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GEOLOGIC SKETCH
OF
PROPOSED GUADALUPE MOUNTAINS NATIONAL PARK, TEXAS

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NATIONAL PARK SERVICE
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GEOLOGIC SKETCH
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Introduction

On July 20, 1965, the Department announced its recommended enactment of legislation authorizing the establishment of the Guadalupe Mountains National Park, an area of approximately 77,500 acres, in western Texas. The proposed park, situated about 100 miles east of El Paso and 55 miles southwest of Carlsbad, New Mexico, is easily accessible by motor vehicle travel over nearby major highways.

Pending legislation, if enacted in its present form, would authorize acquisition by donation, purchase, exchange or other means of some 72,000 acres which would be added to the 1961 Pratt donation (North McKittrick Canyon) of 5,632 acres now administered by the National Park Service.

Eminent scientists and conservationists consider that the area embraced within the proposal contains a combination of scenic and scientific resources which qualify it as an outstanding addition to the National Park System. The scenery is beautiful and diversified representing some of the finest natural landscapes in the whole of the southwestern United States. The Permian marine limestone mountains contain the most extensive and significant fossil reefs in the world.

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The Guadalupe Range resembles a huge "V" with the sheer thousand-foot cliff of El Capitan, visible for more than 50 miles, situated at the vertex. Guadalupe Peak, the highest point in Texas, located about a mile north of El Capitan, rises to an elevation of 8,751 feet above sea level. At the base of the western arm of the mountains the elevation is about 3,650 feet. The streams are ephemeral for the most part but permanent streams do exist in some of the deeper canyons of the area. North McKittick Canyon within the donated tract contains exceptional ecological complex of coniferous and hardwood trees and brush species. In some cases the plant and animal assemblages are clearly a carryover from the Pleistocene epoch which greatly enhances their scientific importance.

The proposed national park also contains significant archeological resources indicating human occupation of the area for at least 6,000 years and perhaps much longer. Past findings are evidence of the need for continued archeological study. Spanish explorers first traversed the general area from the time of the Coronado Expedition in 1540 but it was not until the advent of the United States military expeditions in 1849 that any detailed knowledge of the area was acquired. The Butterfield Trail was established in 1859 and one of its way stations was located at the mouth of Pine Spring Canyon within the proposed park where remnants are found.

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Climate and Ecology

While no temperature data are available, based on records in nearby localities variations between about 110 degrees and minus 10 degrees can be expected. Prevailing winds are from the southwest. Springtimes are dry, dusty, windy, characteristic of desert areas. Thunderstorms with lightning strikes are common in the summer.

The area may be classed as extremely rugged in view of elevations ranging from about 3,641 to 8,751 feet above sea level within relatively short distances. Desert floor extends from the bases of abrupt escarpments which are extensively incised by canyons and ravines. Elevated uplands occur inward from the top of the escarpments. Vertical relief is about 5,000 feet.

As stated in the section on the significance of the area, the proposed park is biologically distinctive. The tropically derived life forms of the Chihuahuan Desert and the water course vegetation derived from both the Mexican Highlands and the Great Plains abruptly meet the northernmost relictual pockets of true coniferous forest of the Rocky Mountains.

Weather regimes variations create an unstable frontier between the three biomes giving rise to a situation of great interest to ecologists. Thus, the area coincides biologically with the Rocky Mountains, Great Plains, and Basin and Range physiographic provinces, influenced by the interaction of Mexican Desert biota.

Past Geologic Studies

Bartlett described the Guadalupe Mountains as he observed them in 1850 in his wagon journey from San Antonio to El Paso in connection with his activities on the United States and Mexican Boundary Commission. In 1854, Captain John Pope and his party surveyed a route for a railroad through Guadalupe Pass. Upon his return the following year, a geologist, Dr. G. G. Shumard, accompanied the party making the first really professional observations. His brother, B. F. Shumard, later examined the fossils collected and called attention to the fact that they resembled those of the Permian system that had previously been established in Europe rather than Carboniferous types.

It was not until 1890 that further significant geologic studies were made and these were based on a brief visit by Tarr during that year. Then in 1901 and again in 1903, Girty and Richardson of the United States Geological Survey worked in the area. Girty's collections proved especially fruitful in the information they yielded. Richardson gave the name Capitan to the white limestone forming the slopes of Guadalupe Peak which is now recognized as its type locality. It was in 1929 that the interpretation of the Capitan limestone as a reef deposit was announced, an interpretation quickly recognized and accepted since that time.

King did much of the field work in 1934 and 1935 resulting in Geological Survey Professional Paper 215, published in 1948. The bulk of the work was done in 1934 and 1935, augmented by additional work at times during the ensuing decade. King's Permian of West Texas and Southeastern New Mexico in the April 1942 issue of the Bulletin of the American Association of Petroleum Geologists is quite completely covered and updated in Professional Paper 215. Mention of the work on the Paleogeology of the Permian sequence, by Newell and others published in 1953, completes the acknowledgment of the major sources drawn upon in this sketch.

Since Carlsbad Caverns are formed in the Capitan limestone which extends northeasterly from El Capitan and Guadalupe Peak as one arm of the V-shaped Guadalupe Mountains, a close relationship exists between the composition, stratigraphy and structure of rocks in the proposed Guadalupe Mountains National Park and those of the Carlsbad Caverns National Park.

Geologic Setting

Regionally, the general area within which the proposed Guadalupe Mountains National Park is situated is underlain by sedimentary rocks of the Permian system. Attaining a total thickness of as much as 12,000 feet, these rocks crop out in high mountain ranges in some places and in low plains in others. In still other places, they are buried where they are reached only by drilling. The total exposed thickness is about 4,000 feet. This system presents stratigraphic features of unusual complexity occurring as red beds in some localities and as evaporites in others but in contrast to rocks of Permian age elsewhere in North America, the system in West Texas is of marine origin.

Geologists suspect that the Permian sequence in West Texas is nearly complete in view of its great thickness which suggests that deposition continued through the entire period with but minor interruptions from the Pennsylvanian to the Triassic. King points out that this surmise is partly confirmed by fossils in the marine strata entitling the West Texas Permian sequence to a position on equal footing with the great Permian sequences of Europe and Asia.

King further points out that in many of the ranges, especially toward the north, a former cover of Mesozoic and Cenozoic rocks has been removed, exposing Permian rocks laid bare on their crests, and on eastward inclined dip slopes. Near the Pecos River, the Permian rocks pass beneath a varying thickness of Triassic and Cretaceous rocks, which are overlain in turn by late Cenozoic rocks that form the cap of gently sloping high plains, the Llano Estacado. Toward the east, the high plains break off in frayed-out escarpments and, in the lower denuded region beyond, the Permian rocks appear again. Here they dip toward the plains as they do west of the Pecos, but in the opposite or westward direction and at a somewhat lower angle.

With this broader perspective based on King's work as a background, the geology of the immediate Guadalupe Mountains area is placed in proper perspective. The following, appropos of local geology, is taken from the excellent description contained in the Area Investigation Report on the Proposed Guadalupe Mountains National Park, dated September 1963:

"The Guadalupe Mountains present a spectacular exposure of the famous Capitan barrier reef and its contemporaneous fore-reef and back-reef marine deposits. The fine display of the several facies of Permian sediments gives the area its prime scientific significance and makes it of outstanding interest to the world's stratigraphers and paleontologists. The world's best known fossil reefs are found within this region. The Capitan, the greatest of the reefs, has been described by Dr. Norman Newell of the American Museum of Natural History as the most extensive fossil organic reef on record.

"The controlling factor in the deposition of the rocks of the Guadalupe Mountains region was the presence in a large part of Texas and New Mexico of a marine basin throughout the Permian period. A portion of that basin, the Delaware Basin, comprising some 10,000 square miles, was the major influence in the formation of the rocks with which we are interested. This basin was roughly oval in shape with a channel to the open sea situated to the southwest of the depression.

"The deep-water, well-stratified deposits of the Delaware Basin grade laterally into the thicker and more massive beds of the reefs. The latter structures were built in the shallower water along the periphery of the basin. The most impressive of these, the Capitan reef, formed a narrow but effective barrier which extended in the form of a giant horseshoe 350 to 400 miles around the basin's margin. The Capitan is well exposed for a distance of some 40 miles along the escarpment separating Guadalupe Ridge from the lower lands of the present Delaware Basin. The older portion of the reef can be seen at the mouth of Walnut Canyon and in other canyons in Carlsbad Caverns National Park, and McKittrick Canyon displays a fine exposure of the middle part of the reef and of the gradational change from fore-reef beds to the massive reef itself.

"Lime-secreting algae were chiefly responsible for the growth of this barrier, and other organisms contributed their remains to the structure and aided in trapping and holding limey sand in the growing deposit. Except for its oval shape, the Capitan is similar to present-day barrier reefs in the Pacific.

"Associated with the reef proper are thick-bedded, steeply dipping rocks that represent recrystallized talus slopes built forward in comparatively deep water and advancing in front of the reef margin. The growth of the Capitan reef was more in a horizontal than vertical direction and, apparently, the reef grew largely on its own talus. Another important feature of the zone between the reef and the fore-reef deposits is the presence of large blocks of rock which slid down the slopes in front of the reef and were incorporated in the basin deposits. These blocks as well as other evidence of submarine slides are seen to advantage at the mouth of McKittrick Canyon and its nearby vicinity.

"Behind the Capitan reef in the shelf or lagoonal area, different types of sediments accumulated simultaneously with the reef and fore-reef deposits. These back-reef equivalents consist predominantly of dolomite with interbedded fine-grained sandstone. Farther behind the reef, in the increasingly saline waters of the shelf, these deposits grade rapidly into evaporites. The near-reef lagoonal beds are well displayed in many places along Guadalupe Ridge, and two of the units of this group of rocks--the Tansill and the Yates--can be seen in the McKittrick Canyon area.

"The section of the Guadalupe here proposed for inclusion in the National Park System contains superb exposures of most of the Pennsylvanian rocks deposited in the Delaware Basin. All the formations of Leonard and Guadalupe time are exposed in the tremendous fault scarp bounding the range on the west. There the relationship of the two main reefs (Gent Sarp and Capitan) to their basin and shelf equivalents is clearly visible to the geologist and, with but little interpretation, to the layman. The exposures in North and South McKittrick Canyons are also classic and of interest to scientists throughout the world.

"It is the remarkable display of deep-water basin deposits, of reef and reef talus, and of shallow-water shelf sediments, all formed at the same time but differing because of differences in the environments in which they originated, that gives this region its geologic significance."

Paleoecology of Permian Sequence

Geologists in recent decades have made considerable progress in determining the environmental conditions under which the celebrated Permian reefs and associated deposits of the southern Guadalupe Mountains, the area of the proposed Guadalupe Mountains National Park, were formed. The most important study along these lines is entitled The Permian Reef Complex of the Guadalupe Mountains Region, Texas, and New Mexico - A Study in Paleoecology by Newell and others, published in 1953.

The conclusions arrived at in this study are based mainly on studies of stratigraphy, petrology, primary structures and paleontology. The following quoted excerpts contain the more important observations and conclusions in the summary of the Newell study:

"Three geologic provinces in the area are characterized by unlike, but stratigraphically equivalent, rocks and fossils:

(1) the Delaware Basin, containing drab-to-black limestones and quartz sandstones; (2) the rim of the basin, occupied by organic reefs and banks of light-colored, massive limestone and dolomite; and (3) a shelf area covered by light-colored, thin-bedded dolomite, sandstones, and evaporites.

"The organic reefs of the Guadalupe Mountains and similar fossil reefs of other regions, notable Greenland, North England, and

the Tyrol, are very much alike in being marginal to stagnant basins.

The frequency of this association suggests common ecological controls.

Rocks of the Delaware Basin are predominantly fine-grained, gray quartz sandstone and siltstone, and black, fine-grained sandy limestone. Both kinds of rock generally are stratified in thin, even laminations which resemble varves. The limestones contain abundant, very small, siliceous spicules of sponges, and minute spherical bodies, probably plant spores. In most places these are the only autochthonous fossils. Maculoid pelocypods, small high-spired gastropods, and rhynchonellid brachiopods occur sparsely in the earlier limestones (Bone Spring and Cherry Canyon formations) but drop out higher in the sequence. Locally, abundant ammonoids are especially characteristic of the fine-grained limestones. Apparently all of these fossils are essentially indigenous to the Delaware Basin; generally they do not show effects of sorting or transportation. At the margin of the basin, many tongues of breccia and calcarenite extend basinward for several miles. They contain great quantities of worn and broken brachiopods, bryozoans, fusulines, and other fossils like those of the reefs. Evidently they were swept far into the basin from the more favorable environment at the margin, probably by turbidity currents. The talus fans of elastic limestone round the edge of the basin provide a record of the evolution of the reefs from which they were derived, and the well-preserved, silicified, allochthonous fossils they contain supply abundant data on the diversity and quantitative importance of the major groups of reef organisms. Each limestone tongue records an epoch of abundant supply of reef detritus, and intervening horizons mark times of sparse supply of reef sediments. Quartz-sand deposition was continuous.

"Striking differences are reported in biofacies of the basin, marginal, and shelf provinces at successive horizons. Primary textures are, in places, well preserved in the Capitan and some of the other reefs but are obliterated in others by dolomitization. The undolomitized reefs are composed of (1) fossils, many of which are in growth position, (2) bioclastic calcarenite, and (3) microcrystalline limestone, a characteristic rock of many fossil reefs throughout the geologic record. The microcrystalline texture of the reef limestone is clearly the result of recrystallization of the original sediments, composed mainly of animal and plant structures. Thin sections show that these rocks are only superficially fine-grained; ghosts of fossil debris are generally visible. It is doubtful if lime mud, which normally does not accumulate in exposed shallow waters, was quantitatively an important constituent of these or, for that matter, any other reefs. Stromatolites and other algal deposits, sponges, massive bryozoans, and hydrocorallines (?) are the chief frame-builders of the reefs.

The reefs are light-colored, gray-to-white, and are totally without
cementation. There are two types: small patch ("knoll") reefs,
at most a few hundred feet across in the largest dimensions, and
barrier reefs extending for scores or hundreds of miles along the
edge of the basin. All of the reefs expanded by rigid accretions
of organic skeletons, which accumulated most rapidly along the
seaward margin, and grew basinward over their own talus deposits.
Direction and rate of reef growth were apparently controlled by the
rate of regional subsidence. In one of the barrier reefs (Goat
Serp) growth was essentially upward, and the reef did not spread
very far basinward. Apparently the rate of reef formation
barely kept pace with subsidence. Growth of the great Capitan
reef, on the other hand, was predominantly horizontal and basin-
ward, so that the entire belt of reef deposition migrated
several miles while it grew vertically about 1,300 feet. Accre-
tion at the reef front was rapid compared with the rate of
regional subsidence.

Shelf deposits immediately behind the reefs are composed of dolo-
mitized reef detritus. Shoreward the dolomite becomes microcrystal-
line, homogeneous, and usually unfossiliferous, and it intertongues
with gypsum and red sandstones. The crystalline fabric of the
dolomite is clearly the result of recrystallization, and the
primary texture of the sediment has been obliterated. There is no
evidence that the sediment was a primary precipitate of dolomite
case; it is more probable that it was a precipitate of calcium
carbonate. Distributions and types of fossils in this province
suggest that the environment was unfavorable for organisms a short
distance beyond the basin margin, and the associated evaporites
indicate that the shelf waters were hypersaline over large areas.

Normal dolomites immediately behind the Capitan barrier reef are characterized by rapid facies changes away from the reef margin. At a stratigraphic horizon there are belts of similar lithology which are roughly parallel to the margin of the shelf. Particular attention is given to facies changes in a representative dolomite of the Yates formation behind the Capitan reef in McKittrick Canyon. The dolomite thins shelfward from the reef margin and merges with terrigenous and evaporite rocks of the lagoon behind the reef barrier. Field and laboratory studies show that there are four facies in the following order of progression away from the reef: (1) reef-derived calcarenite (oolite) deposited in nearly normal marine waters immediately behind the reef; (2) pisolite facies deposited (possibly by algae) as lenses shelfward from the calcarenite under conditions unfavorable for most forms of life; (3) microcrystalline dolomite facies, probably precipitated inorganically as calcium carbonate in hypersaline waters some distance from the reef; and (4) fine-grained red siltstone and sandstone interbedded with anhydrite. These relationships are found in most of the shelf dolomites.

It is doubtful if the Delaware Basin is excelled anywhere in abundance and variety of primary sedimentary features related to depositional slopes. Structures caused by turbidity currents and contemporaneous deformation, such as slump folds, intrastratal flow structures, and great submarine slides, are abundant and well-exposed. Many of these structures are the results of oversteepening of the basin slopes, perhaps by downwarping and by reef growth.

Flanking deposits of reef-derived talus show clearly that the reefs were wave-resistant structures, ultimately reaching above wave base.

Magnesium content in the basin limestones decreases away from the margin. The fine-grained limestones of the Delaware Basin have been compacted in places, perhaps as much as 50 percent, and possibly the most calcareous quartz sandstones have also suffered slight compaction. It is impossible to determine at which stage compaction was largely completed. Flattened fossils on bedding planes of primary folds indicate that some of the compaction was completed at shallow depths beneath the sea floor. All of the limestones and dolomites are recrystallized, and primary textures in the finest-grained rocks are more or less obliterated. It may safely be assumed that recrystallization has resulted in a coarsening of crystalline texture; but, where gross textures were originally formed by bioclastic particles, there has been a progressive change from relatively coarse detrital fabric to a crystalline mosaic of finer grain.

Consideration of the regional stratigraphy of the Permian system in the southwestern United States, and the local characteristics of the rocks and fossils within and adjacent to the Delaware Basin, lead to the following paleoecologic conclusions:

- (1) The topography of the land surface was subdued, and the ubiquity of evaporites in the shelf area suggests that the climate of later Permian times was generally warm and dry.

(2) Permian terrigenous sediments throughout western Texas and southern New Mexico consist of remarkably clean, uniform quartz sandstone, most of which is angular, well sorted, and fine, coming within the range from coarse silt to fine sand. Somewhat larger, scattered, well-rounded, frosted grains are common, but they constitute only a negligible part of the total sediment. Beyond a distance of ten or twenty miles from the Delaware Basin, the sandstone gradually becomes red because of films of red iron oxide around the grains of quartz. Toward the margin of the basin the films of iron oxide become yellowish-brown, and within the basin the iron oxide has undergone redistribution, being concentrated in scattered pores between grains. These regional changes apparently are correlated with a gradient in the quantity of organic matter deposited in the sediments and a related gradient in the redox potential at the time of deposition. Evidently the red beds were deposited in a strongly oxidizing medium, whereas the dark sediments of the basin were deposited in a reducing environment. Most of the quartz sand, in all probability, was sorted, and in part may have been brought to the Permian seas, by the wind. It is almost impossible otherwise to understand the uniform spread, great thickness, and lack of recognizable sedimentary gradients in the sandstone.

- (3) Marine faunas of the reefs and basin deposits closely resemble contemporaneous faunas of the Tethyan seaway of the Eastern Hemisphere, and they are strikingly unlike faunas of high latitudes. This suggests that the Permian faunas of the Delaware Basin are representative of a circumtropical fauna. Permian reefs are known, for example, in Greenland, Germany, and England, but the contained faunas are quite unlike those of western Texas, the Mediterranean, and southern Asia.
- (4) The structural form of the Delaware Basin indicates that the Permian seas reached a maximum depth of about 1,800 feet. This conclusion is in accord with evidence that the bottom waters were stagnant throughout much of the history of the basin. The shelf seas were probably not more than a few tens of feet deep.
- (5) Extensive deposits of evaporites in the shelf province indicate an intermittent or continuous shelfward flow of surface waters from the Delaware Basin, and removal of basin water through an inlet probably at the south of the basin (Hovey Channel), a relationship recalling the Gulf of Karabugaz on the Caspian Sea. Accumulation of heavy waters in the depths of the Delaware Basin, derived in part from the shelf areas, may have impeded circulation and led to stagnation. Accumulation of hypersaline waters to threshold level was possibly responsible for dolomitization of the more permeable calcium carbonate sediments near the basin margin.

(6) Laminations in the basin rocks consist of alternating dark-colored laminae, rich in bitumen and algal (?) spheres, and light-colored laminae, containing less organic matter and relatively more quartz sand. The alternations in content of organic matter suggest productivity cycles of the phytoplankton.

(7) For the most part, the fossils of the basin rocks form thin beds and lenses of sorted, disarticulated, and broken brachiopods, bryozoans, calcareous algal (?) spheres, and abundant ammonoids. The ammonoids are most abundant in limestones of the deeper part of the basin, and they become rare near the basin margin. Where the ammonoid shells are crowded in the rocks, they include shells of many generations, which lived together and evidently were catastrophically exterminated together in mass mortality. Rock and fossil characteristics indicate low pH and negative Eh conditions on the basin floor during deposition of the Permian basin deposits.

(8) The Permian reefs were formed in the favorable shallow waters round the rim of the Delaware Basin by stromatolite-secreting algae, sycon calcareous sponges, massive bryozoans, and hydroceratines (?). Fusulines, brachiopods, bryozoans, crinoids, and other groups occupied the reefs in great profusion and added their skeletons to the calcareous deposits. The reefs were constantly bathed in surface waters of normal salinity and temperature flowing from the basin toward the evaporation pans of the shelf. The close association between reefs and deep basin deposits suggests that an upwelling of stagnant deep waters may have provided a particularly rich source of nutrient salts to the phytoplankton and reef-forming algae.

(9) At times, shoals of bioclastic lime sand were formed at the basin rim by rapid accumulation of the calcareous carbonate skeletons of invertebrates, chiefly crinoids. bank These/deposits are stratified and otherwise are not similar to reefs. They were not wave-resistant, and they lack the frame-building fossils of the reefs.

(10) For the most part, the rocks of the shelf province are poorly fossiliferous in the lower part and unfossiliferous in the upper part of the column. This is only partly a result of dolomitization and recrystallization. There are a few gastropods, brachiopods, scaphopods, and pelerypods, several of which also occur in the marginal and basin provinces. Evidently these forms were tolerant of a broad range of environmental conditions. Proximity to evaporite deposits suggests euryhalinity for the characteristic species of the shelf rocks. Groups which characteristically have always been stenohaline (corals, bryozoans, echinoderms, and ammonoids) are very poorly represented in the shelf faunas. Fossils and, in the beds of Capitanian age, dasycladacean algae are abundant in the calcarenite zone immediately behind the banks and reefs, but they do not extend far from the edge of the Delaware Basin."

Research Needs

Since the area within the proposed Guadalupe Mountains National Park has been studied quite intensively, a vast amount of information on the composition, stratigraphy and structure of the rocks of the area is available. Despite this, however, more geologic data of types helpful to area management is needed. For example, a comprehensive study of the hydrology and soils would provide information needed to effect the restoration of vegetative conditions as they were before the area was subject to grazing and other uses considered an adverse from the park management viewpoint. Further inquiry into the effects of glacial and postglacial climatic variations on area terrain and ecology also gives promise of yielding useful information.

King and others have pointed to the lack of information on physical and chemical conditions in relation to the deposition of the Permian sequence. The same paucity of data seems evident with respect to the age relationships among the major joint systems of the area.

These research needs are apparent from a review of past geological work and suggest projects which might be included in a recommended list for accomplishment in the immediate future.

Geologic Projects Recommended

1. Physical and chemical conditions in relation to deposition of Permian age deposits.
2. Hydrology and soils of southern Guadalupe Mountains in relation to vegetative cover.
3. Physiography of the Guadalupe Mountains with emphasis on that portion within the proposed Guadalupe Mountains National Park.
4. Critical study of age relationships among major joint systems of the southern Guadalupe Mountains area.
5. Relationship of glacial and postglacial climatic variations on area terrain and ecology of the southern Guadalupe Mountains.

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