of 1890, one full year before this detail would have ended, and

just as the Appropriation Committee results were becoming clear, Dutton requested to be relieved of his geological responsibilities and returned to military duty.

As his first military assignment he toured about the western, Pacific, and southern states as a member of a board inspecting gun factories. He maintained his residence in Washington, where he could take advantage of the various scientific societies; where plans were being made for the coming International Geologic Conference (I.G.C.); where billiard and chess in the Cosmos Club remained forums for intellectual exchange.

After spending the month of April, 1891, in Central America, Dutton returned to Washington to find a letter transferring him to the San Antonio Arsenal. His dismay is summarized in his letter to Archibald Geikie:

> "With regard to the meeting of the Congress next August I had anticipated much pleasure therefrom. But during my absence in Central America a new Chief was appointed to my corps and I find on my return an order relieving me from all duties in Washington and ordering me to San Antonio Texas where I shall be quite out of the world with nothing to do and no opportunity to do anything. Of course I am much distressed at the change and surprised also. I know of no reason for it.
>
> I am contemplating the writing of a novel of a cowboy series with sketches from life taken with a Kodak in the Texas Cattle Ranges- Can't you "give me a lift" with a few suggestions as to plot and denouement? Pray do. By the by it was at San Antonio that the celebrated Davy Crockett died with his boots on and the tree where he held his famous colloquy with the 'coon must be hard by. And the stream near which he saw his beloved Susan eating alligator pie can't be far off. Perhaps a historic novel would be better. Seriously I hope nothing will interfere with your coming to Washington where many will be so glad to see you. I shall be with you in spirit -- I do not mean barreled up in alcohol -- but in strong sympathy and longing to be in the presence of the great geologists of the world for whom I feel deep reverence. To you especially to whom I owe so much of instruction and scientific example it would be a delightful privilege to pay homage."[79]

Knowing less than the full story, Dr. Geikie fired off this short note, to be printed in the June 25th issue of *Nature*:

> "Geologists on this side of the Atlantic will learn with deep regret that Captain Dutton, whose admirable memoirs in the reports and Monographs of the U. S. Geological Survey are so widely known and valued, has been ordered to take up military duty in Texas - a wide pastoral region where his genius as a geological explorer will find no scope for exercise. As a member of the Corps of Engineers, he has of course always been liable to be taken away to mere routine service of his kind, for which any ordinary office of his grade would be sufficient. But authorities have hitherto appreciated his remarkable powers and have allowed him free exercise, much to their own credit and greatly for the benefit of science. Whether a new marionette has resolved to apply the rigid rules of the service we do not know.

> But surely there ought to be public spirit enough in the United States to put such pressure on the Engineer Department as will make it reconsider its arrangements. It has only one Captain Dutton, and should be proud of him and make the most of him."[80]

A new marionette indeed. But as a Major, Dutton put as little resistance to the whims of his military superiors as he had fifteen year earlier; there is little public or scientific outcry could have done. His professional career had ended. Ironically, on the same page as this little notice in Nature was an announcement for the coming I.G.C. in the United States. Written by S. F. Emmons, it told of a planned ten-day trip to the Grand Canyon, for all those who wished it, to be conducted by J. W. Powell and C. E. Dutton. Dutton was unable to free himself from the military duties; as two Majors, they were never together in the field.

PRACTICAL BANISHMENT

Dutton continued to dabble in geology. His leave in April of 1891 had been taken to visit the Nicaragua Canal on the border of Nicaragua and Costa Rica, a trip he had made upon invitation from President Miller of the Canal Construction Company. A long contemplated and previously surveyed route, the Nicaragua Canal was the United States' answer to the Panama Canal, which the French had started in 1880. The U.S. canal was to go from Greyton Harbor on the Atlantic side to Briton Harbor on the Pacific, a route often taken by mule train and carriage when getting between the oceans. It was to utilize the great Lake Nicaragua for 60 miles, and a good deal of the San Pedro River on the Atlantic side for another 20 of the 160 miles of passage. Construction was begun in 1889 by a private syndicate, with former Senator Warner Miller as President. The hope of the company was that the U.S. Government would soon take over the initiative, but the Senate failed to act. As an attempt to prove the company's expertise and the canal's feasibility to the capitalists of the world, President Miller invited a party of engineers and capitalists to visit the canal in April of 1891. They inspected both the work accomplished and the entire proposed route of the canal/,Äò8l Dutton's inclusion in the group was as a geologist. His attention was given to the potential volcanic and earthquake hazards of the route.

In both a report to the Senate, and in a letter to President Miller (also used as testimony in Congress), Dutton expressed his optimism for the route's success. In only a few instances does he venture, in his report, to correct cost or time estimates; and he recommend only minor changes in the frequency of exploratory drillings on the Divide Cut (a recommendation made in the light of the French follies in their Culebra Cut in Panama). In the letter to Miller, Dutton rapidly dismisses the problem of volcanic eruptions. The route lies between two zones of activity but is not susceptible itself to volcanism. On earthquakes he draws heavily upon his Charleston Earthquake report to infer that the types of quakes in Nicaragua belt are shallow; thus the intensities and the effects are local. As long as the canal superstructures are finally tied to bedrock, he believed there would be little damage.

The rapidity and the intensity of Dutton's exit from the stage of geology are astonishing. In the Second Annual Report of the Irrigation Survey, Powell had to write those portions that had previously been in Dutton's hands. Dutton considered his residence in San Antonio a "practical banishment" from the intellectual and scientific society of Washington he so greatly relished. He watched from afar as Major Powell was attacked again by the Senate, the wounds inflicted in the 1890 decisions and debates not having satisfied those in the Senate out for black eyes and funding cuts. He watched the U.S.G.S appropriation decline for the first time in its history, reflecting his 1885 prophecy. Powell resigned the Directorship in 1894. His stump of an arm, having pained him considerably over the past few years, had become unbearable. Gilbert assisted him to the hospital, where the remainder of the arm was removed. Upon Powell's request, Professor Charles Walcott succeeded him. Gilbert, who had for decades been Powell's right-hand man in Washington was again freed to do field work; he embarked upon his second career, one which included his study of hydraulic mining in California and his renewed interest in the block fault mountains of the Great Basin.

TRIPS WITH BRACKENRIDGE

Dutton was one to accept what was given him, and make of it what he could. To his great advantage he became closely acquainted with the well-to-do San Antonio banker and industrialist, Mr. George Brackenridge, and was given the opportunity to delight in various voyages about the country and about the world in his company. Mr. B., as Dutton called him, apparently relished his short, but broadly experience companion who seemed to be able to hold his own on most any subject and in any company. It was in his conversations in the ship's smoking rooms that Dutton was at his best, pacing back and forth in a cloud of cigar smoke, exhaling knowledge of one or another subject, inhaling the awe of those about him, some listening, some playing cards. Such smoke talks became a feature on Dutton's only trip abroad, one he took under the bidding and financial padding of Mr. Brackenridge. The itinerary included Italy, Egypt, India. [82] No doubt Dutton's classical, descriptive and geological abilities can admirably into play.

In 1889 Dutton took his last trip with Mr. Brackenridge. This one was to Mexico, and was made under the stipulation that Dutton invite one or two of his geologic colleagues. He chose Gilbert and Holmes. It was a timely break for Gilbert, greatly grieved over the recent loss of his wife. Yet grieve he could not for long, in such company. One of Dutton's short communications with Holmes closes with this hint of the spirit to be taken on the trip.

> "Shall be delighted to see you once more and recall old times when we were young and beautiful and when the roses bloomed and the nightingales sang -- or rather when the coyotes howled and the cactus spines got in you skin."[83]

Mr. B. owned a private railroad car. They packed all their evening suits in trunks under the bedboard, keeping out the day clothes and playing cards, and were on their way by April 2nd. They went directly to Mexico City and from there made several one and two day voyages into the surrounding country. At one point early in the trip Holmes wrote back to his wife:

"Although I have written Orizaba at the top of this sheet I am really at Cordova, twenty miles lower down the road toward Vera station where we were dropped off at three this afternoon. It is eight in the evening and is dark with a dripping rain outside. Dutton and Gilbert are at the table playing cribbage and Mr. Brackenridge is playing "solitaire." Since writing you last in Monterey we have been constantly on the go through dust and rain and chill and heat over half of Mexico. Yesterday afternoon we reached the city of Mexico, attended to some business and then set out for this point. We would have gone on to Vera Cruz but Dutton seemed to fear the Yellow Fever. The trip to Tampico was given up for the same reason. There is as yet no Yellow Fever in the country and there is no danger. Our object in coming here is to see the great peak of Orizaba (see picture in Cosmos Club), the face of the great plateau where the highland breaks off next to the Gulf, and to get a glimpse of Popocatepetl on the way." [84]

It was certainly a pleasure trip. The one piece of science to come out of it was a paper written by the artist-archeologist Holmes on the obsidian mines near Pachuca, a place called the Mountain of Knives. For a couple days they rambled through the talus slopes of flakage from the centuries of workings. Then they returned to the side-tracked car, and on to the next point of geologic, archeological or otherwise interest. The trip lasted one month.

Major Dutton's health was declining by the end of the decade. Upon another change in administration, this time a good change, he was transferred to the post of assistant to the Chief of Ordnance. Though glad to be back in Washington, the job was a bore, and he retired in 1901. He then moved to Englewood, New Jersey, to live with his son.

Major Powell died in 1902, and 910 M. St. was no longer a gathering place for scientists. Yet the comradery between those left from the Plateaus studies on the 1870's was still strong. Gilbert, Holmes, and Dutton rejoined at the 25th anniversary meeting of the Cosmos Club in 1903. Still the core of the club, they each gave an address.

CHAPTER 5. 1901-1912 RETIREMENT

Although removed from formal science for a decade, Dutton again sharpened his intellectual tools and attacked the large task of putting together a book titled *Earthquakes in the Light of the New Seismology*. By his third year of retirement the book was in print, and though criticized by some (principally George Becker) for not being an up-to-date statement of the art, it was a compilation of much of the Major's thought on earth movements and their causes. Again the nugget of his thoughts is nestled amidst a bulk of information. The drift of his argument is prefaced by this statement: "The contractional hypothesis is here regarded as being virtually destroyed by effective criticism, and in the form given it by Mallet as being simply an error."85 Dutton is tidying up his intellectual house, this room being that of physical geology. He expounds further his thoughts on isostasy, a term he had defined in a speech given in

1889 entitled "Problems of Physical Geology." Having hypothesized in that address that the shifting of masses at depth which affect isostatic adjustments may be responsible for mountain building, he backs off of that assertion in his book: "The forces of elevation and depression are of a totally different category and are yet to be discovered and explained." An honest admission of bewilderment.

The whole work is written with a characteristic ease of expression, at times amusing, always informative. No, it is perhaps not a rigorous account of the status of seismology in 1904, but anyone who picks up that book will get more quickly than anywhere else a flavor of the development of that science. It is a popular account, and was intended to be such, appearing in Putnam's Science Series beside such works as James Geikie's *Earth Sculpture* and I. C. Russell's *Rivers of North America*. The general nature of his intended audience is matched by a general knowledge of the subject at hand, enhanced, as was always his custom, by allusions to classical literature. He digs out accounts of connection between earthquakes and volcanoes from Pliny, Aristotle, Strabo, Parsinias as if the 45 years since his college courses did not exist. We learn perhaps more of the history of seismology than of the current concepts, but the basics are laid bare. After treating the older conjectures of tidal, volcanic and down-throw mechanisms for earthquakes, Dutton throws his weight behind the recently elaborated ideas on the stresses imposed by such mass movements implied by none other than his isostatic adjustments. He wishes desperately to fit in his physical geological conclusions, and this haste may be considered a fault of the work. But the historical review is valuable. We are still searching for driving mechanisms, still looking for causes for the accumulations of stress.

The contractional hypothesis was certainly on its deathbed. Shortly after their return from Mexico in 1899 the great debate over "The Age of the Earth as an Abode Fitted for Life" enlivened the scientific journals. T. C. Chamberlain argued nobly from the podium of geological experience, Lord Kelvin from that of experimental and theoretical math and physics. The model espoused by Lord Kelvin, by then a virtually irresistible force in British and American science, was a familiar one. He assumed an initial temperature of 7000"oF for the globe and predicted theoretically by using the Fourier conduction model the time needed for the geothermal gradient to reduce to the present one. His estimates ranged from 20 to 40 million years, and he favored more closely the 20. From his chairmanship of the Department of Geology at the University of Chicago, and from his editorial position of the Journal of Geology, T. C. Chamberlain marshaled the bulk of geologic evidence not only to reply but to dare to refute the great Kelvin. Chamberlain wanted billions of years, and called on the inexorable pace of evolution, sedimentations rates, and the like in his defense. Joining Dutton and others, he looked to physics to come up with another source of heat, the heat needed to reconcile the geologic evidence for a long earth history with Kelvin's conduction theory of a short earth history. In what looks now to be inspired prophesy, he suggests that this source might be locked in the depth of the "atomecule," as it most certainly was and is.

It was a thrilling debate. Lord Kelvin's 1897 annual address before the Victoria Institute came out in the May 12th and 19th, 1899, issues of Science. Chamberlain's response

came out scarcely a month later, also in two parts. Chamberlain's arguments provided the soundest and most extensive devastati0n of the contractional hypothesis, which depended heavily upon the simple conduction model espoused by Kelvin.

Dutton rallied, in his last two works, to heap his own shovelful of insight upon the grave of the contractional hypothesis. In his last paper, read before the National Academy of Sciences on April 17, 1906, Dutton claims to be upon the verge of a solution to the volcanic problem. For decades he had claimed no solution would be found until a new source of heat was discovered by the physicists, the plea echoed by Chamberlain. The title spells out the connection he wishes to elaborate: "Volcanoes and Radioactivity." It is a short, carefully reasoned and elaborately expressed thesis, and was considered by his colleagues a landmark.

Dutton first lays out what was then known about the volcanic problem: that the earth's crust is rigid, that volcanic eruptions are generally small in volume and tend to repeat themselves, and that they originate from shallow chambers. In this simple review is locked a synthesis of his geologic experience, drawing from both his volcanic and earthquake studies. Then the mystery source of heat is revealed; radioactivity, he thought, was the keystone, the first line in the chain he had said was missing thirty years earlier in this High Plateaus report.

> "We may now proceed to state the probable cause of volcanic eruptions. They are caused, I conceive, by a development of heat resulting from radioactivity in limited tracts at a depth of one to three -- at the most, not over four -- miles from the surface, which is sometimes sufficient to melt the rocks affected by it. The melting is gradual, and when a sufficient quantity is melted, the water which it contains becomes explosive and usually suffices to break through the covering, constituting an eruption. When all the lava is erupted and the reservoir is exhausted, it closes up for a time. If the heat continues to be generated, more lava is melted and in due time another eruption occurs. The process may be repeated again. It may be repeated hundreds of thousands of times. The volcanic action may continue in the same place for hundreds of thousands, or even millions of years, or it may repeat itself a few times, or may even occur once. Indeed it may fail altogether to erupt to the surface, and in many cases does fail. In other words, it goes through the entire process of preparing for an eruption and does not consummate it." [86]

It is a tidy little package, and (like many papers dealing with a young science, this time radioactivity) full of falsehoods and simplifications. The remainder of the work is an introduction to the state of the radioactive science as applied to geology. The thrust of the piece, however, is Dutton's final emphasis that the contractional hypothesis is no longer needed to explain volcanic activity. A source of heat had been found which he could plug back into his old expositions of the problem. The short, blocky, and still vandyked Major Dutton stepped from behind the podium in personal satisfaction.

Within half a year Dutton was battling the effect of trachoma. Only through the aid of his wife could be read a paper sent him by Smithsonian for review. In October of 1911, five

years later, and badly ill with arteriosclerosis, Dutton wrote J. S. Diller a long and apparently autobiographical letter, excerpts of which Diller quoted in a short paper on Major Dutton that December.[87] His last words being "Farewell to my old friends on the Geological Survey," C. E. Dutton died quietly on Thursday, January 4th 1912, in Englewood, New Jersey. He was buried in Wallingford, Connecticut, that Saturday.

Diller's article was published again, shortly after Dutton's death, this time in the Geological Society of America Bulletin; Becker's brief obituary came out in the American Journal of Science, and Gilbert was assigned the writing of Dutton's biographical memoir for the National Academy of Sciences. But Gilbert was in no state of health to take on such duties, and was in the process of distancing himself from scientific societies in general. When Gilbert finally resigned the task, no one else was assigned it; the biography lay unwritten until Chester Longwell was given the task in 1957, long after everyone who had known or worked with Dutton had died. The trail was by then largely overgrown and silent.

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FOOTNOTES

CHAPTER 1.

1. Much of the information in this section is taken from a set of Biographical Memoirs published by the National Academy of Sciences -- all listed in the bibliography.
2. See Markes Johnson's short paper in the G.S.A. Bulletin, August 1977 issue, titled "Geology in American Education, 1825-1860" for a review of these two schools' influence.
3. See William Goetzma1m's treatment of Anny exploration in the West in Exploration and Empire, 1966.
4. Marcus Benjamin Papers, December 20, 1886.
5. Most of the general information in this section is derived from three sources: The Yale College I Catalogues from 1856-61; the "Yale Banner," an annual fact sheet published at the beginning of each school year containing lists of faculty, students and clubs; and Kingsley's Yale, which documents Yale College history up to 1879.
6. From a personal communication with Yale archivist, Patricia Bodack, April 1, 1977.
7. Published in Yale Literary Magazine, December 1859.
8. Wallace E. Stegner, "Clarence Edward Dutton, Geologist and Man of Letters: PhD. Thesis for University of Iowa, 1935, p. 86. Two letters from Dutton's son, C. E. Jr., are appended in Stegner's thesis. This one is undated, but was probably in early 1935.

CHAPTER 2.

9. Woolsey Family Papers, Letter from C. E. Dutton, Wallingford, Conn.
10. This chronology is best told in a biographical sketch in Yale, Class of '60, 1860-1906, pp. 95-96.
11. W. E. Stegner, "C. E. Dutton," p. 86.
12. Clarence Edward Dutton, "Memorial of Alexander Lyman Holley," pp. 29-30.
13. Preserved by title only in American Association for the Advancement of Science (A.A.A.S.) Bulletin, 1869.
14. "Office of Secretary", Smithsonian Institute, Record Group 26, v. 101, p. 328.
15. See Samuel Rezneck, Education for a Technological Society, for a thorough treatment of this period in Rensselaer Polytechnic Institute (R.P.I.) history.
16. Benjamin Papers, Dutton autobiographical sketch, December 20, 1886.
17. Letters in "Office of Secretary," Smithsonian Institute, Record Group 26.
18. James Hall, "Contributions to the Geologic History of the American Continent," p. 55.

CHAPTER 3.

21. Stephen Pyne, "Grove Karl Gi1bert. A Biography of American Geology, PhD. thesis for the University of Texas at Austin, l976. See Pyne for treatment of Gilbert's experience with Wheeler and for the latest insights into the great geologist.

22. Benjamin Papers, Dutton autobiographical sketch, December 20, 1886.

23. Goetzmann, Exploration and Empire, p.478.

24. Stegner, "C.E. Dutton," p.4.

25. See the Pacific Railroad Reports in Government Documents: Macomb Report, serial, Ives Report, serial 1058.

26. Letters Received by John Wesley Powell, roll 4, pp.89-91, June 5,1876

27. Letters Received by J.W. Powell, roll 4, pp. 92-94, September l7, 1876

28. Rocky Mountain Survey Letters Sent, v.l, p. 545, May 25, 1877.

29. Letters Received by J.W. Powell, roll 5, pp. 166-167, May 25, 1877.

30. Rocky Mountain Survey Letters Sent, v.l, pp. 1036-1037, November 2, 1877.

31. Letters Received by J.W. Powell, roll 7, pp. 136-137, November 21, 1878.

32. Rocky Mountain Survey Letters Sent, v.2, pp.782-786, September 30, l878.

33. Apparently this is only a part of a large correspondence Geikie had with American geologists, all kept in the Archives of University of Edinburgh.

34. Dutton - Geikie Correspondence, March 16, 1880.

35. Dutton - Geikie, May 27, 1880.

36. The information in this section is taken from several addresses published in The Twenty-fifth Anniversary of the Founding of the Cosmos Club of Washington D.C.

37. Dutton - Geikie, April l, 1880. This letters also reveals Powell's intended retirement from geology to devote all his energy to the Bureau of American Ethnology. The letter is marked "personal."

38. Dutton, Tertiary History of the Grand Canyon District, p. vii.

39. Dutton - Geikie, June 21, 1880.

40. This sketch of Holmes is drawn from Wallace E. Stegner, Beyond the Hundredth Meridian, pp. l86-188. The whole book is an excellent reference tool for the period 1869-1894, Powell's career in geology, exploration, and Western politics.

41. William Henry Holmes, "Random Records of a Lifetime Devoted to Science and Art," v.5, pp.45-47. The-letter is dated August 16, 1880.

42. Holmes, v.5, pp.39-40.

43. Dutton - Geikie, March l6, 1881. For Dutton's more detailed accounts of the first year of the U.S.G.S. see his June 21, 1880 letter to Geikie.

44. Dutton, Tertiary History, p. 9 (footnote).

45. Dutton, Tertiary History, p. viii.

46. Dutton, Tertiary History, p. l4l.

47. Inferred from Dutton's response to the letter, dated September 29, 1881, and preserved in "Dana Scientific Correspondence," Yale Archives.

48. Printed under the title of “Recent Explorations of the Volcanic Phenomena of the Hawaiian Islands” Am. J. Sci. 125, pp. 2l9-226.

49. Stegner, Hundredth Meridian, p.290.

50. Dutton, "Hawaiian Volcanoes," p.102.

51. Dutton, "Hawaiian Volcanoes," pp.193,Äîl94.

52. Letters Received by the United States Geological Survey (U.S.G.S.) roll 21, number 859, June 8, 1884. (This microfilm series is numbered by the letter rather than the page or frame.)

53. Dutton, "Mount Taylor and the Zuni Plateau," p.113.

54. Dutton, "Mount Taylor," p. 122.

55. Letters Received U.S.G.S., roll 23, number 1808, August 21, 1884.

56. Dutton, "Mount Taylor," p. 196.

57. Dutton, "Mount Taylor," p. 116.

58. Dutton, "Mount Taylor," pp. 126-127.

59. Letters Received U.S.G.S., roll 26, number 486, undated.

60. Dutton - Geikie, February 26, 1885.

61. See Stegner's chapter "The Opportunity" in Hundredth Meridian for a detailed account of this period.

62. Letters Received U.S.G.S., roll 28, number 1171, June 8, 1885.

63. Letters Received U.S.G.S., roll 31, number 1198, June 2, 1886.

64. Letters Received U.S.G.S., roll 29, number 1741, June 24, 1885.

65. Eighth Annual Report of the Director of the United States Geological Survey, 1886-87, p. 157.

66. Letters Received U.S.G.S., roll 29, number 1748, July 13, 1885.

67. Most of the knowledge of Dutton's Cascades work is included in his reports to Powell, published in the 7th and 8th Annual Reports.

68. Benjamin Papers, Dutton autobiographical sketch, December 20, 1885
69. Ellen C. McCornack, Thomas Condon, Pioneer Geologist of Oregon, pp. 169-171.

70. Stegner has perhaps the most detailed account of the Irrigation Survey and the legislation surrounding it. In "The Opportunity" chapter of Hundredth Meridian.

71. United States Statutes at Large, v.25, pp.6l7-618. (For other laws pertaining to the Irrigation Survey, see Statutes at Large volumes 25 and 26 as listed in the bibliography.)

72. Letters Received U.S.G.S., roll 42, number 2705, December 2l, 1888.

73. See United States Government Documents, serial numbers 2707 and 2708, for "Report of the Special Committee of the U.S. Senate on the Irrigation and the Reclamation of the Arid Lands."

74. U.S. Government Documents, serial number 2708, part 5, p. 142.

75. Letters Received U.S.G.S., roll 43, number 42, December 21, 1888

76. Stegner, Hundredth Meridian, pp.304-324.
77. Government Documents, serial number 2813, "House Reports, First Session, Fifty-first Congress, Volume 7," p. 69.

78. Government Documents, serial number 2813, p.74.

CHAPTER 4.

79. Dutton - Geikie, June 6, 1891.

80. Nature, v.44, p.183, June 25, 1891.

81. See Simmon's Nicaragua Canal, 1900, for a detailed history of the canal construction attempt.

82. Stegner, “C.E.Dutton,” p.91. (In a letter to W.E. Stegner from C.E. Dutton, Jr., dated July 9, 1935.)

83. Holmes, "Random Records," v.8, 9.94. Dated March 22, 1899.

84. Holmes, "Random Records," v.8, p.89. Dated April 7, 1899.

CHAPTER 5.

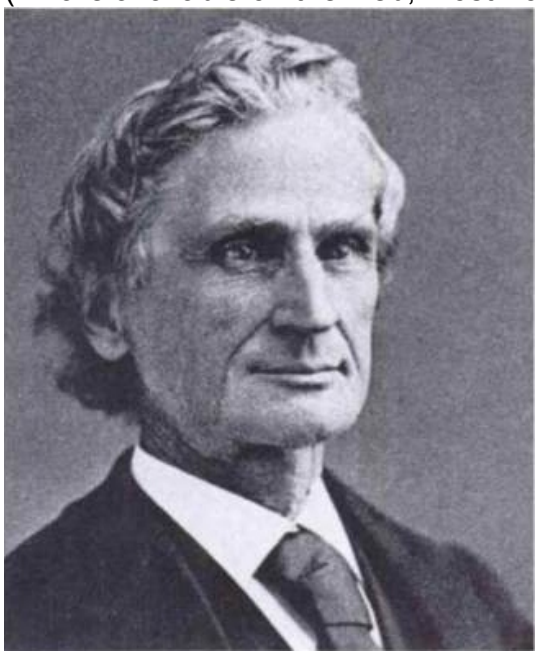
85. Dutton, Earthquakes in the Light of the New Seismology, p. 30.

86. Dutton, "Volcanoes and Radioactivity," p. 6.

87. J.S. Diller, "Major Clarence Edward Dutton," Bulletin of the Seismological Society of America, v.1, pp. l38-141.

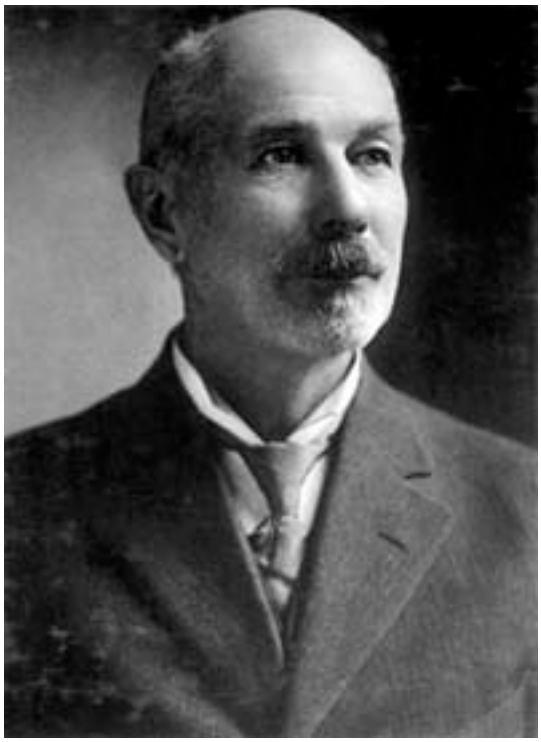
Images of some of the major players in Dutton's life

(All are available on the web, most from National Archives in public domain)



James Dwight Dana 1890

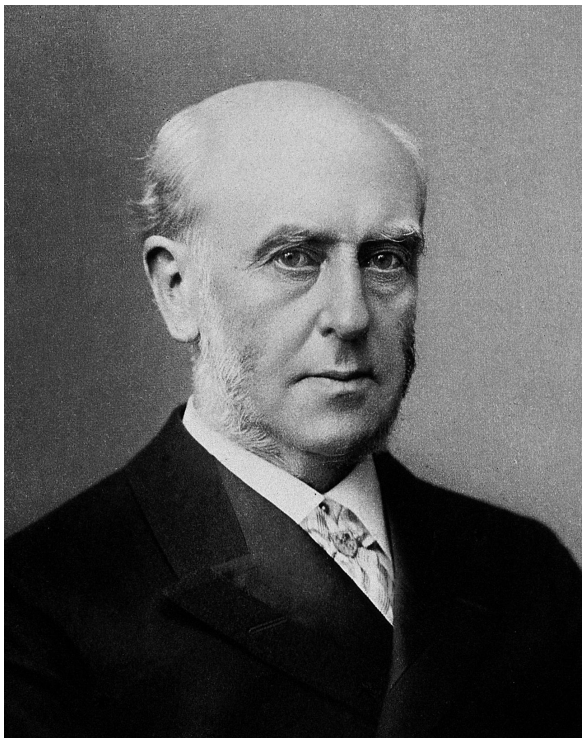
"Speaking of geoscience" site



Joseph Silas Diller 1850-1928

C.E. Dutton (1841-1912)

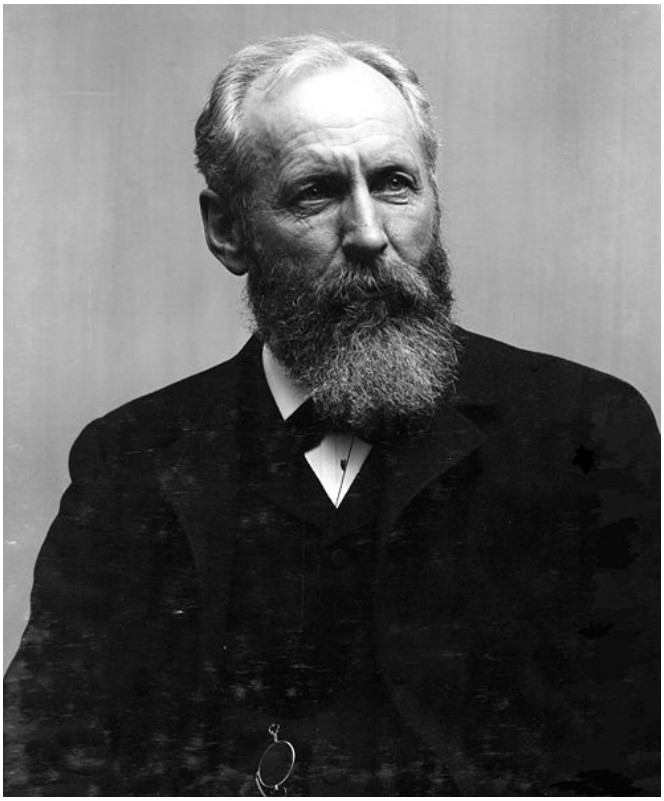
Captain Clarence Edward Dutton



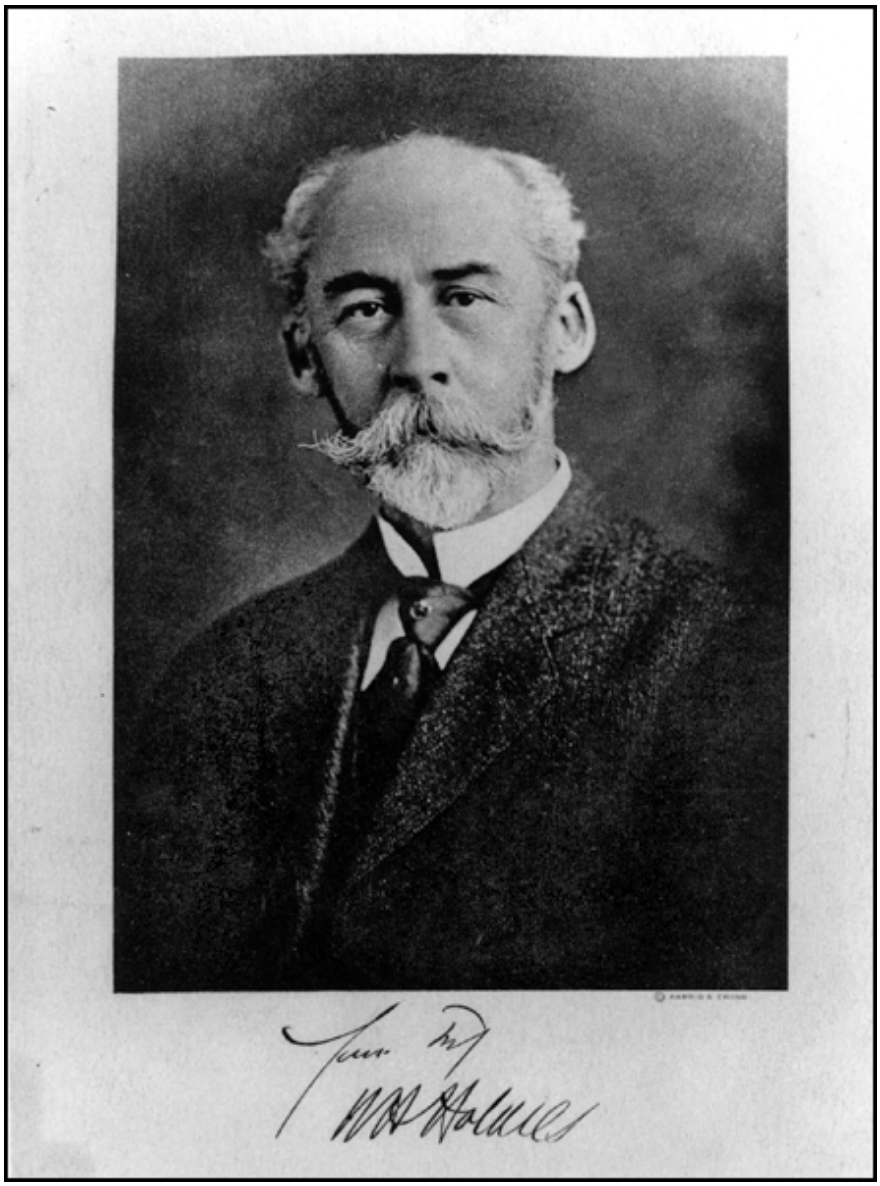
Archibald Geikie (1835-1924)

Charles Doolittle Walcott, John Wesley Powell, and Sir Archibald Geikie on a geological field excursion to Harpers Ferry, West Virginia, May 1897, following the George Huntington Williams Memorial Lectures delivered by Sir Archibald Geikie at Johns Hopkins University. Original caption: Geikie excursion party, Jefferson Rock, Harpers Ferry, West Virginia, May, 1897. Joseph Diller USGS photographic library.

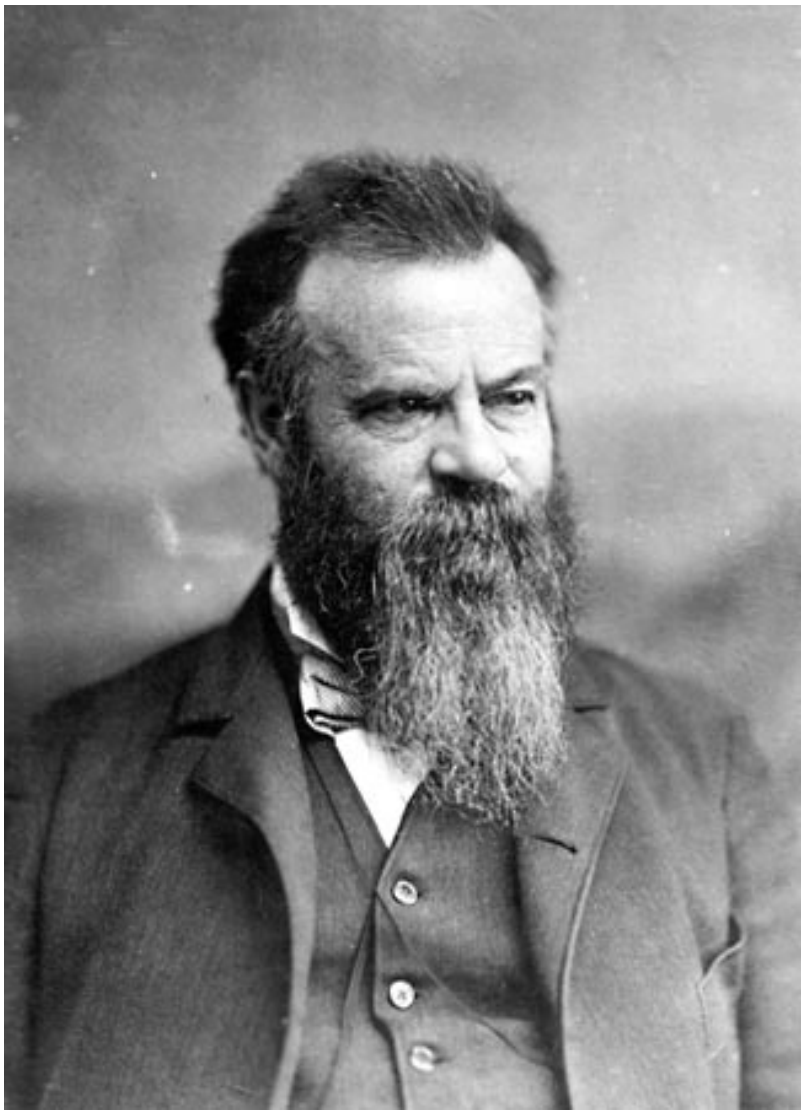
Grove Karl Gilbert in 1890
Grove Karl Gilbert (1843-1918)



Grove Karl Gilbert in 1891



William Henry Holmes (1846-1933)



Major John Wesley Powell (1834-1902)
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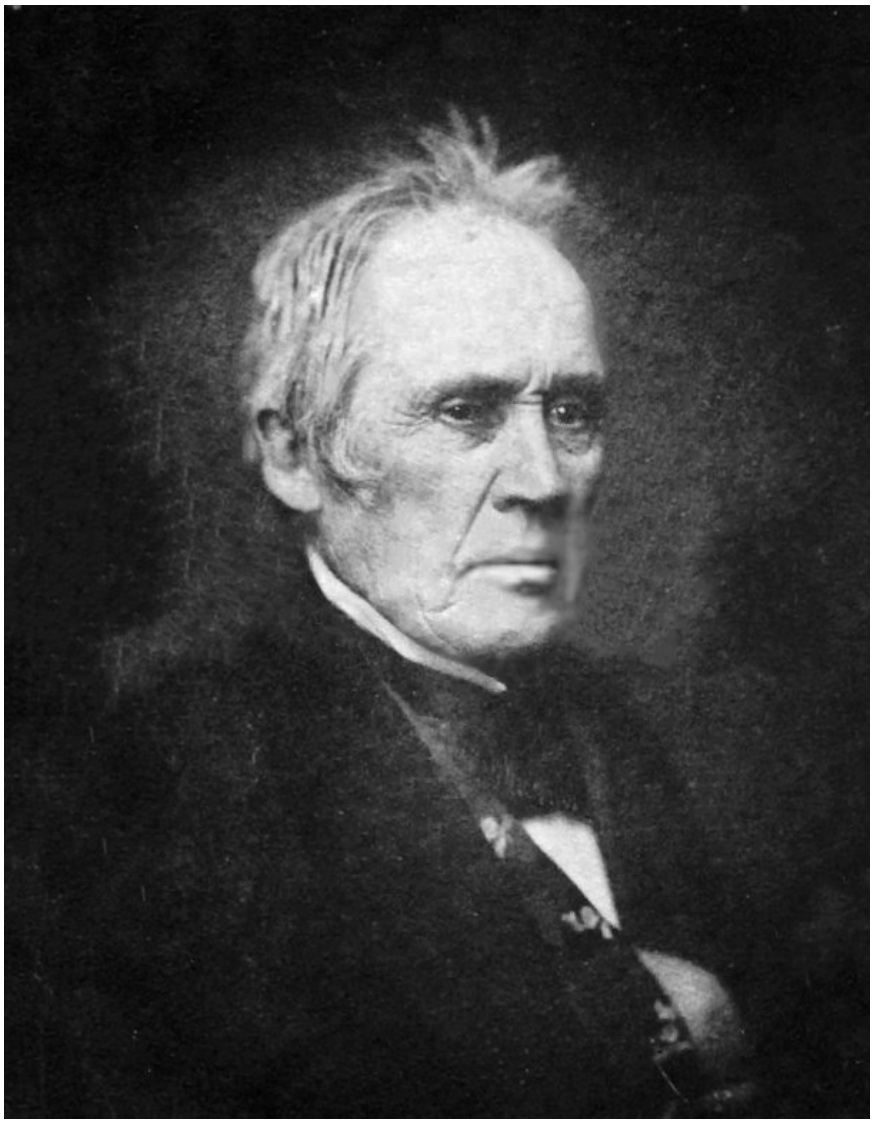

Benjamin Silliman (around 1850)