DEATH VALLEY THROUGH TIME

The Precambrian — 1.8 billion years to 570 million years ago

Middle Precambrian time

The Earth is 4.55 billion years old, but most rocks dating from the earlier half of that long history lie hidden beneath thick accumulations of younger rocks. In the Death Valley region the crust has been stretched, torn, and has collapsed into a system of enormous basins. Faults along the mountain range fronts have lifted deeply buried rocks up to the surface, revealing Death Valley's ancient basement rocks. The oldest rocks exposed in Death Valley are about 1.8 billion years, almost half the age of the Earth. These venerable rocks are the remnants of an ancient volcanic mountain belt with its flanking deposits of mud and sand.

At about 1.8-1.7 billion years ago, these volcanic and sedimentary rocks were severely metamorphosed--altered, recrystallized, and partially remelted by the Earth's internal heat and by the load of overlying younger rocks. The original rocks were transformed to contorted schist and gneiss, making their original parentage almost unrecognizable. At about 1.4 billion years ago, the metamorphic complex was injected with dikes and larger blobs of granitic magma.

Late Precambrian — Sediments blanket Death Valley's metamorphic basement

After 1.4 billion years ago, the metamorphosed Precambrian basement rocks had begun to be uplifted. Huge volumes of rocky metamorphic debris must have been eroded and redeposited, but no one knows where. By about 1.3 billion years ago, sediment began to accumulate on Death Valley's metamorphosed basement rock. At first, muddy debris (now conglomerate) was deposited on land. A shallow sea then washed over these terrestrial deposits, covering the region with thick layers of limestone and dolomite. Algal mats spread across the sea bottom, forming lumpy structures called stromatolites. The Death Valley region once again rose above sea level and terrestrial deposition resumed, then sank beneath the seas again. The deposits left behind by this alternating sequence of shallow marine, then terrestrial deposition make up the "Pahrump Group" of sandstones, carbonates, and conglomerates.

Glaciers in the Tropics?

The Kingston Peak Formation (prominent near Wildrose, Harrisburg Flats, and Butte Valley) contains thick conglomerate beds of pebbles and boulders in a sandy-muddy matrix (figs. 46 and 47). Above and below it are dolomite formations with algal and current features common in warm shallow waters and tidal flats. (Dolomite is forming today on arid mudflats fringing the Persian Gulf.) But boulders rarely move on flat surfaces, and unsorted mixtures of boulders with mud and sand reflect rapid downslope transport, a far cry from the winnowing of large and small particles accomplished by waves and currents on tidal flats. We thus have a contradiction and another enigma.

A few solutions come to mind, but none is wholly satisfactory. (1) Erosion of nearby uplifts might temporarily have permitted alluvial fans to spread offshore onto the dolomite platform. (2) During opening of the rift which was to become the Pacific Ocean, the offshore area profoundly deepened, promoting great submarine landslides. (3) Glaciers (or shelf-ice such as fringes the Antarctic today) might have moved the bouldery Kingston Peak debris onto the marine shelf.

Each mechanism can explain the conglomerates, but there is no agreement on which was dominant. Conceivably, all three might have coincided, but our picture of that remote time remains clouded.

Scratched boulders in the Kingston Peak Formation do, however, resemble striated stones in modern glaciers. And occasional isolated boulders found in beds of mudstone or limestone on Tucki Mountain are reminiscent of dropstones from melting icebergs, settling onto muddy bottoms far from shore. Only three periods of glacial advance from polar regions are well-documented: (1) the Quaternary Ice age of the past one-million years; (2) a late Paleozoic Ice-age, 250 million years ago; and (3) a late Precambrian Ice-age, known on most continents and roughly contemporaneous with the Kingston Peak Formation! If the Death Valley area truly had Precambrian glaciers, how then do we explain the warm- climate dolomites adjacent to the glacial deposits? One very speculative hypothesis makes an interesting story: By late Precambrian time, the atmosphere's ozone layer had for the first time become an adequate screen against ultraviolet radiation, permitting invasion of shallow open waters by marine organisms. An enormously expanded population of photosynthesizing marine plants might then have fixed so much carbonate in shallow-water dolomites to have reduced significantly the C02 in the atmosphere. Since atmospheric C02 is known to create a "greenhouse effect" promoting warmer climates, its abrupt loss could conversely have introduced a glacial epoch. A 7% drop in atmospheric C02 today would cool world climate by 40C. (70F.). Perhaps the dolomite-to-conglomerate sequence in late- Precambrian rocks all over the world is not a coincidence but represents an Ice-age triggered by one of the greatest advances in the history of life.

The Paleozoic — 570-250 million years ago: Death Valley at the equator

Latest Precambrian and Early Cambrian time — The Earliest Animals

The dullness of that late Precambrian mudflat, however, was deceiving, for during those quiet times the first animals were developing in the oxygen- rich shelter of marine plant communities. Bacterial and algal plant-life had already prospered for nearly three billion years, and with the appearance of cell nuclei (certainly by Pahrump times) the stage was set for more complex life forms. On Death Valley's tidal flats, algae with its filaments and slime had long been binding mud into wavy laminated mats (stromatolites) which may have provided havens for the newcomers. The very earliest animals are exceedingly rare, occurring well west of Death Valley in limy offshore muds contemporary to the Stirling Quartzite. The developmental pace increased in Wood Canyon times, for this sandy formation preserves a host of worm tubes and enigmatic trails. Ultimately, in late Wood Canyon sediments the first animals with durable shells emerge to open the earliest copiously fossiliferous period, the Cambrian. The base of the Cambrian marks a great leap forward for the animal kingdom, but doubt lingers whether the evolutionary burst represented a major expansion of animal species themselves or simply the origin of readily-fossilized protective shells.

In either case, what environmental change might have prompted the animal revolution? The late Precambrian ice-age? The melting of its glaciers with consequent flooding of continental margins? Attainment of an oxygen level in the atmosphere finally sufficient for animal respiration? The last idea reasons that adequate oxygen (about 1% of the modern amount) liberated the primitive naked animals from dependence on their host plants, permitting abrupt wholesale invasion of well-aerated shallow surface waters and tidal flats. In view of the thin air of the time, hard shells may then have been a shallow-water protection against ultraviolet radiation. Or were they simply a response to predation, this planet's first evidence of aggression? In Death Valley, the animal revolution is marked in the upper Wood Canyon Formation by appearance of trilobites, archaeocyathids, and primitive echinoderms. Many lineages arose at the time, but the world was truly won by trilobites, the now-extinct inch-long mud-grovellers (a bit like horseshoe crabs), who ruled the Earth for 100 times the period of man's recent dominance.

Middle Cambrian to Permian time

The sandy mudflats gave way about 550 million years ago to a carbonate platform which lasted for the next 300 million years of Paleozoic time. Erosion had so subdued nearby parts of the continent that rivers ran clear, no longer supplying abundant sand and silt to the continental shelf. Since, in addition, Death Valley's position was then within ten or twenty degrees of the Paleozoic equator, the combination of a warm sunlit climate and clear mud-free waters promoted prolific organic carbonate production. Just as in the bays, lagoons, banks, and channels of the Bahamas and Florida today, the skeletal disintegration of countless generations of flourishing corals, shellfish, and algae created a wealth of lime mud and sand. When buried by yet more sediment, this consolidated into the limestone and dolomite formations, more than two miles thick, which today comprise Death Valley's craggiest terrain. Such rocks are especially prominent in the Grapevine and Cottonwood Mountains, along the rugged northeast wall of Furnace Creek Wash, and on the lower slopes of the Panamint Range from Death Valley Canyon to Tucki Mountain. Thickest of these units is the dolomitic Bonanza King Formation which forms the dark-and- Iight-banded lower slopes of Pyramid Peak and the gorges of Titus and Grotto Canyons.

Although details of geography varied during this immense interval of time, a northnortheasterly trending coastline generally ran from Arizona up through Utah. A marine carbonate platform only tens of feet deep but more than 100 miles wide stretched westward to a fringing rim of offshore reefs. (One such reef is still identifiable in rocks of Ordovician age twenty miles east of Death Valley on Meiklejohn Peak above the town of Beatty.) Down gentle slopes to the west of such rims of reefs, limy mud and sand eroded by storm waves from the reefs and platform collected on the quieter ocean floor at depths of 100 feet or so. Death Valley's carbonates appear to represent all three environments (down-slope basin, reef, and back-reef platform) owing to fluctuating geographic position of the reef-line itself. The extent and stability of this great shallow carbonate-rich sea are not matched in today's restless world. Caribbean analogs are tiny by comparison. The low-lying Paleozoic continent had far less freeboard than does rugged North America today, so inland encroachment of shallow shelf-seas was much more extensive.

The carbonate uniformity was seriously interrupted only twice. (1) About 450 million years ago, an immense sheet of pure quartz sand swept across the platform to produce the 400-foot thick Eureka Quartzite. This great white band of Ordovician rock stands out on the summit of Pyramid Peak, widely near the Racetrack, and high on the east shoulder of Tucki Mountain. No American source is known for the Eureka sand, which once blanketed a 150,000 square-mile belt from California to Alberta. It may have been swept southward by longshore currents from an eroding sandstone terrain in Canada, but the origin of both the Eureka and contemporaneous sands blanketing much of the Midwest remains shrouded in mystery. (2) Between 350 and 250 million years ago sporadic pulses of mud swept southward into the Death Valley region during the erosion of highlands in north-central Nevada. These occasional brief interruptions of carbonate formation were warnings of momentous events, thrust-faulting and mountain-building, already in progress well to the north and eventually to overwhelm the Death Valley area as well. For the brachiopods, ostracods, corals, and clams the days were numbered. The billion- year-old marine shelf was soon to dry up, the coastline to shift far to the west.

The Mesozoic — 250-65 million years ago: Uplift and Erosion

The Earth Shook, the Sea Withdrew

During Late Paleozoic and Mesozoic time (225 - 65 million years ago), the Death Valley landscape changed dramatically. To the west, the collision of tectonic plates changed the quiet, sea-covered continental margin into a zone erupting volcanoes, uplifting mountains, and intense compression. A deep trench formed when the oceanic Pacific plate began to sink (subduct) beneath the more buoyant continental rock of the North America plate. A chain of volcanoes rose through the continental crust parallel to the deep trench. Thousands of feet of lavas erupted, pushing the ocean over 200 miles to the west. The Death Valley region was no longer coastal real estate, as it had been for the previous billion years.

Most of the volcanic activity was centered just to the west of Death Valley, although some of the oldest Mesozoic rocks are exposed in the southern Panamint Range. The deep magma chambers feeding the volcanoes eventually cooled and solidified, forming the granites widely exposed in the Sierra Nevada Mountains. A few of these granitic bodies intruded the Panamint and Cottonwood Mountains, but these rocks are not easily accessible. One of these relatively small granitic plutons emplaced 67-87 million years ago, right near the end of the Mesozoic Era, spawned one of the more profitable precious metal deposits in Death Valley, giving rise to the town and mines of Skidoo (although these gold deposits were quite small compared to the larger California goldfields west of the Sierra Nevada Mountains).

Death Valley itself was a broad, mountainous region during this time. Mountains are mostly sites of erosion, not deposition, and the sediments worn off the Death Valley region were shed both east and west carried by wind and water; the eastern sediments which ended up in Colorado are now famous for their dinosaur fossils.

Thrust-faults

During this continental collision and volcanism, Death Valley's older rocks were squeezed and cooked, adding another episode of metamorphism to their already complex history. Some thick layers of rock (miles thick!) were also shoved many miles eastward along thrust faults, and in some cases, older rocks were thrown up over younger rocks, just to confuse future geologists!

The Cenozoic — 65 million to 10,000 years ago: Quiet to chaos

After 150 million years of volcanism, plutonism, metamorphism, and thrust-faulting had run their course, the early part of the Cenozoic Era (early Tertiary, 65-30 million years ago) was a time of repose. Neither igneous nor sedimentary rocks of this age are known here. No great events were recorded here, simply the weathering away of the region to a rolling landscape of low relief. Beginning in Miocene time, the geologic tranquility was shattered. Volcanism and faulting started up again, but this time caused by extension in the crust rather than compression.

The birth of the Death Valley landscape familiar to us today was beginning. Usually younger geologic events are easier for the geologists to interpret, however here in Death Valley, the faulting and movements of rocks and indeed entire mountain ranges has been so extensive that scores of geologists are still marching up and down canyons, mapping rocks layers, testing theories, forming new ones, and enthusiastically debating these theories among themselves. In this section, as you will read about this very active chapter in Death Valley's history, do not forget that the same tectonic forces are going on today, and Death Valley will continue to evolve into the future.

<u>Forces driving mountain building in Death Valley</u>
Big mountain building projects require big forces, and that usually means plate tectonics. In early Tertiary time, the North American plate was riding up over the Pacific plate, however, starting about 30 million years ago, plate motions changed and the two plates began sliding past each other. For reasons still not fully understood, this change in plate motion began stretching the continental crust between the Sierra Nevada Mountains on the west and the Colorado Plateau on the east. In this region, known as the Basin and Range province, mountain blocks were uplifted and valleys formed as the floors between ranges dropped along normal faults. The big action started in the Death Valley region about 14 million years ago. Be prepared - we're talking big changes! In response to the shifting tectonic plates, strike-slip faults developed in Death Valley. Between two strike slip faults, tension gashes opened up, forming the modern basins of Death Valley. The rocks that would become the Panamint Range were stacked on top of the rocks that would become the Black Mountains. If that's not crazy enough, the Cottonwood Mountains, now north of the Panamints, were also piggy-backed on top of the entire stack!

In the next several million years, The Black Mountains began to rise, and the Panamint/Cottonwood Mountains slid westward off the Black Mountains along low-angle normal faults. Imagine a tall stack of magazines tilting and sliding sideways, except our geological magazines are several miles thick and 50 miles wide! Starting about 6 million years ago, the Cottonwood Mountains slid northwest off the top of the Panamint Range. And there's some evidence that the Grapevine Mountains may have slid off the Funeral Mountains! Some geologists aren't satisfied that we have enough evidence to believe that the mountains were stacked on top of each other, but were rather stacked adjacent to each other. Major research efforts are still underway in Death Valley. In either case, as these mountains slid apart, the valley floors dropped and began receiving sediments washed off the newly formed mountains. During this entire time, volcanic eruptions spewed basalt flows and blanketed the area with volcanic ash, mixing with eroded sediments and forming spectacular rock layers such as the Funeral Formation and Furnace Creek Formation visible from Zabriskie Point and Golden Canyon.

Geologists may disagree on the details of how far these mountains moved, but a reasonable estimate is that they've moved 95 to 130 km (60-80 mi) to the northwest. That's quite a distance to be moving entire mountain ranges! The mountains are still moving too - regional estimates suggest the mountains are moving on average about a half inch per year (although no motion has occurred in the last few decades). Thus while the rocks of Death valley's mountains may be millions or billions of years old, the mountain topography is very young, and still growing. While these mountain blocks were shifting about, the floor of Death Valley was also dropping. Nature doesn't like deep holes surrounded by mountains, so naturally the hole began to get filled up. There is something like eight thousand of feet of gravel, sand, and mud overlying the bedrock of the valley floor. The fact that the valley floor is still below sea level tells us that it is still dropping, even as it receives more sediments.

Recent Geologic Changes

By about 2 million years ago, Pleistocene time in Death Valley, the major topographic features of Death Valley had formed. However, there were still big changes ahead. Earth's climate began to oscillate between warm conditions (like today's climate) and colder conditions (ice ages). During these colder conditions, continental ice sheets expanded from the polar regions of the globe to lower latitudes, and the nearby Sierra Nevada Mountains sported alpine glaciers. There were no glaciers in Death Valley, but with the cooler and wetter climate, rivers flowed into the valley year round. Since the valleys in the Basin and Range region formed by faulting, not by river erosion, many of the basins have no outlets, meaning they will fill up with water like a bathtub until they overflow into the next valley. During the cooler and wetter climates, much of eastern California, all of Nevada, and western Utah was covered by large lakes. Death Valley was the last of chain of lakes fed by the Amargosa and Mojave Rivers, and possibly also the Owens River.