Contents

Maps and Tables

MAPS

TABLES

The Explorer's Guide to
Death Valley National Park

Figure 0.1. *"Greetings from Death Valley!" Courtesy Frasher Foto Postcard Collection, Pomona Public Library.*

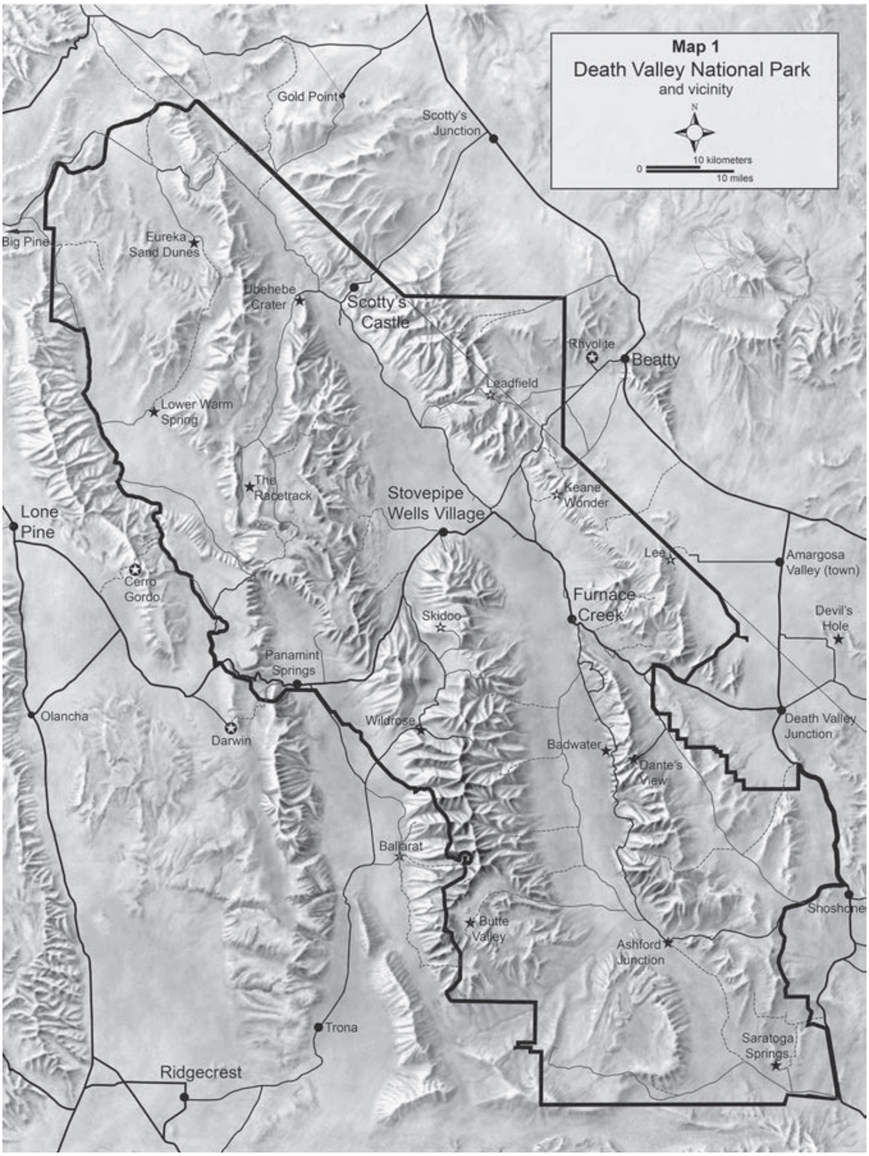
Introduction

DEATH VALLEY NATIONAL PARK AND VICINITY

In 1957, famous naturalist Dr. Edmund C. Jaeger wrote: “The complete natural history of Death Valley will never be written. . . . [It] is a subject too vast.” That might well be true, for Death Valley National Park encompasses an immense area that is unique in its diversity.

- The park is nearly 150 miles long from north to south, about 60 miles wide from east to west, and covers 3,422,024 acres (or 5,347 square miles). In addition, considerable portions of the adjacent mountains and valleys are culturally and biologically part of Death Valley.
- The park’s elevations range from desiccated salt flats 282 feet below sea level near Badwater, where the average rainfall is less than 2 inches per year, to pine-clad peaks higher than 11,000 feet above sea level in the Panamint Range, where heavy snow falls in the winter.
- Death Valley’s life zones follow the changes in elevation, ranging from the Lower Sonoran life zone, through the Upper Sonoran and Transition life zones, to the Canadian life zone; the very highest peaks qualify for the Arctic (or Boreal) life zone.
- Summer temperatures on the valley floor routinely reach over 120°F (50°C), and there is nothing unusual about winter days colder than 0°F (–18°C) in the higher mountains.
- More than 1,000 species of plants, at least 14 of which are Class I endemics found nowhere else, inhabit the park along with at least 440 species of animals.
- Death Valley includes hundreds of archaeological sites, most of which have never been fully documented but some of which may be more than 9,000 years old.
- The park’s geology encompasses everything from recrystallized metamorphic rocks at least 1.8 billion years old to salt crystals that grow larger as you watch them.
- Mining for precious metals, borax, and talc led directly to Death Valley’s discovery, fame, tourist industry, and the creation of the national park itself.
- The park contains 260 miles of paved highways and over 1,000 miles of dirt roads, everything from major state highways to four-wheel-drive routes of poor quality.

Obviously, it takes time and effort to fully experience the variety that Death Valley has to offer. This book provides information for all of Death Valley’s visitors,



Map 1. *Death Valley National Park*

from first-time travelers just learning about the area to those who are able to return for in-depth explorations.

> "If you go there," the old prospector had said, "you will see something you won't see anywhere else on earth."
>
> EDNA BRUSH PERKINS, *THE WHITE HEART OF THE MOJAVE*, 1922

FORMAT OF THIS BOOK

This book is divided into five sections.

PART I (Chapters 1 through 6) discusses the geology, human history, plantlife, and wildlife of the park.

PART II (Chapter 7) deals with the desert environment—Death Valley's climate and, with that, the precautions that explorers should take before venturing into the park. This includes the National Park Service regulations that all park visitors should keep in mind.

PART III (Chapters 8 and 9) provides ideas for day hiking, backpacking, and bicycling in Death Valley.

PART IV (Chapters 10 through 21) first introduces and then describes the entire park in eleven sections of detailed mile-by-mile road logs that cover every road within and several roads outside the national park boundary.

PART V (Appendices A, B, and C) provides historical information about Death Valley's ghost towns and railroads, and the modern interpretive services, lodging and camping facilities, and special events. There is also a suggested reading list for sources of further information.

LAND CLASSIFICATION

NATIONAL PARK SERVICE. Most of the land described in this book lies within Death Valley National Park, which is a unit of the National Park Service (NPS) of the U.S. Department of the Interior. Land-use regulations within the park are more stringent than they are on most of the public lands outside the park boundary. Especially worth noting is that most of the national park is wilderness, and the wilderness boundary is just 50 feet from the centerline of nearly all backcountry dirt roads. No collecting of any kind—plant, animal, fossil, mineral, or archaeological artifact—is allowed within the national park. The headquarters for the park is adjacent to the Furnace Creek Visitor Center.

BUREAU OF LAND MANAGEMENT. Much of the land immediately surrounding Death Valley National Park is administered by the Bureau of Land Management (BLM), which is an agency of the Department of the Interior. Land-use regulations here are generally less stringent than those of the NPS, but much of this land is wilderness where off-road travel is not allowed. The collecting of mineral specimens for personal, noncommercial use is permitted in most areas. Detailed regulations are available at the offices of the BLM Desert District in the town of Ridgecrest, California. Also, the Eastern Sierra Visitor Center, at the intersection of highways 395 and 136 just south of Lone Pine, California, has BLM as well as Forest Service, National Park Service, and regional county information along with interpretive displays and a native plant garden.

U.S. FOREST SERVICE. Relatively small areas bounding the northwestern part of the national park lie within Inyo National Forest, a unit of the U.S. Forest Service

(USFS), an agency of the U.S. Department of Agriculture. Again, land-use regulations here are somewhat less stringent than they are within the national park, but they are also significantly different from those that apply to the BLM areas. The national forest's offices in Bishop and Lone Pine as well as the Eastern Sierra Visitor Center, 2 miles south of Lone Pine, have detailed information and use regulations.

U.S. FISH & WILDLIFE SERVICE. Several miles east of Death Valley National Park is the Ash Meadows National Wildlife Refuge, operated by the U.S. Fish & Wildlife Service (FWS), an agency of the U.S. Department of the Interior, where all plants and animals are strictly protected. The refuge has a visitor center and several interpretive boardwalks. Devils Hole, a detached unit of the national park, lies within the Ash Meadows NWR.

INDIAN RESERVATION. The Timbisha Shoshone Indian Village at Furnace Creek and Indian Ranch in Panamint Valley are private areas. With the exception of the small Timbisha Tacos café near the entrance to the village, these places are closed to entry except by invitation or on an occasion when the Indians are holding an advertised public event.

MILITARY GROUND. The land bordering the extreme southwestern part of Death Valley National Park is within the Mojave Range B of the Naval Air Weapons Station China Lake, and the land immediately south of the park's southern boundary lies within the U.S. Army Ft. Irwin National Training Center. These areas are fenced and well marked, and entry into them is strictly forbidden.

PRIVATE PROPERTY. There is very little private property within Death Valley National Park. Most of these places are patented mining and related millsite claims that date to the late 1800s and early 1900s, before the establishment of the original national monument. A few other private inholdings remain, mostly unoccupied and undeveloped and scattered in those areas that were added to the park by the 1994 expansion. Some may be posted against trespass. In addition, the grounds of The Inn and The Ranch at Death Valley (i.e., The Oasis at Death Valley resort facilities) and those of the Panamint Springs Resort are private properties.

ROAD CLASSIFICATIONS

Death Valley's roads fall into four use categories.

PAVED ROUTES. Paved all-weather roads accessible to any vehicle. Some of these roads are narrow and may have broken asphalt and unmarked sharp curves.

HIGH-CLEARANCE ROUTES. Dirt roads on which vehicles with high clearance are recommended. Although some of these roads are graded on occasion and then can be driven with caution in any vehicle, they are subject to washouts and also may be extremely rough, making high-clearance vehicles desirable if not outright necessary.

FOUR-WHEEL-DRIVE (4WD) ROUTES. Unimproved dirt roads on which full 4WD, high-clearance vehicles may be required. Television commercials and other promotions notwithstanding, all-wheel-drive automobiles are not true 4WD, and they are not recommended for these routes. These roads typically have areas of loose sand or gravel, high centers, sharp pitches, steep grades, and so on (often in combination).

SEVERE OR QUESTIONABLE ROUTES. Roads that are extremely rough and narrow and in such poor condition that driving them is not recommended except by experienced drivers accompanied by others.

As of mid-2020, all of the roads described here are open to use. This could change, however. Explorers are always encouraged to check with the Park Service for any updates about a road's status and condition as well as about any changes in backcountry use regulations.

MAPS

All of the maps used in this book have been produced from public-domain base maps available online from the National Park Service, Harpers Ferry Center (www.nps.gov/hfc/carto/index). The shaded-relief background was a jpeg file obtained from the same site. For this book, the originals were downloaded as large-format Adobe Illustrator files that were cut into smaller areas as appropriate. Symbols to indicate points of interest and road classifications were superimposed onto the base maps. All of these maps were produced at full, original scale but then were variously resized to fit this publication. The distance scales therefore vary from one map to another, but all show accurate layouts.

ROAD LOG MILEAGES AND GPS LOCATIONS

MILEAGES. Each route that is described in Part IV of this book has viewpoints, specific places of interest, and road turnoffs referenced according to car odometer readings. These must be taken as approximate only because trip odometer readings often vary from one trip to another, even when driven in the same vehicle; this is especially true on rough dirt roads. Also, most odometers only record the distance every one-tenth mile so that one "click" to the next represents more than 500 feet.

GLOBAL POSITIONING SYSTEM (GPS) COORDINATES. Especially in Death Valley's backcountry but also from time to time along the main roads, there are road intersections or points of interest that are unmarked and difficult to find. These places are noted by their geographic locations using coordinates that are easily checked using many handheld or vehicle GPS units. In this book, latitude-longitude coordinates are used because that is the system employed by Death Valley National Park in its park maintenance database (which was used to double-check coordinates determined in the field or from topographic maps). All GPS coordinates in this book are considered accurate to within 50 feet. **Special note**: Please do not try to use a GPS unit as a route-finding tool within Death Valley. Those results are often inaccurate, sometimes indicating roads that do not exist, real cases of which have led people into life-threatening situations.

Part I
Geological, Human, and Natural History

1
Geologic History

THE SETTING

Death Valley National Park has an extraordinarily long and complex geologic history. Its most ancient rocks are more than 1.8 billion years old, whereas its youngest are forming today. They have been folded, faulted, and recrystallized in every imaginable way, inundated by volcanic lava and ash beds, and deeply sliced by erosion. The result is a wonderland that represents both the driest part of the Great Basin and the most extreme portion of the Basin and Range.

The Great Basin is a geographic region that covers parts of Oregon, Idaho, Wyoming, Utah, Nevada, and California. It is defined by its climate and hydrology. Heavy rain and snow may fall in the mountains, but the intervening valleys are dry because of the storm-blocking "rain shadow" effect of its mountain ranges. Streams draining the slopes simply soak into the ground or evaporate. None of the rivers reaches the ocean. In the spring and early summer there is sometimes enough runoff to form small lakes on the valley floors, but they soon dry up in the summer heat, leaving behind shimmering playas—that is, barren lake beds of salt and clay.

The Basin and Range is the geologic province that formed the Great Basin's mountains. The crust of the earth was uplifted and stretched under severe tension, and large-scale fault zones broke it into a series of parallel north-south-trending valleys and ranges that march east one after another from the Sierra Nevada in California to central Utah, north into Idaho and Wyoming, and south through Arizona into Mexico.

The Basin and Range is geologically young—less than 65 million years old. Its development began in Utah. As time went on, the action gradually migrated westward and produced greater relief. Because it is nearly westernmost in the province, the Death Valley region boasts some of the youngest and most extreme topography of all the Basin and Range. Its mountains are still growing taller, and the valleys are becoming deeper. Rock exposures are fresh and reveal nearly every variety of stone that exists. The rocks in one mountain range are often completely different from those a few miles away, and sometimes the age difference can vary a billion years in only a few inches. Great earthquakes and volcanic eruptions have torn the surface. Ice Age lakes filled the valleys with hundreds of feet of water and left behind wave-cut terraces, beaches, and salt beds. Wind has stripped the surface bare in some places and piled up sand dunes in others. The result is a geological paradise.

What we see today is only the latest development in a region that contains many complex ingredients that have gone through countless processes. A little understanding about rocks and time helps make sense of Death Valley National Park's otherwise incomprehensible hodgepodge of geology.

PRECAMBRIAN TIME

Geologic time is divided into four major eras based mostly on the types of life that existed during each. The fossil record indicates that life had somehow developed on Earth nearly 3.5 billion years ago, but from then through most of the next 3 billion years there was little change. Life existed entirely as single-celled forms such as archaea, bacteria, and cyanobacteria. These cells reproduce by simple cell division, and there is little evolution because the offspring is genetically identical to the parent. Colonies of bacteria sometimes caused mounded mineral accumulations called stromatolites to grow around them, but only rarely were the cells themselves preserved as fossils. Because of this lack of preserved cells, and also because rocks this old have almost always been recrystallized during later mountain-building episodes, very little is known about the first 4 billion years—87 percent—of the Earth's history. All of this vast time span, from the creation of the entire Earth 4.7 billion years ago up to "only" 700 million years ago, is commonly lumped together as Precambrian Time.

Death Valley's Precambrian rocks are divided into three main sections. Oldest are high-grade metamorphic materials that make up much of the bedrock in Death Valley's mountain ranges. Little can be said about these rocks, but because of their

Table 1.1. *Geologic Time Scale*

Era	*Period*	*Rock Formation*	*Events in Death Valley*
Cenozoic	Quaternary	none specifically named except Ubehebe Volcanics	Holocene Epoch—modern alluvial fans, playas, salt pans, and sand dunes form; Pleistocene Epoch—Lake Manly
	Tertiary	Mormon Point Funeral Nova Furnace Creek Artists Drive Timber Mountain and other volcanics	Opening of modern Death Valley Development of the Basin & Range province with major regional volcanism, lakebed sediments in localized basins
		Titus Canyon	Oliogocene Epoch—localized deposits

continued on next page

Table 1.1.—*continued*

Era	*Period*	*Rock Formation*	*Events in Death Valley*
Mesozoic	Cretaceous Jurassic	miscellaneous igneous intrusions such as Skidoo granite and Hunter Mountain grandiorite	Nevadan Orogeny mountain biolding and volcanic activity; thrust faulting and regional uplift in Death Valley; ocean withdraws from area
	Triassic	Butte Valley	Localized shallow marine deposition
Paleozoic	Permian	Owens Valley	long inundation by tropical ocean begins to end as deposits contain progressively more silt and sand.
	Pennsylvanian	Keeler Canyon Tihvipah Rest Spring	
	Mississippian	Lee Flat Perdido Tin Mountain	Long period of sediment deposition on stable continental margin. Most sediment is limestone and often is highly fossiliferous; occasional interruptions with withdrawal of the ocean and deposition of non-marine sand and silt.
	Devonian	Lost Burro	
	Silurian	Hidden Valley	
	Ordovician	Ely Spring Eureka Barrel Spring Pogonip	
	Cambrian	Nopah Racetrack	
		Bonanza King Carrara Zabriskie Wood Canyon	Thick wedge of coarse sand and silt shows the opening of a new ocean basin.
Precambrian	Vendian (Ediacaran)	Stirling Johnnie	Dominated by sand and silt indicating rifting of the continent
		Noonday	Shallow marine limestones of a tropical environment
		unconformity (gap in the geologic record)	
	Proterozoic	Kingtson Peak	Coarse-grained sediment including glacial debris
		Beck Spring Crystal Springs	Shallow marine sediments, locally converted to talc within Crystal Springs
		unconformity (gap in the geologic record)	
		unnamed assemblage of igneous and high-grade metamorphics	Death Valley's "basement rock," at least 1.8 billion yers old
	Archaean Hadean	Rocks of these periods (older than 1.8 billion years) are not exposed anywhere in the Death Valley Region.	

original composition of sand and silt, we know they were deposited as sediment on a gentle floodplain about 1.8 billion years ago. Later they were severely metamorphosed during major mountain building. Those mountains were stripped away by erosion long before the end of the Precambrian. These rocks are exposed at the surface in relatively small areas. Two places where they can be easily seen are the cliffs above Badwater and along Lower Wildrose Canyon below the campground.

Later a series of sedimentary rocks known as the Pahrump Group was deposited. These formations—Crystal Springs, Beck Spring, and Kingston Peak—were laid down mostly in a shallow marine environment. Later metamorphism affected them too, but it was less intense and the original sedimentary structures often remain visible. The most important aspect of these rocks is that sometime much later they were intruded by an igneous rock called diabase. Where it encountered the dolomite (calcium-magnesium carbonate) of the Crystal Springs Formation, large deposits of talc were formed.

Again, there was a hiatus before the deposition of sedimentary rocks resumed. These last Precambrian rocks are commonly assigned to the Vendian (or Ediacaran) Period, a time transitional to the Paleozoic Era. Trace fossils, such as burrows and feeding trails but not fossils of the animals that made them, are occasionally found in these rocks.

THE PALEOZOIC ERA

The abrupt appearance of complex multicellular life between about 700 million and 540 million years ago marks the end of the Precambrian and the start of the Paleozoic Era. In time, shallow ocean waters teemed with mollusks (clams and snails), echinoderms (starfish, urchins, and crinoids), arthropods (trilobites), brachiopods, and bryozoans. Many of the Paleozoic formations contain abundant fossils. Since the geologic time scale is based mostly on the fossil record, it is in the Paleozoic that time is first divided into spans shorter than eras. From oldest to youngest, these periods are called the Cambrian, Ordovician, Silurian, Devonian, Carboniferous-Mississippian, Carboniferous-Pennsylvanian, and Permian. Each period is represented within Death Valley National Park.

During the Paleozoic, the entire West Coast of North America was a quiet continental shelf. The setting was much like that along the East Coast of modern North America. There was dry land to the east, about where the Rocky Mountains are now, and gentle rivers flowed to the sea to deposit layers of sand, silt, and clay along the seashore. The water was clear and tropical most of the time, and extensive limestone platforms and reefs formed a short distance offshore. These layered rock formations make up most of the exposed rock in the Funeral, Grapevine, Panamint, Cottonwood, and Inyo mountains.

People often think of catastrophes when they consider geology, but the real stories of geology involve slow, uniform events. A total of more than 25,000 feet of sed-

Figure 1.1. *Most rocks in Death Valley's mountains are Precambrian or Paleozoic sediments. These in the Last Chance Range near the Eureka Dunes are dominated by the striped Bonanza King Formation of Cambrian age.*

iment was deposited in this region during the Paleozoic Era. However, the era lasted 450 million years. Put together, this means that the sediment was deposited at a net average rate of much less than one one-thousandth of an inch per year! Time was responsible for the vast accumulation of rock.

THE MESOZOIC ERA

Conditions abruptly changed at the end of the Paleozoic Era as the passive continental margin became part of an active igneous belt that was building a range of mountains. The unifying theory for geology is called plate tectonics. Masses of continental and oceanic rocks move as plates of crust on top of a deeper, semifluid material called the asthenosphere. It is a simple process. During those quiet Paleozoic years, North America was being carried eastward. At the end of the Paleozoic, it abruptly reversed its direction toward the west, causing a process called subduction.

Subduction occurs when a slab of oceanic crust is forced to slide beneath a plate of continental crust, such as North America. Some of the subducted plate melts, and magma rises up into the overriding material. During this particular mountain-building episode, called the Nevadan Orogeny (from *oros*, "mountain," and *genes*, "birth"), this region must have looked quite a lot like today's Cascade Range—rolling hills studded with volcanoes similar to Mt. St. Helens, Mt. Rainier, or Crater Lake's Mt. Mazama.

The start of the Nevadan Orogeny marks the beginning of the Mesozoic Era. Comprising the Triassic, Jurassic, and Cretaceous periods, it covers the geologic time span from about 250 million to 65 million years ago. The quiet sedimentary setting of earlier times was completely disrupted. (The only known Mesozoic sedimentary rock in the Death Valley region is the Butte Valley Formation, exposed in a limited part of the southern Panamint Mountains.) Intrusions of magma penetrated into the older rocks, cooling and solidifying as granite thousands of feet below the surface. The older sedimentary rocks were deformed and often recrystallized at high temperatures and pressures into a miscellany of metamorphic rocks, and solutions percolating through them created ore deposits of gold, lead-silver-zinc, and copper. Compression forced huge chunks of rocks to slide horizontally along thrust faults, superimposing the sequences of sedimentary formations on top of one another. At the surface, volcanoes erupted and laid down ash beds and lava flows.

It is only by chance that the Nevadan Orogeny occupied the entire Mesozoic Era. Elsewhere around the world this was the "Age of the Dinosaurs," but you will not find dinosaur remains in Death Valley. The environment was not suitable; there was very little dry land, and most of what did exist was on the slopes of the active volcanoes.

The volcanic rock eroded away long ago, since it was originally perched on top of everything else. Intrusive rocks can be found in many places, such as around the ghost town of Skidoo, on Hunter Mountain, in the Owlshead Mountains, and in other areas where high uplift and deep erosion have revealed what once were deep-seated materials.

THE CENOZOIC ERA

The Mesozoic Era and Nevadan Orogeny ended nearly simultaneously as time entered the Cenozoic Era. During this era the Basin and Range Province began to form, a process that started 65 million years ago and continues to this day. The Earth's crust was stretched by tension. Estimates are that the east-west distance across the entire Basin and Range Province has increased by at least 150 miles. To accommodate the stresses, the rocks fractured in a series of north-south faults along each of which the block of rock on one side moved up relative to the block on the other side. This kind of vertical movement produces what is called a normal dip-slip fault. The down-dropped valley blocks like Death, Panamint, and Saline valleys

Figure 1.2. *The smooth face of the mountains just north of Badwater is the Badwater Turtleback, where younger sedimentary rocks literally slid across a detachment fault to expose much older, erosion-resistant Precambrian rocks.*

are grabens, whereas the intervening uplifted mountains such as the Panamint and Funeral ranges are horsts. These alternating down-up-down-up fault blocks are the basins and ranges of the province. (In the Death Valley region each of the valleys has had much more fault activity along one side than the other, and the faults flatten into horizontal planes at depth. Technically, these modified normal faults are called listric faults, and the valleys are half-grabens.)

As the valleys were pulled open, some of the rocks were twisted and bowed upward into broad curving forms. Where hard igneous and metamorphic rocks were overlain by softer sedimentary materials, the younger rocks literally slid off of the older. Pulled by gravity down into the valley via detachment faults, they quickly eroded away to expose curving turtleback surfaces of Precambrian basement rock. A series of turtlebacks is found in southeastern Death Valley, and the jumbled rocks of the Amargosa Chaos near Jubilee Pass show where another detachment fault began but did not complete the process.

As the mountains are thrown up relative to the valleys, erosion tries to strip them away. The debris is deposited as new sediment on the valley floors and hides much of the true geologic structure. The highest point in the Panamint Range at Telescope

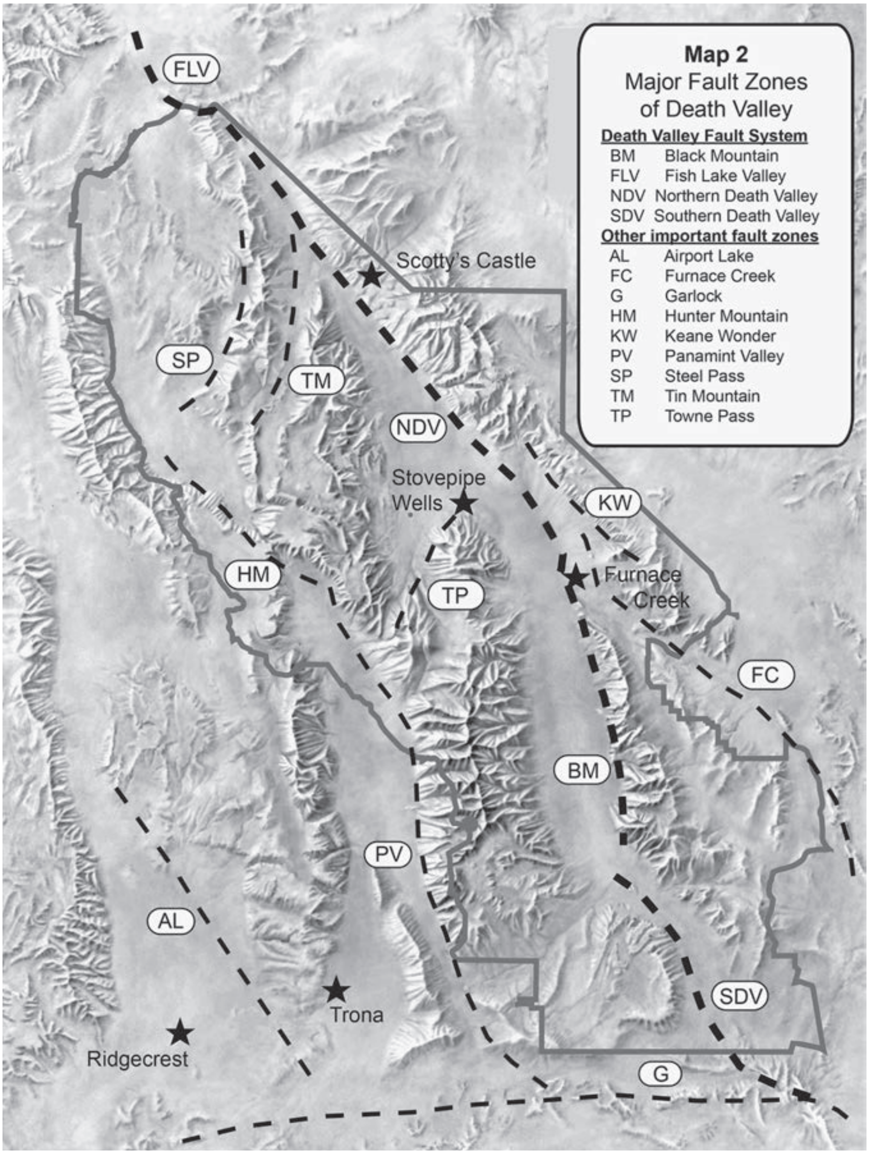
Peak reaches 11,049 feet above sea level. Directly below it, near Badwater, are the two lowest points in North America, both 282 feet below sea level, as measured by the U.S. Geological Survey. (Unofficial reports of an elevation of –289 are officially considered to be "misinformation.") That change of elevation is actually only about half the total relief. To reach the bedrock of the valley floor west of Badwater, one would have to dig through nearly 9,000 feet of sand, gravel, and salt. The true amount of vertical fault offset has been more than 20,000 feet.

This basin and range faulting is only part of the structural story. The national park is also cut by strike-slip faults. On these, most of the movement is horizontal. In effect, dip-slip faults create the mountain blocks, and strike-slip faults slide them past one another. The total offset along the Northern Death Valley Fault Zone through central Death Valley north toward Nevada may be as great as 50 miles. In a similar manner, the Southern Death Valley Fault Zone has generated as much as 20 miles of movement. Fully as important, probably, is the fault zone that links the Panamint Valley and Hunter Mountain faults into a single system perhaps 150 miles long.

These faults and uncountable others have slashed Death Valley's rocks into thousands of pieces. Each has been moved a bit differently than the others. Some are tilted on end, others severely folded, and a few are completely upside-down. The details are exceedingly complex, and geologists working with these exposures have recently reinterpreted many of their meanings. The complete story is far from being fully understood.

The geologic creation of Death Valley National Park is still underway. Every time a fault ruptures, the result is an earthquake. Reasonably fresh fault scarps formed by prehistoric shocks are visible along Badwater Road south of the Furnace Creek Inn, parallel to Scotty's Castle Road, and along the east side of Panamint Valley. Several earthquakes of significant size have occurred within the park area during recorded times. One on November 4, 1908, had a Richter magnitude of at least 6.5 and was probably centered somewhere in the Panamint Mountains, possibly near Butte Valley. Another quake stuck south of, but near, Death Valley on November 15, 1916, with a magnitude of at least 6.1. A quake of magnitude 6.2 struck Eureka Valley on May 17, 1993. The largest earthquake to have actually occurred within the national park area in recorded time, this 1993 quake caused minor damage in Owens Valley but was not strong enough to form a new scarp. Several small tremors were recorded at Harrisburg Flat in 1994, and in December 2008 there was a series of small (up to magnitude 4.4) quakes in the Slate Range near Trona. Most notable so far in recorded history were the quakes of magnitudes 6.4 and 7.1 that struck between Trona and Ridgecrest on July 4–5, 2019. Those tremors caused more than $5 billion in damage to the Naval Air Weapons Station China Lake as well as extensive damage and some outright destruction in those towns, but there were remarkably few effects other than roadside rockfalls within Death Valley. It is certain that more earthquakes, some of large scale, will take place in the future.

Figure 1.3. *A small normal fault in Johnson Canyon.*



Map 2. *Major Fault Zones of Death Valley*

FIRE AND ICE

The tension that caused the faulting also thinned the crust throughout the Basin and Range Province. Continental crust is usually about 25 miles thick, but below Death Valley it might reach down as little as 12 miles. Faults can serve as conduits for magma to rise toward the surface, especially in thin crust areas, so the park has been

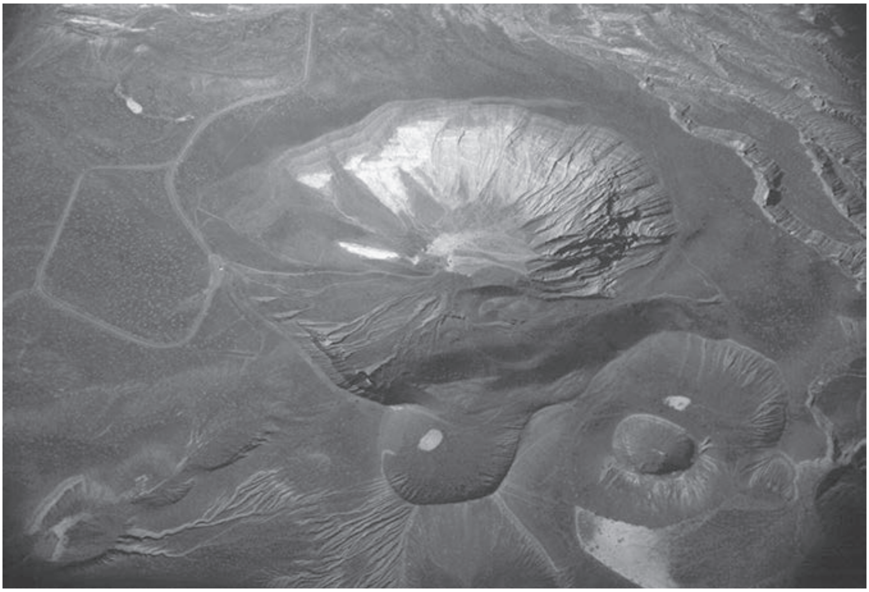


Figure 1.4. *Ubehebe Crater is the pit of a maar crater—that is, a steam explosion caused by volcanically heated groundwater that might have occurred as recently as 300 years ago. The prominent crater to the lower right is Little Hebe. Courtesy California Volcano Observatory, U.S. Geological Survey.*

the site of geologically young volcanic activity. About 28 million years ago, the entire region was blanketed with ash from huge eruptions within what is now the Nevada Test Site. In places, this ejecta was piled in layers over 1,000 feet deep. Much of the rock in the Black Mountains, in the Saline Range between Saline and Eureka valleys, and in the Argus Mountains west of Panamint Valley is composed of lava flows and ash beds formed between 12 million and 2.5 million years ago. Still younger are cinder cones in southern Death Valley and in Saline Valley. Especially remarkable is the Ubehebe Crater complex of volcanic explosion pits, sixteen maar craters that completed their development within the last 2,100 years (possibly as little as 300 years ago), when Ubehebe Crater blanketed 15 square miles of the surroundings with as much as 150 feet of volcanic ash and cinders.

During the Ice Age glacial episodes, there was much greater runoff out of both the Sierra Nevada to the west and the local ranges. The Owens River twice reached as far as Panamint Valley and Death Valley. Panamint Lake was as deep as 900 feet—it is amazing to realize that those terraces high above the ghost town of Ballarat were verdant lake shores about 130,000 years ago. The Amargosa River was a large and permanent stream that flowed through Lake Tecopa and into Death Valley, where Lake Manly was 640 feet deep, up to 8 miles wide, and more than 90 miles long. Other lakes occupied Saline and Eureka valleys at the same time. Smaller temporary lakes have existed many times since then, and the evaporation of each one left behind salt beds such as the Devil's Golf Course and Saline Salt Marsh on the valley floors. The process continues as new salt is added with every spring runoff and flash flood.

We do not usually notice the slow but uniform events that make geology work, but there is constant change. It is difficult for anyone to understand what the span of geologic time really means. Geologists toss around billions and millions of years as if they were nothing, but time is everything. Somebody once remarked that in geology the impossible becomes possible, the possible is probable, and the probable is certain. Nowhere are the seeming impossibilities of geology better revealed than in the realities of Death Valley National Park and vicinity.

It must be emphasized that collecting rock, mineral, fossil, and archaeological specimens is prohibited within the national park. Mineral collecting remains legal in many areas surrounding the park, provided that the location is on public land and not on a valid mineral claim. The collection of fossil specimens is a matter subject to revision, confusion, and debate. A strict interpretation of the Paleontological Resources Protection Act of 2009 implies that there can be no fossil collecting of any kind on any public land without a permit from the Department of the Interior. However, a Bureau of Land Management brochure distributed since the passage of the act states that limited collection of invertebrate and plant fossils is allowed, provided that the specimens are for personal use only; such specimens cannot be bartered or sold. Collectors are strongly advised to check with the appropriate agency for current regulations.