

“Fire and Ice”

Bill Maloney
MMSA Host Department

This brief outline is a supplement to the presentation on 11/20/11 describing the most notable natural wonders behind *what you see when you ski Mammoth Mountain*. It is my hope that knowing their story you will see them all with new eyes, as will those lucky enough to take your tour this season.

The title, “Fire and Ice” refers to the two main characters in this story; volcano and glacier that dominate the topography of our immediate neighborhood, and meet at the border between the geologic provinces of the Sierra Nevada and Basin and Range. With very few exceptions, everything seen to the east of Mammoth Mountain and this borderline is volcanic in origin and resides in Basin and Range Province while those landmarks to our south, west and North West are the glaciated granite of the Sierra Nevada Geologic Province.

The phrase, “Fire and Ice” is used so frequently in reference to ski areas that it has become something of a cliché. However, there is no mountain where this description is more aptly used than Mammoth!

Mammoth Mountain itself is a group of lava domes. Volcanic in every way, it is **geologically** part of the Basin and Range and not the Sierra Nevada. However, as we’ll see shortly, due to its unique position at a key juncture along the eastern Sierra Border, Mammoth Mountain can certainly be considered to be **geographically** within the domain of the Sierra Range. Situated in such a privileged position, it certainly feels that way.

THE MAKING OF MAMMOTH MOUNTAIN

Mammoth Mountain’s volcanic eruptions were a brief but, at least for us skiers, notable episode in the 3 M year history of volcanic activity within the Long Valley Volcanic Field. Marked most emphatically by the cataclysmic Caldera Eruption 760 K years ago, Long Valley’s volcanic activity continues to the present and is best categorized in three main eruption eras:

1. Pre Caldera Eruptions 3 M to 760 K years ago
2. Caldera Eruption 760 K years ago
3. Post Caldera Activity 650 K years ago to present (Mammoth Mountain erupted late in this stage)
 1. Pre Caldera Eruptions 3 M to 760 K
 - a. San Joaquin Ridge 3 M years ago forming the NW rim of the future caldera
 - b. Glass Mountain Ridge 2 M years ago forming the NE rim of the future caldera
 - c. Several singular eruptions scattered within the center of the future caldera. One of these may have been nearly as large as the 1980 Mt.

St. Helen eruption. However nothing in this era suggested the enormity of what was about to occur with the Caldera eruption.

2. Caldera Eruption 760 K years ago

- d. A cataclysmic eruption classified as a rare Super Volcano, it was among the largest eruptions on earth. In fact Yellowstone is thought by most to be the only larger volcanic event in history. The sudden explosion of the large magma chamber destroyed its 'roof' which collapsed more than 6000' in three days, leaving the 20 by 10 mile bowl-like caldera we see today. Ash floated with the prevailing westerly winds to reach as far as mid Kansas and Nebraska.
- e. Lavas flowed north along the current 395 corridor into Mono basin, and west over the present position of Mammoth Mtn. into the Red's Meadow region. The vast majority of lava flowed down to the SE toward Bishop forming the 450 sq. mile 'volcanic tableland' of the Bishop Tuff that we see today.
- f. The Owens River, flush with glacial waters in the centuries following the eruption, cut the Owens River Gorge through this Bishop Tuff as did lower Rock Creek forming its smaller gorge.

2. Post Caldera Activity 650 K to present

- a. Resurgent Dome 650 K. Not an eruptive event but rather a gradual lifting of the reformed roof immediately above the magma chamber that was by now (100 K years after the caldera eruption) reheating and slowly rising. The resurgent dome is a 5 by 7 mile area of undulating hills that dominates the view to the east and serves as is a template marking the location of the magma chamber still beneath.
With the resurgent dome, the caldera had its three major components in place; a central 'island' (resurgent dome) surrounded by a 'moat' in turn surrounded by the caldera rim. Eruptions continued in a series of relatively small lava domes, beginning in the North Moat.
- b. North Moat Dome 600 K. Lookout Mountain
- c. West Moat Domes 400 to 150 K; Earthquake 400 K, Knowles 360 K, Dry Creek 300 K and Southwest Dome 150 K.
- d. SW Rim Domes 150 to 50 K. Mammoth Mountain finally makes the map with a series of eruptions located not in the moat but up on the SW rim of the caldera. Twelve domes erupted over 100 K years in close proximity forming the rare cumulo-volcano that has become Mammoth Mountain. The tops of most of these 12 domes remain quite apparent, especially those toward the upper half of the mountain which are the later domes within this 100 K year eruption period punctuated by:

- i. Southwest Dome 150 K although also classified with the West Moat Domes, it is considered by many to be the first Mammoth eruption.
 - ii. Lincoln Mtn. 50 K typically considered the last of Mammoth's 12 domes.
- e. Inyo Mono Domes (often called Craters) 40 K to 250 years ago. This chain of domes is generally considered to be still active since the 250 years since the last eruption constitutes but a brief moment in geologic time. From south to north, but not in the chronological order of eruption:
 - i. Deer Mtn is a prominent landmark in the west moat and readily seen from Mammoth Mountain looking to the north. It erupted in conjunction with the two adjacent "Inyo Craters" to its immediate south that are sub-surface and not visible from the mountain
 - ii. S. Deadman Flow
 - iii. N. Deadman Flow
 - iv. Glass Creek Flow 1350. Initial explosion created White Wing by decimating the pine grove there. Radio carbon dating of the preserved tree trunks still present allowed this unusually precise dating of the Glass Creek eruption. In that time the tree line dropped due to climate change, preventing re-growth; thus Whitewing.
 - v. Obsidian Dome. The 'glass pancake'. The lava here is highly viscous preventing widespread flow.
 - vi. Wilson Butte. Also highly viscous lava resulting in its steep walled structure.
 - vii. Mono Craters. 9000'. The youngest mountain range in N. America
 - viii. Panum Crater 500 years ago; most recent of the mono eruption chain.
- f. Mono Lake eruptions
 - ix. Paoha Island. 250 years ago. "White Island". Not eruptive. Actually a small resurgent dome formation
 - x. Negit Island. 250 years ago. "Black Island"
 - xi. Black Point. 10 K. Erupted underwater when Mono Lake (ancient Lake Russell) was 8 times larger due to glacial melt.
- g. South Moat Activity 30 years ago to present
 - xii. 1980 renewed activity moved to the south of the resurgent dome. Three 6.0 earthquakes announced the return of resurgent dome lifting by the magma chamber beneath. In that year it rose 2 ft. -an astounding rate of lift. Since 1980 it has risen an additional 6" and geologists have continued to study its significance.

Once we know the long sequence of activity within the Long Valley Field it becomes easier to interpret the view from Mammoth Mtn. to the East; a scene completely dominated by the Volcano.

THE ROLE OF PLATE TECTONICS IN THE MAMMOTH SIERRA AND BEYOND

In the 1960's the Earth Science theory of plate tectonics became widely accepted. It describes the movement of the plates comprising the earth's crust. This plate movement ultimately results in the creation of both lava volcanoes and granite mountains including the entire Sierra Range and all of the volcanoes seen from Mammoth Mtn...

In locations where the plates converge, the subduction of one plate beneath the other generates molten rock and magma. This new magma can either erupt to the surface as lava (10%) or remain beneath the surface. (90%). Much of this un-erupted, sub-surface magma eventually cools, crystallizing into granite.

In this manner the ancient Farrallon Plate followed by the Pacific Plate subducted beneath the North American Plate. This process both created (200 M to 65 M) and later, lifted (65 M to present) the granite block of the Sierra Nevada Range. The lifting process resulted in part from the 'buckling' of the overlying plate (think of pushing the edge of an area rug with your foot).

Even when lifted to its current height, the Sierra Nevada looked very different than today. It took the sculpting action of the glacier to transform the Sierra into the dramatic high-relief range of sharp peaks and deep valleys we know. That dramatic transformation began with the onset of the Ice Ages 2 M years ago.

THE GLACIER'S IMPACT ON THE MAMMOTH SIERRA

The Ice Ages that transformed the Sierra began 2 M years ago. There have been at least 5 separate ice ages:

McGee Ice Age 2 M
Sherwin Ice Age 1.4 M
Tahoe Ice Age 100 K
Tioga Ice Age 20 K
Little Ice Age 200 years ago

Note that the periods between glaciers have been as long as 1 M years and we may currently be in such an inter-glacial period.

Two of the most prominent glacial landforms of the Sierra Range dominate the view from Mammoth Mtn. To the West, the Ritter Range and Valley and to the immediate south, the Cirque Glacial Lakes Basin of the Mammoth Lakes.

(Note to attendees on 11/20/11:

The following section on the glacial formations seen from Mammoth Mtn was omitted from the presentation due to the audio-visual difficulties.)

The Ritter Range and Valley

John Muir described glacial action as that of a master sculptor who removes the overlying rock to reveal the masterpiece within. Although self-taught, he became the world's leading authority on the glacial activity of the Sierra Nevada and in particular The Yosemite.

When considering legislation to make Yosemite the 2nd National Park, Congress relied upon Muir's border map that included three 'textbook' glacial landforms best illustrating the effects of glacial action:

1. Yosemite Valley. The confluence of the Merced and Tanaya Glaciers
2. Grand Canyon of the Tuolumne Glacier
3. Ritter Range and Valley Glacier

The Ritter Range, the signature image of Mammoth Mtn was one of Muir's favorite. From 1890 to 1905 the Range and its glacial valley including Red's Meadow, Devil's Postpile and the current San Joaquin River valley (middle fork) were an important part of the new National Park with Mt. Ritter its highest peak. Intense pressure from miners interested in the Ritter Range succeeded in moving the border to its present location transferring that honor to Mt. Lyell in 1905 (30 ft. lower than Ritter).

The three glacial horns of the Ritter Range are considered among the finest examples of this dramatic glacial formation in the Sierra. (Banner 12,900, Ritter 13,150, Minarets 12,250). The glacial tarn lakes at the base of these horns (1000 Island, Garnet and Ediza) separated by their glacial arêtes and ending in their very characteristic 'hanging valleys' are all among the finest examples of these glacial landforms in the Sierra Nevada.

Further, the primary glacial valley of the Ritter Range (current route of the San Joaquin River's middle fork) is a prime example of the classic 'U' shape that characteristically results from the glacier's widely carved path. Its heavy 'leaning' as this huge glacier began to negotiate the sharp 90 degree turn from south to west in the vicinity of Red's Meadow is very evident from the west end of Mammoth Mountain.

Cirque Glacier Lakes Basin

Perhaps the finest example of the glacier's impact that is evident from Mammoth Mtn. is the Mammoth Lakes Basin; likely the largest and most finely shaped Cirque glacial landform in the Sierra Range. It is the signature image from the SE end of Mammoth Mtn. The path of this large amphitheater-shaped glacier flowed out of the basin shouldering off a large part of Gold Mountain in the process as it leaned heavily into its turn. It also snipped off the tip of Dragon's Tail in that process.

Gold Mountain (also sometimes called Red Mountain) was the location of the Mammoth Mining Company activity during the late 1870's and the source of the name "Mammoth", later taken up by the town and then the mountain.

The terminal moraine of the lakes Basin Glacier is still very evident in Panorama Dome and most notably the 'Bluffs' above Old Mammoth.

THE ONE PLACE IT HAD TO BE

How did it come to be that a dozen insignificant lava domes –none more than 3000 ft high- of the western Basin and Range become a world-class ski area? (The Mammoth eruptions occurred on top of a base of 8500 ft.) The answer is found in its particularly privileged location at a critical point in the adjacent Sierra Range.

Mammoth Embayment:

The Eastern Sierra border is quite irregular with several scallop-shaped intrusions of the Basin and Range to the West into the domain of the Sierra. The most pronounced of these Eastern Sierra indentations is the Mammoth Embayment with Mammoth Mountain at its western most point; penetrating 26 miles into the Sierra Range. Because of this protrusion to the West, Mammoth Mountain is literally enveloped by the surrounding Sierra. Thus while geologically Mammoth Mountain is a group of Basin and Range volcanic domes, it can be considered geographically within the Sierra.

Mammoth Pass:

The Sierra Range lifted in distinct segments, rising higher with each progressive segment from north to south. Between each uplifted segment is a border or a 'seam' of relatively unlifted terrain. These deep 'divits' in the profile of the Sierra Crest became the mountain passes of today. Mammoth Pass is by far the deepest of these unlifted seams. Where the High Sierra Crest is absent so too is the effect of its rain shadow; a factor profoundly impacting the weather on Mammoth Mountain.

The One Place

The intersection of the Mammoth Embayment with the Mammoth Pass -this single point at the eastern edge of the Sierra Range- was given to the Mammoth Mountain volcanic eruptions. Without a Sierra rain shadow Mammoth Mountain has a unique unobstructed weather channel carrying water-laden storms directly to its slopes. We see direct evidence of this weather channel in the form of:

1. Largest Jeffrey Pines stand on earth at the east end of Mammoth Pass
2. Snow load far in excess of the surrounding terrain.
3. High wind exposure. This is typically a concern for the uninitiated until they learn of the benefits of 'nature's groomer' and on the right days, the amazing wind-buff snow on those slopes tangential to the wind (3, 5, 25, avi chutes)

The Powerful Play Goes On...

As we return to the mountain this year, we encounter all of the same familiar landmarks but hopefully we'll see them differently now that we understand their story. We can now appreciate how each had its given role -its moment on center stage- in Nature's Most Powerful Play. That Play returns along with us for yet another season in its long march through the ages.

NOTE

There are a few notable volcanic eruptions excluded from this account because there is no consensus on how best to classify them;

- Devil's Postpile: erupted 100 K years ago near the west flank of Mammoth Mountain. The eruption coincided with the Mammoth eruptions (150 K to 50 K years ago) but it may have been a separate event.
- Red Cones: erupted 10 K years ago coinciding with the Inyo-Mono chain. Although located further to the south, the Red Cones may be part of that chain
- Mammoth Mountain fumarole: exploded 1000 years ago. Largely thought to be an isolated event or perhaps part of the Inyo-Mono chain. The recent onset of the CO₂ tree kill activity on both the east and west flank of the mountain has