Laccolithic Mountains of the Colorado Plateau

by John Weisheit

Introduction

The last mountains to be included on the map of the continental United States were the Henry Mountains (the Henrys). They were named by John Wesley Powell for Joseph Henry, director of the Smithonsionian Institute and contributor of the scientific equipment used during Powell's historic boating expedition of 1869. The Henrys are igneous intrusive mountains -- more specifically a *laccolith* -- and are located in southeastern Utah bounded on the north by the Fremont River, on the east by the Dirty Devil and the Colorado rivers, on the south and west by the Waterpocket Fold. Mt. Ellen is the highest peak at 11,615 feet with a vertical relief of about 8000 feet. Of the many laccolithic mountains on the Colorado Plateau, the Henrys have received the most attention by the United States Geological Survey. First, by geologist Grove K. Gilbert and second by geologist Charles B. Hunt.

The first geologist to actually describe laccolithic mountains on the Colorado Plateau was Albert C. Peale, during a government sponsored survey under the direction of Ferdinand V. Hayden in the 1870's. When Hayden's team was in the laccolithic La Sal Mountain group near Moab, Utah, they named the highest peak in Mr. Peale's honor, which is the tallest mountain on the Colorado Plateau, standing at 12,721 feet. Said Peale, "[A laccolith mountain] presents one of the most promising fields for future detail investigation to be found in any part of the West, and will well repay the labor of the geologist who shall devote himself to their special study."

I perceive that geologist to be Charles Hunt, because his investigations would later develop into the most comprehensive work available concerning the Cenozoic Era's geological history of the Colorado Plateau and of the Colorado River. These would include USGS Professional Papers 279 and 669C which may be the most eye-opening primary documents ever produced about the Colorado Plateau.

Kinds of Igneous Mountains

There are two kinds of igneous mountains on the Colorado Plateau and are termed as being either intrusive or extrusive. The Henrys are an igneous intrusive structure that formed about 45 million years ago. Molten rock (magma) was injected between sedimentary rocks, which made the overlying rocks bulge, and then cooled slowly within the structure. In this particular process of slow cooling, the magma crystallized into a rock type called granite. This intrusive phenomenon is called a laccolith -- a word of Greek origin meaning cistern or pit. Erosion (mostly glacial) has since stripped away the overlying sedimentary rock, exposing the granite and leaving its present sawtooth-like appearance.

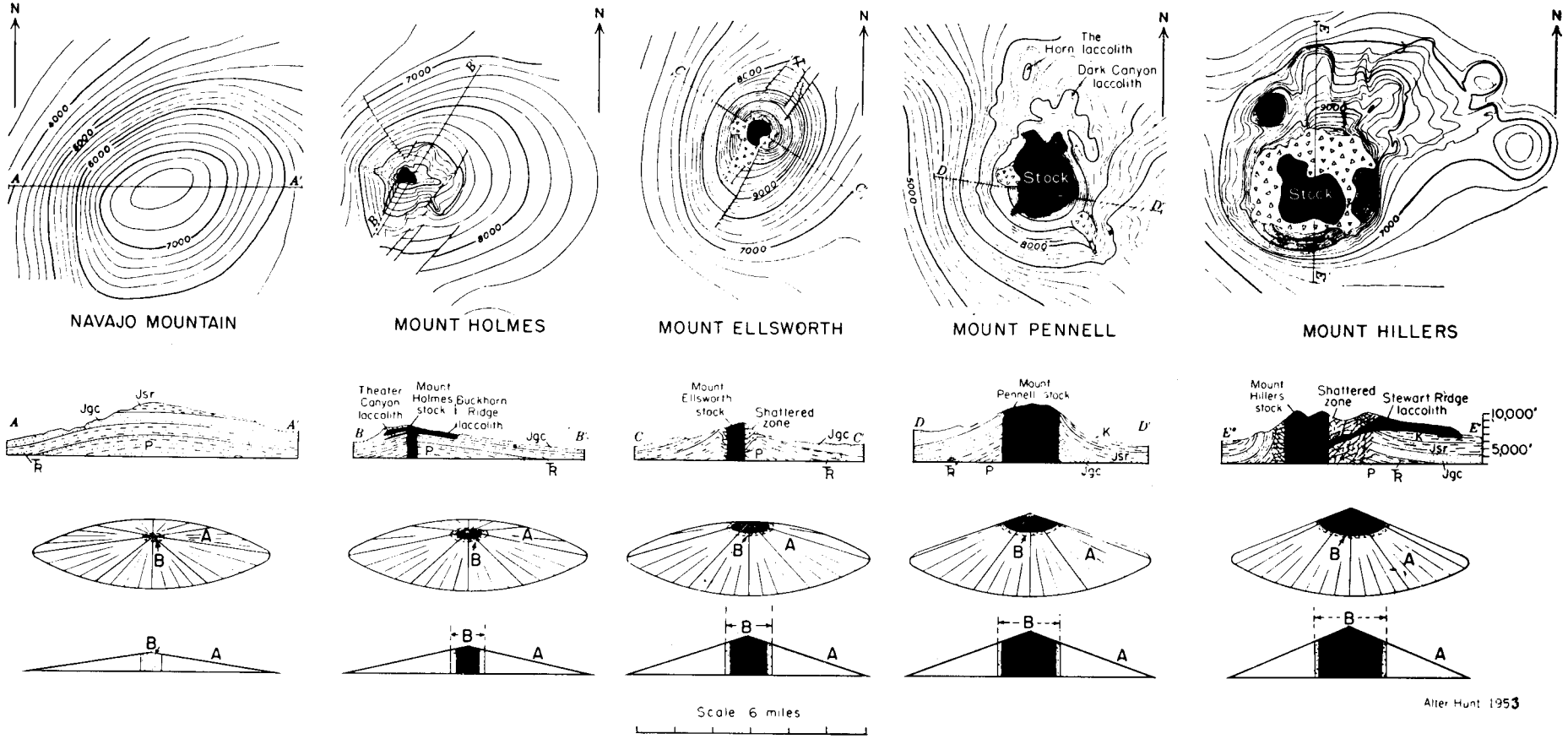
There are two parts to a laccolithic mountain -- the stock and the foot. The stock is the point of injection from the sub-surface magma zone. We will later learn in the upcoming discussion of plate tectonics, that standing water on the surface was sufficient enough to thwart the complete upward travel of the magma, which then moved laterally (sideways) into sedimentary rock. This laterally injected magma is called the foot and the true laccolith. Hydrothermal activity was associated with the stock, which vented vertically through joints caused by the bending of the sedimentary layers. In the case of the northern flank of the La Sal Mountains, a foot vented magma and formed a curious extrusive lava deposit which can be observed in upper Castle Valley. For the La Sal Mountains, most of the intrusive activity started first as a viscous diorite porphyry followed later by a less viscous monzonite porphyry. A diorite porphyry is a granite rich in calcium and sodium. A monzonite porphyry has a similar matrix but contains more potassium and makes for a lighter colored granite.

There are three other kinds of intrusive structures found within the Western United States. This would include the *batholith*, which is defined as an intrusive structure greater than 40 square miles. Their shape is equidimensional and good example is found in Yosemite National Park. A *dike* is an intrusion that fills a vertical fracture within a rock formation. Dikes are seen in the metamorphic schist and gneiss formations of Grand Canyon and Westwater Canyon. An intrusive *sill* fills a fracture that runs parallel to the plane of the mother rock. In the Grand Canyon a sill is observable in the Bass Limestone of the Unkar Group near Hance Rapid and is associated with the asbestos fibers once mined there.

A good example of an igneous extrusive structure (volcano) on the Colorado Plateau are the San Francisco Mountains near Flagstaff, Arizona. Magma was ejected onto the earth's surface (lava) and cooled quickly forming basalt and tuff (ash). Mount Humphreys is the highest peak reaching a summit of 12,670 feet and is Arizona's tallest mountain. The original vertical relief amounted to 8,800 feet, but erosion has since reduced the relief down to about 5,800 feet.

Plate Tectonics

There are other laccolithic mountains on the Colorado Plateau which can be grouped according to age and cause. For ages of about 80 to 65 million years (Cretaceous Period) we have the La Platas, the Carrizos, the Utes, El Late, the Ricos, and the San Miquels, all of which are associated with the Laramide *orogeny* -- mountain building. Interestingly, some of the laccoliths associated with the Laramide orogeny bear mineral wealth; these minerals may have been introduced by the magma content of that time period.



K, Cretaceous rocks; Jsr, rocks of San Rafael group; Jgc, rocks of Glen Canyon group; R, Triassic rocks; P, Permian rocks. Structure contours drawn on base of Ferron sandstone member of Mancos shale. Contour interval is 200 feet; datum is sea level.

Structure contour maps, cross sections, and diagrams of Navajo Mountain and of Mounts Holmes, Ellsworth, Pennell, and Hillers in the Henry Mountains. The location of the cross sections is shown by lines on the maps. The diagrams are on the same scale as the structure-contour maps and geologic cross sections of the mountains.

Each diagram is set beneath the mountain it portrays. In the oblique diagrams of the conically deformed circular areas the lined area A on the lateral surface of each cone equals the area of the basal circle, and the area B is the amount by which the lateral surface exceeds the circular base.

On the Navajo Mountain cone the stippled area B (0.5 sq. mi.) represents the extent of stretching of the domed strata. Areas of the same size are represented by stippling on the other cones. On the assumption that this 0.5 sq. mi. is the limit of stretching of the domed strata, the black areas in the cones of the Henry Mountains represents the theoretical space formed by doming of the strata and available for the intruding stock.

FIGURE 1.—Diagrams illustrating the relationship between the stocks and the domes at the laccolithic mountains on the Colorado Plateau.

During the ages of about 45 to 25 million years ago (Oligocene and Miocene Periods [Olig/Miocene]) we have the Henrys, the La Sals, the Abajos, and Navajo; which are associated with the *extensional rifting* (stretching) of our study area.

As mentioned, it is hypothesized that the reason why magma did not extrude to the surface was due to water. In the case of the Laramide laccoliths a Cretaceous sea, and in the case of the rifting laccoliths an Olig/Miocene lake. The presence of this Olig/Miocene lake indicates the Colorado River system was yet to develop an outlet to sea level. Through-drainage of the Plateau and development of the Colorado River system occurred later, probably about 10 to 20 million years ago and continues to evolve its course such as through Westwater Canyon, which formed some two million years of ago.

About 144 million years ago, the continental North American plate started to press into the oceanic Pacific plate and resulted in the building of the mountains referred to as the Nevada orogeny. Tectonic pressures continued and the Pacific Plate subducted under the advancing North American plate and a second set of mountains were built around 105 million years ago and called the Sevier orogeny. About 80 million years ago, tectonics began to create the Rocky Mountains of the Laramide orogeny. For the Colorado Plateau area, this orogeny also included the Cretaceous laccoliths and other surface bulges such as the Monument Upwarp and the San Rafael Swell. These surface bulges probably then appeared either as islands or at least as a seamount (submarine mountain) in the Cretaceous sea.

About 65 million years ago, in the Tertiary Period, tectonic pressure continued and began slowly to uplift the Colorado Plateau. The strata tilted to the northeast forming a southern barrier that made the Colorado Plateau area a hugh continental basin without an outlet to an ocean. Ancestral rivers feeding this basin flowed west from the Rockies and east from the Sevier resulting in a lake setting for our Tertiary Colorado Plateau. Some of the sediments from this continental lake have escaped erosion and are visible in Desolation Canyon on the Green River.

Eventually the pressures moving the North American plate eased and the affected area began to spread apart (rift), much like the expanding bellows of an accordion. This spreading introduced magma to flow up into the sedimentary rock of the Colorado Plateau and hence, our Olig/Miocene laccolithic mountains, which too probably appeared as islands. Rifting was especially dominate west and south of the Plateau because this area does not seem to have the thick basement rock of the Precambrian crystalline structures as seen in the inner gorge of the Grand Canyon and Westwater Canyon. This area segmented and whole sections dropped (a graben) to form the Great Basin Province of Nevada and western Utah, and the Basin and Range Province of eastern California and southern Arizona; this occurrence left the Colorado Plateau at a higher elevation. Rifting also formed a large oceanic trench (Gulf of California) which opened up to about present-day Needles, California, and became the eventual destination point of the Colorado River when the lake finally over-spilled the Colorado Plateau. That erosive point of discharge from the southern hingeline of the Colorado Plateau (Mogollon Rim/Grand Wash Cliffs) began canyon cutting and is better known as the process of *headward erosion*. However, it was hypothesized that discharge first occurred as a waterfall from an underground river in cavernous Paleozoic limestones and exited the hingeline escarpment as an upscale Vasey's Paradise or Thunder River (Grand Canyon tributaries).

Conclusion

This particular study of the Colorado Plateau is yet to be fully determined. Part of the problem is that the technology is not advanced as the theory. It is difficult to probe into the deep, thermal, and resistant basement rocks of continental and oceanic plates. The other problem is that the uppermost rock evidence has forever been eroded away.

I propose that while Mr. Hunt was studying the formation of the laccolithic Henrys that the anomalies of the Colorado Plateau within his distant view, such as the Book/Roan Cliffs, the San Rafael Swell, the Waterpocket Fold, the Aquarius Plateau, the Circle Cliffs, the Kaiparowits Plateau, the Monument Upwarp, and all the other laccolithic mountains, inspired him to formulate his Cenozoic history of the Colorado Plateau. He took on a monumental task and deserves that special reward Mr. Peale spoke of.

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