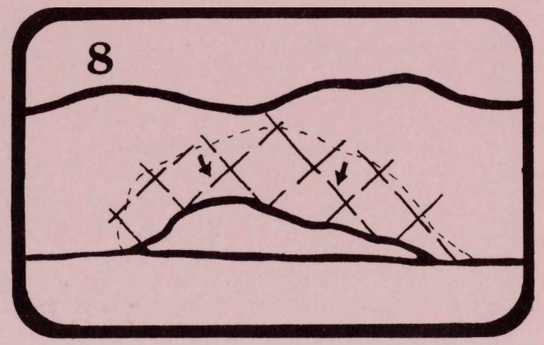
The Entrada Sandstone is a relatively soft rock formed of rounded sand grains weakly cemented together by *calcium carbonate*. Ordinary rainwater picks up carbon dioxide from the air as it falls, making the water slightly acidic. The *acid dissolves* the cement between sand grains, slowly weakening the sandstone. Several other processes contribute to the formation of hollows and openings in the weak stone:

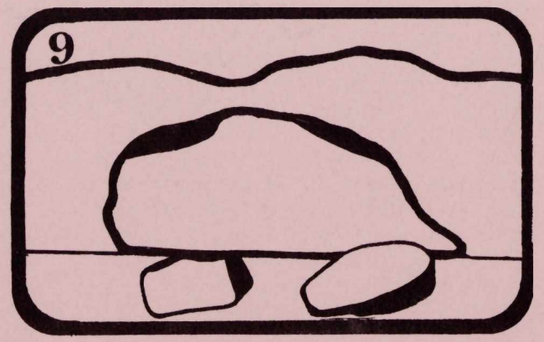
Frost Wedging: Water freezing in narrow crevices expands, exerting tremendous outward pressure, popping off slabs and chunks of rock.

Stress Release: The Entrada was once buried beneath thousands of feet of rock that pressed down on the sandstone. As erosion removed the overlying layers, the Entrada was relieved of this pressure, and the rock slowly re-adjusted, shifting and expanding. This caused slabs and blocks to peel off the rock surface, a process that still continues.

Layers of Differing Hardness: Throughout the Park, two distinctive layers of the Entrada Sandstone can be seen. The **Dewey Bridge Member** is the lower brick-red layer which is *soft and crumbly*. The **Slickrock Member** is the upper lighter red layer which is a *stronger* more smoothly weathering sandstone. The softer Dewey Bridge Member erodes more quickly, forming pockets that undermine the Slickrock Member, which is then left bridging the hollow beneath. **Double Arch,** in the Windows Section, was formed in this manner. Balanced rocks are formed where blocks of Slickrock protect the softer Dewey Bridge from rapid erosion, leaving Slickrock boulders perched on pedestals of wrinkly looking Dewey Bridge.

When any combination of these processes makes a hole in a fin, the opening grows larger as more blocks of rock break off and fall out, until a stable, curved arch is all that remains. (figs. 8 & 9) Like man-made arches, a *stone arch is a stable form* because all pressures are directed toward the center. In other words, the arches' own weight makes them stronger.



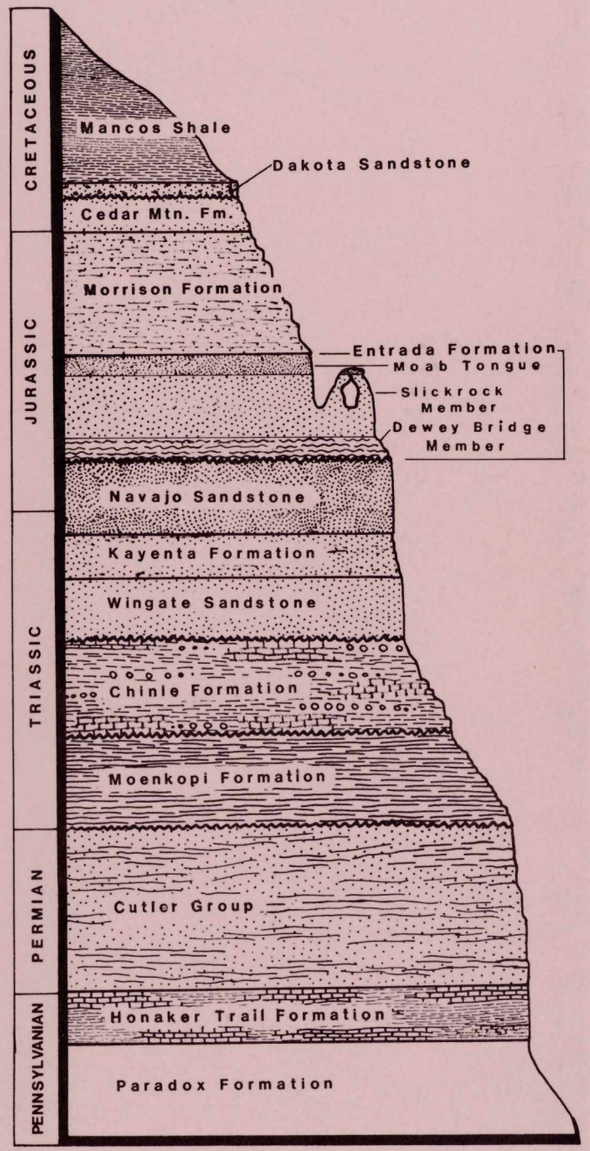


The *arid climate* plays an important role in shaping this striking landscape. Arches is a **high desert,** receiving only 8-12 inches of rain a year. In a climate such as this, *weathering and erosion are slow*. If you picked up the canyon country and placed it in a climate like Louisiana's, the abundant moisture there would saturate the rock, making it break apart like sawdust. The angular arches and towers would topple and become rounded lumps covered with vegetation. (fig. 10)

As arches are formed, they are also destroyed. The same forces that created them whittle them thinner and thinner, until after thousands of years, they fracture and collapse. The arches are but fleeting creations in the stream of time.

Sequence of Rock Layers

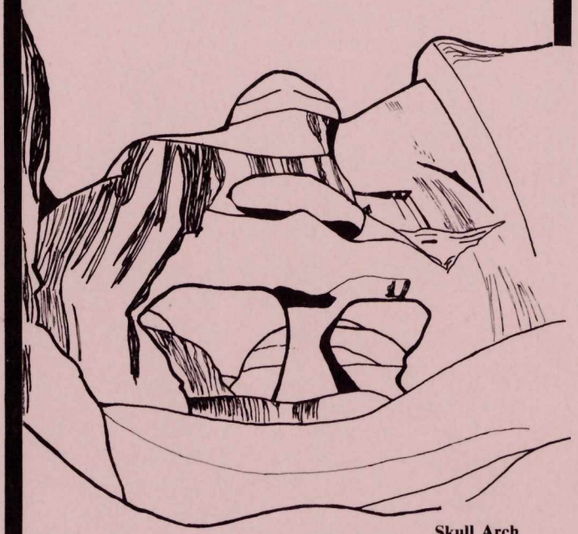
Arches National Park



Text and Drawings: Marcia Phillips
Editing: Mike Price/Helmutt Doelling

3/88-3M

GEOLOGY



Skull Arch

Arches, framing circles of sky, standing in clear desert sunlight -- more arches than in any other place in the world of comparable size. Salt, sandstone, and immeasurable centuries have all come together to form this land of stone windows.

Arches National Park

Canyonlands Natural History Association

125 West 2nd South • Moab, UT 84532 • 801-259-6003

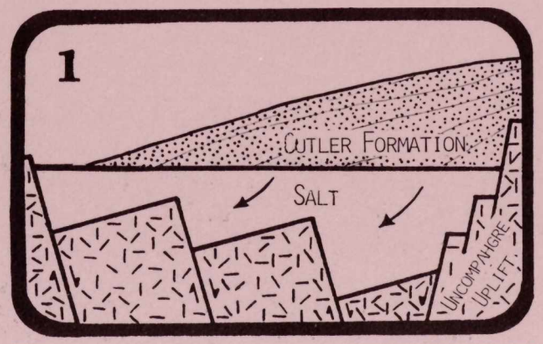
The Plateau

Arches National Park is a part of the **Colorado Plateau**, a spectacular geologic region which covers 130,000 square miles in Utah, Colorado, Arizona, and New Mexico. Here, layer upon layer of colorful rock lie in nearly *horizontal* positions. Although these rocks have been lifted 5,000 to 10,000 feet above sea level since they were formed, they have otherwise remained relatively *undisturbed.* Because of the layered orderliness of the rocks, the plateau is an accessible, tangible voyage into the distant geologic past. The spires and arches speak of a vast passage of time. Millions of years of geologic change have contributed to the landscape which exists today.

Salt — The Unstable Foundation of Canyon Country

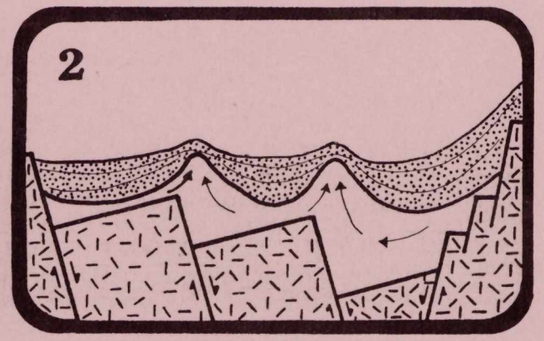
The rock record of Arches, composed of several named layers of rock, extends back at least *300 million years.* The layer that most influenced the formation of fins, arches, and spires is one that is rarely seen at the surface --the **Paradox Formation**, a layer composed mostly of salt with some gypsum and shale.

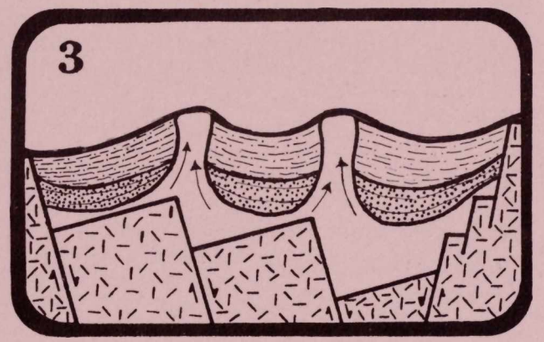
About 300 million years ago, blocks of the earth's crust sank downward along faults forming a deep basin (the **Paradox Basin**). The floor of the basin was broken into a series of step-like ridges and troughs. The Paradox Formation was created as an arm of the sea repeatedly invaded this basin filling it with salt water, which evaporated under desert conditions, leaving *beds of salt.* Layer after layer was laid down, eventually filling the basin to a thickness of 5,000 to 6,000 feet. As the basin sank and filled with salt, a tremendous mountain range, the **Uncompahgre Uplift**, rose to the northeast. Rivers and streams rapidly eroded this growing mountain range and *carried the debris* southeastward, dumping millions of tons of sand and gravel and other sediment *on top of the salt beds.* (fig. 1)



Salt is an unusual substance, different in two important ways from the layers of sandstone and shale that make up the rest of the Colorado Plateau; it is *plastic* and *soluble.* Salt will deform under pressure and will move to an area of less pressure, like toothpaste squeezed out of a tube. When brought in contact with fresh water, salt readily dissolves.

As more and more layers of rock were laid down upon the salt and the faults continued to move, inequities of pressure were created and the salt deformed, moving to areas of the least pressure. These areas were localized along and above the faults. The salt pushed upward into long linear upfolds, pushing the overlying layers of sand and gravel and other sediment aside. The salt in the upfolds or *salt anticlines* doubled in thickness. Drillholes have penetrated more than 10,000 feet of salt into what is now Salt Valley. (figs. 2 & 3)



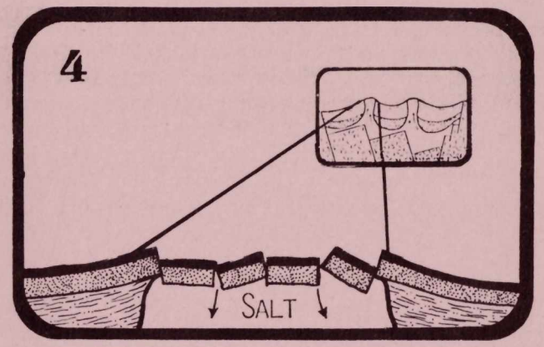


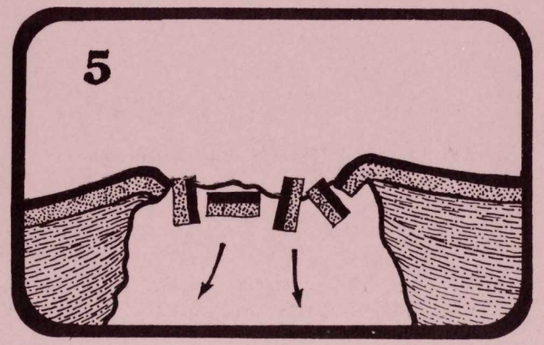
Eventually, the salt became "sealed" under thousands of feet of sediment which continued to be deposited in the area, and it ceased to move. Through time the region changed from meandering streams to sand dune desert, then back to meandering streams. About 90 million years ago it was covered by another ocean. Deep seated crustal disturbances downfolded the area between the salt anticlines into what scientists call *synclines.* Faults formed, which elevated the rocks on one side of the rupture and lowered them on the other.

The Great Uplift

During the past 10 million years, the Colorado Plateau has been slowly, inexorably lifted high above sea level. As this occurred, the process of canyon cutting began. The **Colorado**, the **Green**, the **San Juan Rivers**, and their tributaries incised their courses into the plateau during this period of uplift and continue to do so today. These silt-laden rivers rasp their way through the rock layers, carrying the resulting eroded debris and sediments to the sea. In so doing, the great rivers of the plateau have *cut downward* through thousands of feet of rock, exposing them to view.

As *erosion* stripped off the uppermost layers of rock, the salt-cored folds were once again exposed at the surface. As tributary streams flowed across the faults and fractures above the salt, some of the water leaked down into them and began to *dissolve the salt.* The remaining overlying rocks began to collapse into these faults and fractures. (fig. 4) Formerly horizontal beds of rock *collapsed* and *tilted* into hogbacks and ridges. Some of the layers even rotated enough to stand vertically. (fig. 5) Most of

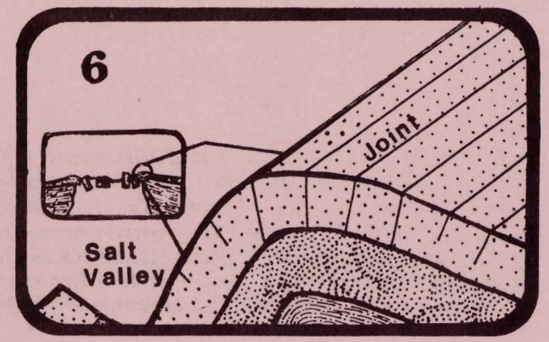




this activity was concentrated over the crests of the anticlines so that valleys, such as **Salt Valley** and **Moab Valley**, formed. High ridges or cliffs mark the edges of these valleys. Toward the eastern end of Salt Valley, near Wolfe Ranch, collapsed rock layers tilt quite steeply into the valley. The youngest rocks are preserved in the valleys, while the rocks along the edges are much older.

Joints, Fins and Arches

One of the layers that was deposited on top of the salt beds is the **Entrada Sandstone.** As the Entrada and other layers collapsed into the salt-cored valleys, they arched over the edges. The brittle Entrada Sandstone flexed and cracked parallel to the valley and fractured into closely spaced orderly lines, called *joints.* (fig. 6) The process of



weathering widened and deepened the joints, forming free-standing blades of sandstone -- the *fins* of **Devil's Garden**, the **Fiery Furnace, Klondike Bluffs** and **Herdina park.** (fig. 7) These fins are easily pierced by weathering, leading to the formation of *arches.*