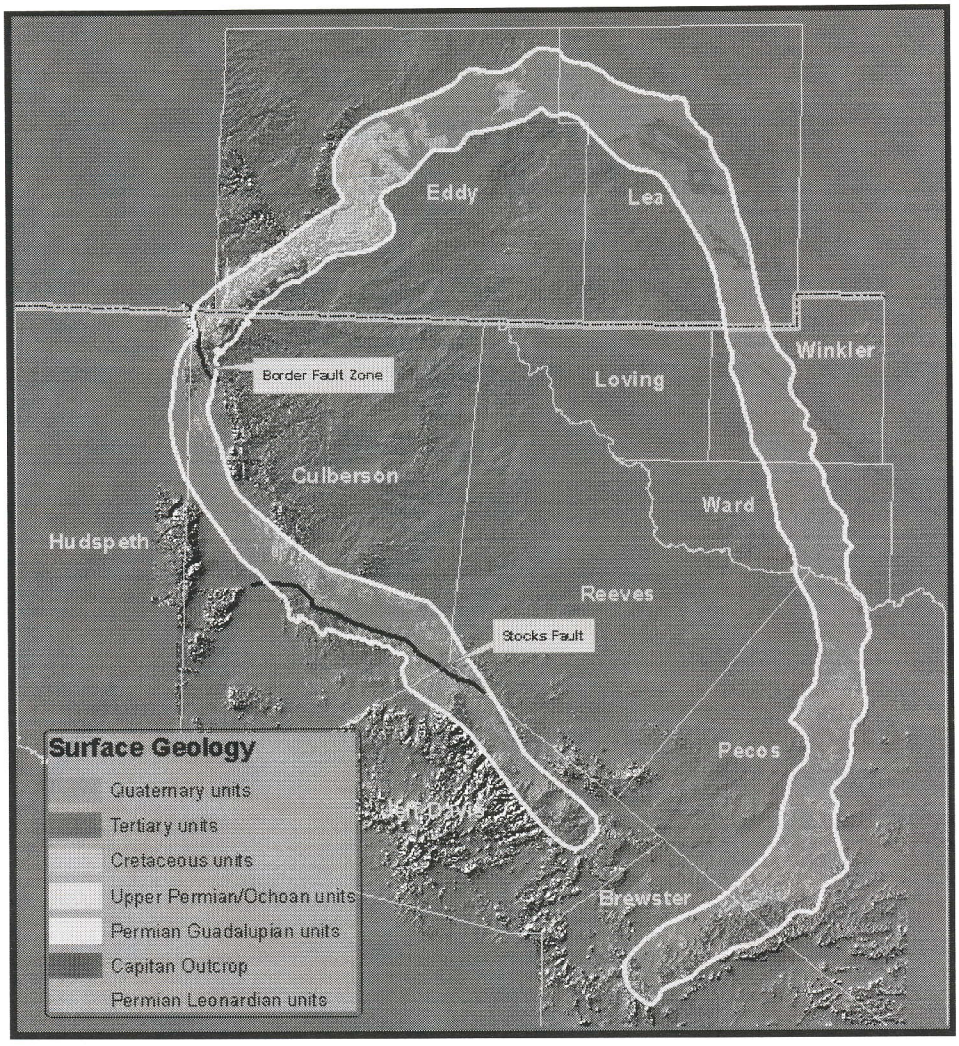
Capitan Reef Complex
Structure and Stratigraphy



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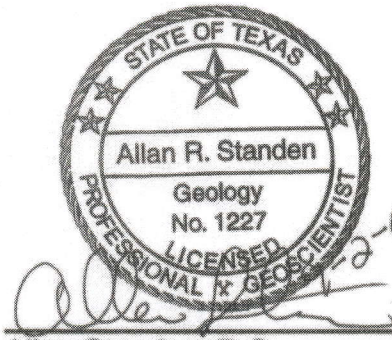

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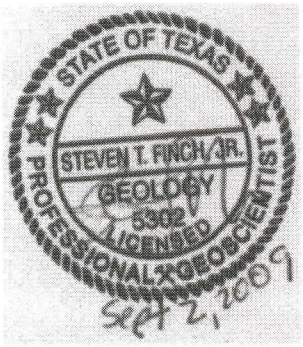

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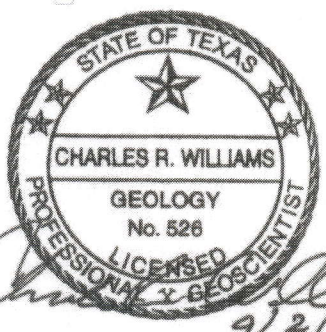

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3.1.1 Bone Spring Limestone

The Bone Spring Limestone is part of the Leonard Series, and consists predominantly of thin beds of cherty black limestone. Total thickness of the Bone Spring Limestone ranges between 1,500 and 2,000 feet. In general, these rocks are located basin-side and below the Capitan Reef Complex. In the western part of the study area, the distribution of the Bone Spring Limestone is complicated by the faulting associated with the Salt Basin. As a result of this faulting, rocks of the Bone Spring Limestone crop out along the western side of the Delaware Mountains. In Culberson County where the formation commonly crops out, the thickness of the Bone Spring Limestone varies from 900 to 1,700 feet (Dietrich and others, 1983).

West of the Capitan Reef Complex and toward the Delaware Basin fringe, the Bone Spring Limestone grades into the Victorio Peak Limestone (gray limestone) and the time-equivalent Yeso, Leonard and Hess Member of the Leonard Formation. The Bone Spring Limestone has been subdivided into two members, the Victorio Peak Member and the overlying Cutoff Shale Member. The Cutoff Shale Member is a black, platy, siliceous shale and shaly sandstone ranging from 50 to 150 feet in thickness (King, 1948). The Cutoff Shale Member forms a low permeability barrier between the underlying Victorio Peak Limestone and the overlying San Andres or Delaware Mountain Group stratigraphic equivalent (Table 1, Figure 3).

3.1.2 San Andres Formation

The San Andres Formation was deposited during Guadalupian time. The San Andres has been subdivided into the Upper and Lower San Andres formation (Ward and others, 1986; Kerans and others, 1994). The lower half is called the lower cherty limestone member and the top half is referred to as the upper non-cherty limestone member. Total thickness of the San Andres Formation is 700 to 1,000 feet. The San Andres Formation is a widespread shelf carbonate deposit found throughout most of New Mexico and west Texas. The lower member of the San Andres Formation grades downward forming an unconformity with the Cutoff Shale Member of the Bone Spring Limestone, Cherry Canyon, and Brushy Canyon Formations of the Delaware Mountain Group (Hill, 1996; Hiss, 1975; Kerans and others, 1994; Kerans and Tinker, 1999; Ward and others, 1986).

In the Delaware Basin, the San Andres Formation transition from shelf carbonate to reef environments is approximately 3 miles long and trends parallel to the Capitan Reef front (Hill, 1996; Hiss, 1975). In the reef margin, the San Andres Formation grades up into the Capitan Reef Complex (Table 1).

3.1.3 Delaware Mountain Group

The Delaware Mountain Group consists of several formations and members of the Guadalupe Series. Most of the Delaware Mountain Group includes formations that were deposited in the Delaware Basin at the same time that the Capitan Reef complex was being deposited on the basin margin (Table 1). Units include the Brushy Canyon, Cherry Canyon, and Bell Canyon Formations. Parts of the Brushy Canyon and Bell Canyon Formations were deposited prior to the formation of the Capitan Reef Complex (Hill, 1996; Hiss, 1975).

The Delaware Mountain Group consists primarily of interbedded sandstones, shales, and limestones. The sandstone beds are commonly massive basin-side and adjacent to the Capitan Reef Complex and thin toward the basin center.

The basal formation of the Delaware Mountain Group is primarily an interbedded coarse- to fine-grained sandstone and sandy shale unit with a maximum thickness of 1,000 feet (King, 1948). At the base of the Brushy Canyon is the persistent black platy Pipeline Shale interbedded with shaly sandstone, sandstone and limestone, and a basal conglomerate (King, 1948).

The Cherry Canyon member of the Delaware Mountain Group is primarily thin-bedded, with very fine-grained quartz sandstone and a few shale beds (Dietrich and others, 1983). The thickness of the formation is up to 1,000 feet (King, 1948).

The Bell Canyon Member of the Delaware Mountain Group is mostly very fine-grained sandstone with a thickness ranging from 670 to 1,000 feet (Dietrich and others, 1983). The Delaware Mountain Group is overlain by evaporites and carbonates of the Castile and Rustler Formations in the Rustler Hills east of the Delaware Mountains (Table 1, Figures 2 and 3).

The Word Formation is approximately time equivalent to the Delaware Mountain Group formations and is located in the Glass Mountains (Hill, 1996; Hiss, 1975). The Word Formation consists of siliceous shale, chert with very thin units of fossiliferous limestone, sandstone, and conglomerate with thickness up to 1,500 feet.

3.1.4 Capitan Reef Complex

For practical purposes, the Capitan Reef Complex Aquifer (Table 1) is defined as Permian carbonate reef-forming rocks that include the Goat Seep Limestone, Capitan Limestone, and Carlsbad Limestone (Hiss, 1975). In the eastern section of the Capitan Reef Complex near the Glass Mountains, equivalent rocks include the Vidrio and Tessey Formations described by King (1930) and Hill (1996). The Munn Formation underlies the Capitan Reef Complex in the Apache Mountains, is up to 450 feet thick and consists of primarily a thin-bedded dolomite and is stratigraphically equivalent to the Goat Seep Limestone and Vidrio (Barnes and others, 1968; Wood, 1968; Hiss, 1975).

Deposition occurred around the margin of the Permian Delaware Basin and on the edge of the northwestern shelf. Surface outcrops and subsurface expression of the Capitan Reef Complex in the Capitan, Apache, and Glass Mountains are shown on Figure 1. The arc-shaped reef structure is about 10 to 14 miles wide and is dissected by the Hovey Channel in Brewster County (Hill, 1996; Hiss, 1975).

The Capitan Reef Complex is composed of massive white to gray fossiliferous limestone beds. The limestone beds grade from fore-reef to back-reef deposits. The gradation into fore-reef deposits is typically abrupt, with a defined geologic contact, whereas the gradation into back-reef deposits is more transitional, with difficult to identify geologic contacts (Hill, 1996; Hiss, 1975).

The rocks that make up the reef complex have been locally dissected by faulting; consequently, they do not form one continuous aquifer but rather a series of disconnected highly permeable

aquifers (Hill, 1996; Hiss, 1975). For example, the uplifted Guadalupe Mountains divide the Capitan Reef Complex Aquifer into two separate disconnected aquifers (Figure 1): one that trends to the northeast and discharges to the Pecos River in New Mexico and one that originates along the western flank of the Guadalupe Mountains and flows south from the Patterson Hills southeast toward the Apache Mountains (Hiss, 1975; King, 1948).

3.1.5 Artesia Group

The Artesia Group includes the back-reef (youngest to oldest) Tansill, Yates, Seven Rivers, Queen, and Grayburg Formations (Table 1, Figures 2 and 3). (The term *Artesia Group* replaced the older Carlsbad Group nomenclature.) All of these formations gradually grade into the Capitan Reef Complex. The formations that make up the Artesia Group have rapid lateral facies changes with cyclic deposits of sandstone, sandy dolomite, and dolomite (Hill, 1996; Hiss, 1975). The Grayburg and Queen Formations grade into the Goat Seep Limestone, whereas the Seven Rivers, Yates, and Tansill Formations grade into the Capitan Limestone. Characteristics of these formations are:

- The basal formation of the Artesia Group is the Grayburg Formation, which overlies the San Andres Formation and underlies the Queen Formation, and consists of interbedded dolomite with thin layers of fine-grained sandstone. Total thickness of this formation is approximately 300 to 400 feet (Hill, 1996; Hiss, 1975).
- The Queen Formation is similar to the Grayburg Formation, but with a 100-foot-thick sandstone layer near the top of the formation with thin interbedded dolomite and shale. Because of this upper sand unit, the contact between the Queen and overlying Seven Rivers Formation is often identifiable (Hill, 1996; Hiss, 1975). This formation is up to 420 feet thick.
- The Seven Rivers Formation is a thin-bedded dolomite sandwiched between the upper Queen sandstone and the Yates sand. This formation laterally grades from evaporite to a carbonate facies as it grades into the Capitan Reef Complex. The bedding disappears as it grades into the Capitan Limestone. This formation is up to 500 feet thick (Hiss, 1975)
- The Yates Formation was named after the Yates Oil Field in Pecos County, and it is the most widespread horizon used for structure contouring in the Delaware Basin. The Yates Formation consists of siltstone and sandstone beds totaling approximately 300 to 400 feet in thickness near the reef margin (Hill, 1996; Hiss, 1975).
- The Tansill Formation conformably overlies the Yates Formation near the reef margin. East of the Guadalupe Mountains, the formation is overlain by the Ochoan time evaporites (Salado Formation). The Tansill Formation consists of gypsum, red clay, and silt (evaporite facies) that laterally grades into dolomite near the reef margin. The thickness increases from 100 to 300 feet near the reef margin (Hill, 1996; Hiss, 1975).

3.1.6 Castile and Salado Formations

During the Ochoan epoch, the Delaware Basin began to fill with evaporite deposits of the Castile and Salado Formations. In places, these evaporite deposits overlie the Capitan Reef Complex.

The Castile Formation is made up of gypsum, anhydrite, and intermittent, thin- to medium-bedded limestone. The thickness of the formation varies from 1,500 to 2,000 feet (Anderson and others, 1995; King, 1948). The dissolution and collapse of this formation has led to the development of cavernous features, including sink holes, springs, and brecciation of upper layers as they fell into caves and other dissolution features (King, 1948).

The Salado Formation is the second major basin-filling sequence of the Ochoan epoch following the Castile Formation. The Salado Formation is essentially a halite formation with supplementary beds of anhydrite, potash salts, and red sandy clay layers (Hill, 1996). Thickness of the formation is variable due to a combination of deposition location (basin, reef, and back-reef margins) and later dissolution. Thicknesses are typically 1,500 to 2,000 feet in the basin and less than 1,000 feet where the salt beds overlie the Tansill Formation on the shelf (on top the former reef and back-reef margins (King, 1948).

3.1.7 Rustler Formation

The Rustler Formation was deposited in the Delaware Basin and consists of deeper water carbonates with inter-layered sand, siltstone, and shale. Salts such as anhydrite, gypsum, and halite (rock salt) formed after the basin filled in (King, 1948). The Rustler Formation is of the Ochoan epoch and overlies the Capitan Reef Complex in Pecos County, west of the Hovey Channel (Figure 1).

3.1.8 Triassic Bissett Conglomerate

In the Glass Mountains area, the Capitan Reef Complex is covered by the Bissett Conglomerate, which consists of calcareous limestone and dolomite pebbles and cobbles interbedded with crystalline dolomite. The Bissett Conglomerate thickness is up to 740 feet (King, 1937).

3.1.9 Cretaceous Formations

In the Glass Mountains area, the Capitan Reef Complex is covered by Cretaceous limestone and sandstone. Thick sequences of thin-bedded Cretaceous rocks are found in the Hovey Channel between the Davis and Glass Mountains (Hill, 1996; King, 1930). North of the Davis Mountains, the Cretaceous Buda, Boquillas, and Washita Formations overlie the extended outline of the Capitan Reef Complex.

3.1.10 Quaternary-Tertiary Sedimentary Deposits and Volcanics

The Salt Basin forms a valley that extends from just north of the Texas-New Mexico state line into Culberson County (Figure 1). Within the study area boundary, the areal extent of Salt Basin sediments north of Wild Horse Flat total about 106 square miles. In the northern part of Culberson County, the Salt Basin is bounded on the west by the Diablo Plateau and Sierra Diablo Mountains and on the east by the Guadalupe and Delaware Mountains (Angle, 2001).

Regional basin and range extension (pulling apart of the earth's crust) provided the mechanism for the collapse of the Salt Basin Graben and the uplift of the mountains to the east and west. The thickness of Salt Basin sediments (Table 1) was first mapped by Gates and others (1980),