Entering Zion National Park from the east, along the Zion-Mount Carmel highway, the cliff exposures reveal the unbelievable stack of cross-bedded sets that make up the Navajo Sandstone. Without a type locality, and named for the ‘Navajo Country’ of the southwestern United States, the dramatic exposures and widespread occurrence make it one of the most famous and recognized rock formations in the world.

The extent of the Navajo/Nugget Sandstone and National parklands that feature Navajo outcrops.
Found in five western states, the Jurassic Navajo Sandstone and the equivalent Nugget Sandstone is one of the largest wind-deposited formations in the geologic record. The sandstones that form spectacular cliff exposures are both the focal points of tourist cameras and the primary reservoir targets for oil and gas drillers in the central Utah and the Utah-Wyoming thrust belts.

The Navajo Sandstone forms spectacular cliffs and domes like these views up the Zion–Mount Carmel highway or the view of the Court of the Patriarchs. The Navajo exhibits a wide range of colors that reflect a long history of alteration by groundwater and other subsurface fluids. The different colors, except white, are caused by varying mixtures and amounts of iron oxides/hydroxides (hematite, goethite, and limonite). These minerals fill the pore space within the quartz sand framework of the sandstone. Dissolution of the iron coatings by reducing fluids has bleached large volumes of the Navajo to a brilliant white.
While visiting this area back in the Early Jurassic, you would have seen a dune field that stretched as far as you could see. It was a landscape similar to the present day Sahara Desert in North Africa or the Alashan area of the Gobi in northern China, covering an estimated one million sq km, an area about the size of the state of California. The resulting Navajo and equivalent Nugget Sandstones are now found in parts of five western states.

Regional uplift and subsequent erosion that have exposed these formations help form the beautiful scenery found in northern Arizona and throughout southern and eastern Utah. Numerous national parks and monuments have been created around some of the more spectacular exposures and unique landforms.

To the earth scientist, the area is more than just scenery. These rock exposures tell a story of a desert covered by a sea of huge straight-crested to sinuous, coalescing bar-chanoid dunes being driven by north to northwest winds; a desert interrupted by springs (oases) and playa lakes. Around these vegetated areas, traces and fossils can be found left behind by prehistoric life ranging from small invertebrate animals to huge vertebrates.

The Grand Staircase

The Navajo Sandstone forms only part of the spectacular geology of this region. In the 1870’s, U.S. Geological Survey geologist Clarence Dutton studied the Grand Canyon and the high plateaus of central Utah. His concept of this region was a huge stairway ascending out of the bottom of the Grand Canyon northward with each cliff edge forming giant steps. These five steps, or cliff formers, were named by their prominent color with the oldest being the Chocolate Cliffs, followed by the Vermilion Cliffs, White Cliffs (Navajo Sandstone), Grey Cliffs, and finally the Pink Cliffs.

The Grand Staircase preserves more geologic history than any other place on the earth. The ages range from the two billion year old Vishnu Schist in the Grand Canyon to the Middle Tertiary rocks of the
Bryce Canyon. Each step area has shared rock units. For instance, the oldest exposed formation in Zion National Park (Kaibab Limestone) is the youngest exposed in the Grand Canyon. The rock units that comprise the lower cliffs of the Grand Canyon and the Grand Staircase remain largely intact and represent nearly 600 million years of continuous geologic history.

This area has undergone 1500 to 3000 m of uplift starting with the Late Cretaceous Laramide orogeny and the later uplift of the Colorado Plateau 10 to 15 million years ago. Major canyons started to form about six million years ago when the Gulf of California opened up lowering the area's river base levels.

Zion National Park

At over 670 m., the Navajo Sandstone is at its thickest in the Zion National Park. Here, the sandstone forms some of the highest sandstone cliffs in the world, some exceeding 700 m. The sandstone is typically pale tan to red forming large monoliths. The sandstone here is remarkably homogeneous with obvious sand dune cross-bedding patterns clearly exposed. The upper part of the sandstone is pale tan to nearly white becoming reddish in the lower part from iron oxide that has percolated down from upper formations.

The ease of access and the deep canyon carved by the Virgin River make Zion the most visited, and arguably the nicest, of all the parks centered around Navajo Sandstone exposures. The park features a user-friendly shuttle bus system, hiking trails for all abilities, a variety of accommodations in and near the park, and scenery that—in my view—rivals just about any found on the planet.

Using shuttle buses to explore the paved road up the Virgin River canyon, the geotourist can find a variety of landforms and exposures right from the road or take short hikes to view the beauty the canyon has to offer. Allow at least 90 minutes for shuttle round trip and several days if one is to extensively explore and hike this area. The shuttle busses make eight convenient stops at trail heads, a lodge and picnic areas. Trails like Riverside Walk, Emerald Pools, and Weeping Rock stay in the confines of the canyon and all can be easily completed in a day. The Angels Landing and Observation Point trails lead to views at or near the top of the canyon and require five to 12 hours of moderate to strenuous hiking to complete.

A variety of hikes in the lower canyon await the geotourist. Hiking along and up the Virgin River affords views of towering cliffs in this steep sided, narrow canyon. The narrow canyon can be hazardous, caution must be used when hiking up this stream.

At Weeping Rock, water seeping out of the base of the Navajo has cut an overhang. Standing behind the constant dripping gives the traveler a much different view of Zion Canyon. Interpretative signs along this short, paved hike highlight the variety of plants that flourish where water is available.

In the Grand Staircase-Escalante National Monument, the Jurassic Carmel Formation that directly overlies the Navajo is sculpted into mystical shapes.
**Lithofacies and Oil and Gas Production**

The Nugget Sandstone play is found along Utah-Wyoming thrust belt. After the initial discovery of the Pineview field in 1975, the Nugget has produced over 46 million m6 pt (288 million barrels) oil and 145 billion m3 (5.1 TCF) gas from 13 fields. The Nugget in this area is typically 340 m thick.

The Navajo sandstone play in the central Utah thrust belt was recently found to be productive with the 2004 discovery of the Covenant field (see GEO ExPro Vol. 3, No. 6). This discovery opens up a large area containing anticlinal traps associated with Cretaceous to Early Tertiary detached thrusting similar to the Nugget play. The Navajo reservoir is thicker, over 360 m thick, and in some places exceeding 400 m in thickness.

The Navajo/Nugget Sandstone has heterogeneous reservoir properties because of cyclic dune-interdune deposition, diagenetic effects, and fracturing. In producing oil and gas from either of the sandstones, it is important to recognize the different lithofacies as they affect production rates and the petroleum paths of movement.

The extensive dune fields left behind classic aeolian bedforms such as tabular, wedge planar, and trough cross-bedding. Cross-bedded sets occur up to 8 m in thickness and dips of cross-beds between set boundaries can vary as much as 40 degrees. Wind ripples are occasionally preserved on top set deposits. The sandstones are composed of 90 percent quartz grains (usually frosted) and have an average porosity of 14 percent.

Interdune environments such as playas and oases are preserved in the form of thin bedded, lenticular limestone beds. Oasis deposits are represented by light-gray, 2 to 3 m thick, thin-bedded limestone that commonly contains oscillation ripples and mudcracks. They pinch out over very short distances. In some areas, a high water table existed over long periods of time, allowing for small fresh water oases lakes to form. Playa deposits are recognized by planar beds composed of mud, silt and very fine-grained sand. Small channel deposits left behind by wadi or desert washes are found in erosional or deflation interdune areas. All of the interdune lithofacies have significantly poorer reservoir qualities than the dune lithofacies.

**Outside Zion**

Exposures of the Navajo Sandstone cover a huge area outside Zion. Exploring the more remote and primitive areas requires more planning and time but can lead to fantastic experiences. Canyon Lands, Capitol Reef, Arches, and Dinosaur National Parks, along with the Grand Staircase-Escalante National Monument, all feature Navajo Sandstone outcrops in south and eastern Utah. All have their own characteristics and attractions.

**For visitors**

Before visiting Zion or any of the other national parks, excellent planning information is available at the National Park Service website, www.nps.gov. You will find information on planning your visit including directions, operating hours and seasons, fees and reservations, things to know before you come, and things to do while you are there. Once at the park, a good place to start is the visitor center. Here you will find exhibits and a film that will help plan and make the most of your time there. Rangers can answer questions and help you make the most of your visit.