A Geologic Investigation of Death Valley California

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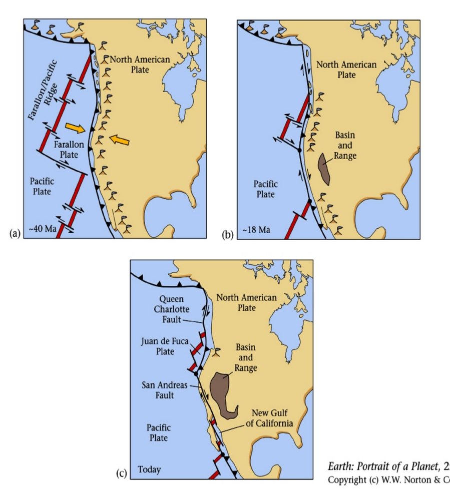
Abstract

Death Valley California has a rich geologic history and a landscape shaped by diverse tectonic and volcanic activities. Modern-day Death Valley is the product of extensional tectonism, rhyolitic volcanism, and basin development during Miocene basin and range extension. Fault scarps, turtleback faults, alluvial fans, eolian processes, and weathering can be observed in an environment which lacks vegetation making this an ideal locale to study geologic relationships. The most recent Miocene extensional basin and range tectonics have produced a series of normal faults which shaped the horst and graben features observed on the floor of Death Valley.

Extensive Miocene volcanism produced widespread pyroclastic sheets which dominate most of Death Valley. To gain insight on magmatic partitioning a detailed Geochemical investigation was conducted on a compound cooling unit of the Miocene (ca 9 ma) Resting Springs Tuff, east of Shoshone, California. The sequence included a basal vitrophyre, slightly welded rhyolitic tuff, strongly welded rhyolitic tuff, rhyolitic tuff, and welded rhyolitic tuff. Major and trace element geochemical stratigraphy analyses were conducted using X-ray fluorescence to assess elemental partitioning during pyroclastic transport.

Basin and Range Tectonics



The Basin and Range Province covers most of the western margin of the United States and part of Mexico and stretches from Oregon to Northwestern Mexico. It consists of hundreds of mountain ranges interspersed with basins. The province extends laterally in a roughly north-south direction, and contains valley floors whicl tend to tilt slightly eastward.

This area is the product of the extension of the western portion of the United States for approximately the past 20 million years, which is represented by normal faults. Extension initiated when the spreading center driving the movement of the Farallon Plate was subducted beneath the western margin of the North American pla Subduction of the spreading center turned the western edge of California from a subduction zone into a transform boundary. There are strike-slip faults on both side of the Basin and Range Province; it is the movement of these two faults that is causing the extension in between.

Death Valley is an extreme example of the Basin and Range Province with an altitude ranging from 282 feet below sea level to 11,049 ft. above. Generally, the basins fill almost as quickly as the ranges rise. Death Valley is as deep as it is because there is less precipitation resulting in less erosion which means that the valley has not been filled in with as much sediment as other similar valleys in the region. Rain shadows, cast by the mountains between Death Valley and the Pacific Ocean, are the reason that Death Valley is so dry.

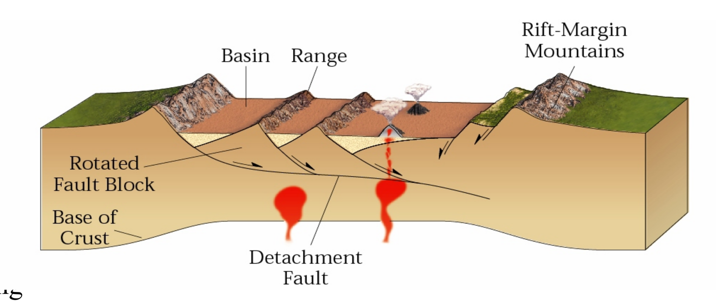
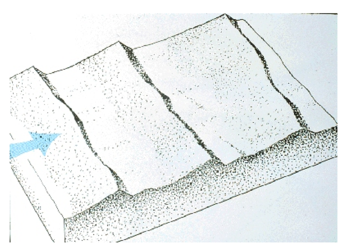
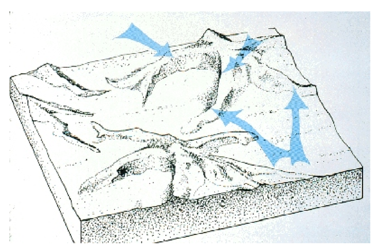


Figure above shows development of basin and range provenance which is prevalent in Death Valley

Sand Dunes and Aeolian Processes



Tranverse Dunes
blue arrow indicates wind direction



Star Dunes blue arrow indicates wind direction

Sand Dunes are formed in arid environments as the result of aeolian sedimentary processes. The main method of transport for particles that compose sand dunes is saltation. Saltation is the process where grains of sand hop or bounce along the ground. Fine grained sand can begin to saltate at winds speeds of 4.5 m/sec.

Different types of sand dunes form based on varying wind regime is present. In Death Valley we observed two different types of sand dunes. Transverse dunes (figure far left) from where there is a single predominant wind direction. Transverse dunes have ridges parallel to one another that are perpendicular to the wind direction, which migrate over time.

If the direction of wind is variable then a star dune may form (figure left). Star dunes resemble a mountain with spurs extending from on or more peaks. There is a single large star dune present in Death Valley. Star dunes do not migrate but instead build upward often causing them to be much taller than transverse dunes.

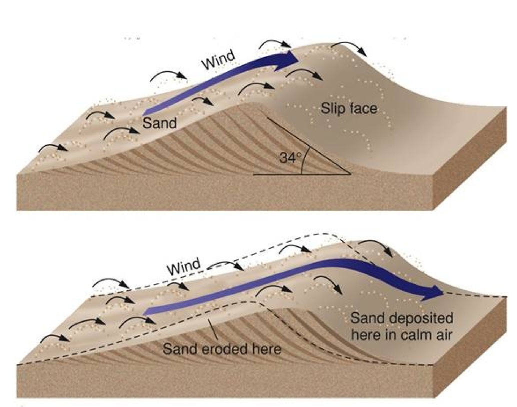
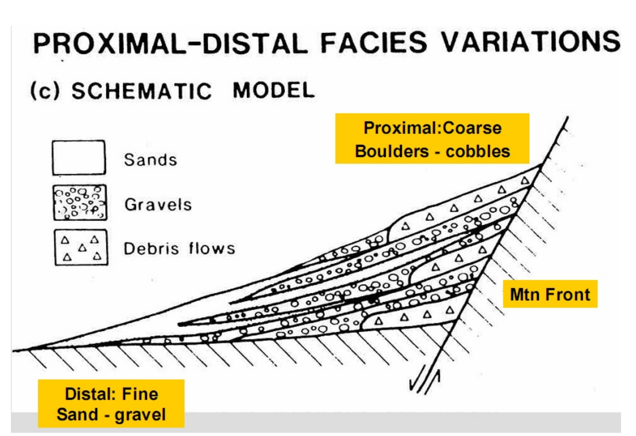


Figure showing saltation process

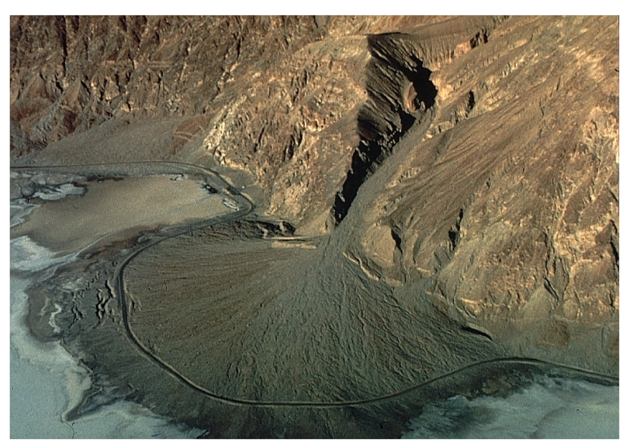
Alluvial Fans



Schematic cross section of alluvial fan sediments from proximal to distal

Alluvial fans are depositional features which are associated with specific tectonic settings including areas which contain fault scarps or normal faulting. They are created when a confined, high velocity water flow carries sediments down a high relief slope which are deposited into a flat basin. Primary erosion takes place high in the mountains where a combination mechanical and chemical weathering breaks down rocks. Rainfall transports these sediments down gradient, gaining velocity and picking up sediments along the way.

When the sediments in transport get to the apex, they transition between suspension and deposition. Sediments entering the basin are deposited as water spreads out and the system loses energy. Coarser sediments are deposited first in the proximal fan and smaller sediments are later deposited in the distal fan. Most fans consist of an incised-channel flow; when a stream exits the apex in cuts down and creates what is called a modern channel which is 1-4m high. This channel then breaks off into many smaller channels. The modern channel will systematically move back and forth across the fan.



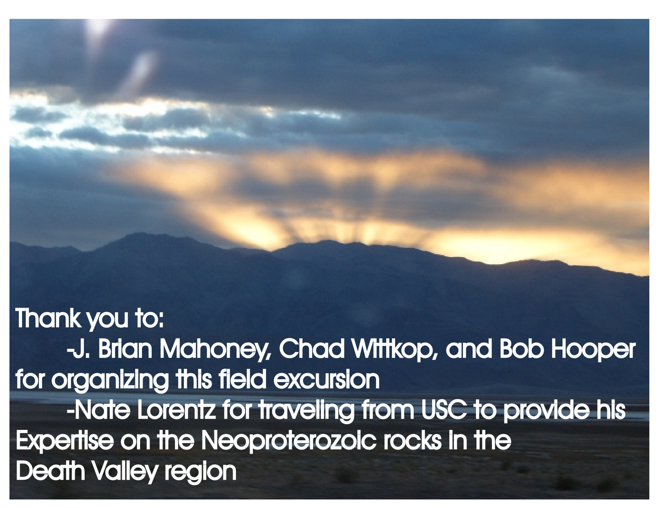
Picture of alluvial fan showing incised flow

Geology 343

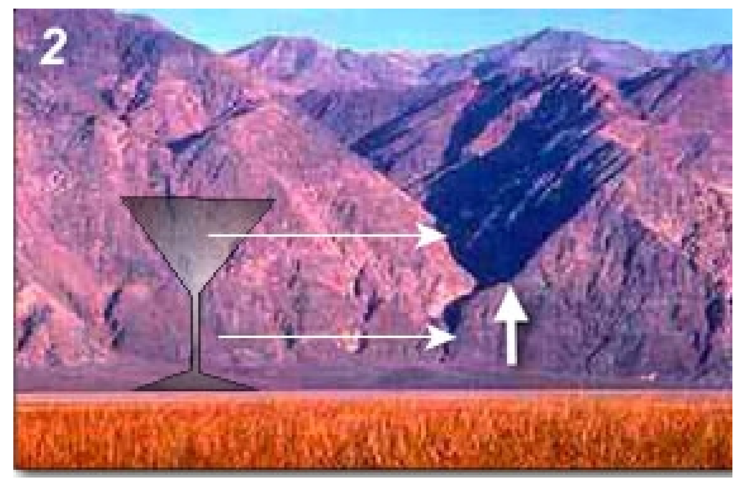
Geology 343 was an extended field excursion course that traveled to Death Valley, CA in March of 2007, to study the Basin and Range Provence of the western margin of the U.S. The purpose of this course was to discover and observe in detail the various geological processes responsible for the formation of the basin and range complex.

To prepare for the field study, the class researched various topics pertinent to the Death Valley region including: geology, biology, ecology, and culture .

Scientific study of Death Valley focused on:
-Bedrock deformation by means of metamorphism, volcanism, sedimentary deposits, faulting, and fluvial processes.
-Observation of modern processes including saltation and sand transport within dune systems, and geomorphology in the form of alluvial fans, wineglass canyons, fault scarps, and faceted spurs

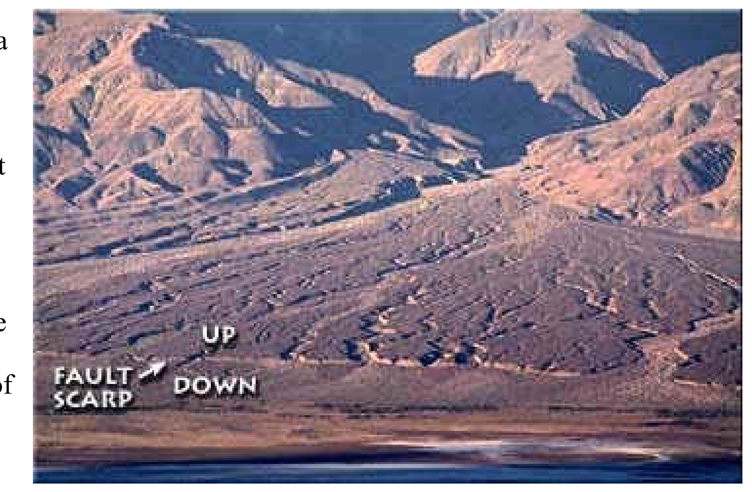


Wineglass Canyons



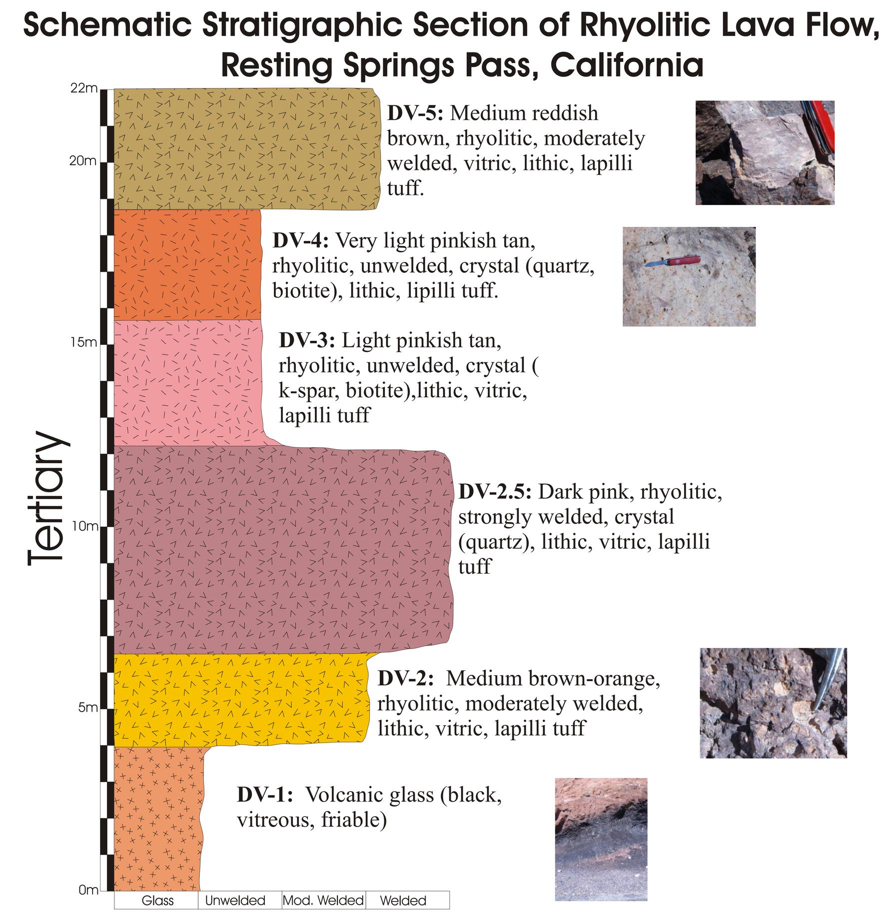
A wineglass canyon in Death Valley.

Death Valley is an excellent place to observe active tectonic geomorphology due to the lack of vegetation in a desert environment. One feature, the fault scarp, is created when a fault reaches the Earth's surface. When this happens, a visible "cliff" can be created that may be as tall as a few meters (right figure). Another feature that is associated with active tectonism, and which is prevalent in Death Valley are wineglass canyons. Wineglass canyons are formed when a river valley coming off of a mountain is suddenly pushed up above the main valley floor by faulting. When this happens, the river that was eroding the valley erodes quickly downward creating a very narrow canyon at the bottom of the valley. At the same time, an alluvial fan forms at the mouth of the canyon. From the front, this feature looks like a wineglass with the original valley resembling the bowl, the narrow-freshly cut-valley resembling the stem, and the alluvial fan resembling the base (Figure to the left).



A view of a fault scarp in Death Valley. The up and down-thrown side of the fault is labled

Investigating a Compound Cooling Unit



Abundant continental volcanism is associated with the Tertiary Basin and Range extension in the western U.S. Tuff - a volcanic rock formed from pyroclastic ash and debris eruptions is common throughout the region. We examined a tuff exhibiting a compound cooling structures just outside of Death Valley National Park at Resting Spring Pass, near Shoshone, California.

A compound cooling unit is a tuff derived from pyroclastic flows that underwent different rates of cooling. Welding (the sintering of hot ash fragments) and vapor-phase crystallization (reactions between hot volcanic gasses and ash) are two possible mechanisms responsible for the varying textures observed. The amount of welding is dependent on the thickness of overlying pyroclastic deposits and the temperature and composition of the fragments (Cas and Wright, 1987).

The succession of rocks that we observed near Death Valley displayed some of the characteristics of a compound cooling unit. We observed six separate rock layers with similar compositions that are differentiated by degree of welding. The lower most layer appears markedly different than the surrounding rocks because of its black color and glassy matrix; characteristics of a vitrophyre. The most strongly welded layer was the third from the bottom bordered on top by two unwelded layers and bounded on the bottom by a moderately welded layer. Due to the heterogeneity of the degree of welding it is not certain whether this succession of rocks is the result of a single flow or a succession of flows.

Geochemical analysis was performed on a sample from each of the rock units and can be seen below. The high content of SiO_2 and Na_2O confirms our field observations that these rocks are rhyolites. All of the layers are chemically homogeneous which could either be the result of them being deposited by the same flow or by successive flow from a single magmatic source.

Reference Cited

Cas, R.A.F., and Wright, J.V., 1987. Volcanic Successions Modern and Ancient. Allen and Unwin, London, 528 p.