East Vacuum Grayburg San Andres Unit Geologic Overview

May 19, 2016

Subsurface Description of the San Andres

The East Vacuum Grayburg San Andres Unit in southeastern New Mexico was unitized in 1978 with the aim of flooding the unitized interval. The producing formation is mainly the San Andres with some wells also being completed in the Grayburg formation. Although surrounding units began water injection at an earlier date, waterflooding in EVGSAU did not begin until 1980. The goal of waterflooding was to displace oil and increase reservoir pressure in preparation for CO2 flooding. CO2 injection began in 1985 with a WAG ratio of 2:1. CO2 flooding has continued since that time and has recovered in the range of 12.5 % OOIP in the unit overall. Oil recovery from CO2 flooding has been better than expected even with the adverse mobility ratio of CO2.

1. EVGSAU Geologic Setting

The Vacuum Field is located on the Northwest shelf of the Permian Basin in Lea County, New Mexico, about 15 miles northwest of Hobbs (Figure 1). The field consists of the Central Vacuum Unit (CVU) on the west and the East Vacuum Grayburg San Andres Unit (EVGSAU) on the east, covering more than 7000 acres. The Vacuum Field produces from several formations, but the primary productive interval is the San Andres formation. To date, the majority of the production has been from the upper few hundred feet of the San Andres Formation, which is mainly composed of dolomitized carbonate sequences. More recently, the lower San Andres has contributed to overall oil production through a Transition Zone/Residual Oil Zone tertiary recovery project, which will be discussed in a later section.

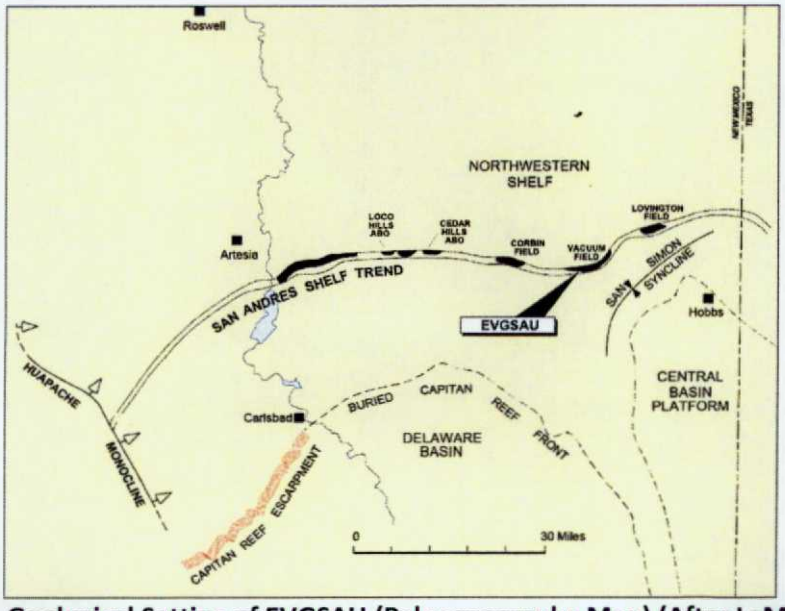

Figure 1 – Geological Setting of EVGSAU (Paleogeography Map) (After LeMay, 1972)

The Permian Basin is composed of a series of northwest/southeast trending structural platforms and basins that were created during Late Mississippian to Late Pennsylvanian, during the generation of the Ouachita-Marathon fold and thrust belt. The New Mexico portion of the Permian Basin is sub-divided into the Northwestern Shelf, Central Basin Platform, and Delaware Basin. EVGSAU is located on the northern

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margin of the Permian Basin, known as the Northwestern Shelf (Figure 1). The Vacuum Field is located just northwest of the Central Basin Platform, at the western edge of the shallow San Simone Channel that separated the Northwest shelf from the Central Basin Platform.

2. Reservoir Lithofacies and Stratigraphy

The San Andres formation is representative of a shallow marine, carbonate ramp/shelf system with the depositional geometry controlled by eustatic sea level fluctuations. Within EVGSAU, the San Andres reservoir is composed of two major, fining upward, higher-order composite sequences. These major sequences are subdivided into a series of repeated, anhydritic, dolomitized, carbonate successions in which subtidal grain-rich lithofacies grade upward into peritidal mud-rich carbonates and siliciclastics (Siemers, 1996). The field grades laterally with shallow-water, peritidal deposits dominating the lithofacies in the north, grading to the south into more high-energy, subtidal shelf margin and open water carbonate ramp lithofacies. The subtidal, grain-rich carbonate facies deposited proximal to the margin of the carbonate shelf form the primary reservoir-producing units. The mud-rich lithofacies are generally considered to be non-productive and in most cases present a baffle to vertical flow. Across the northern and central portion of the field, the San Andres Formation is divided into an Upper and Lower member by the Lovington Sandstone Member, which is a 40 to 50 feet thick, siliciclastic tidal flat sequence most likely deposited during a sea level low stand (Siemers, 1996). The Lovington member pinches out to the south, resulting in the division of the Upper and Lower San Andres becoming less defined closer to the shelf margin (Figure 2). EVGSAU produces from the Upper and Lower San Andres, where the Lower San Andres is above the current oil/water contact.

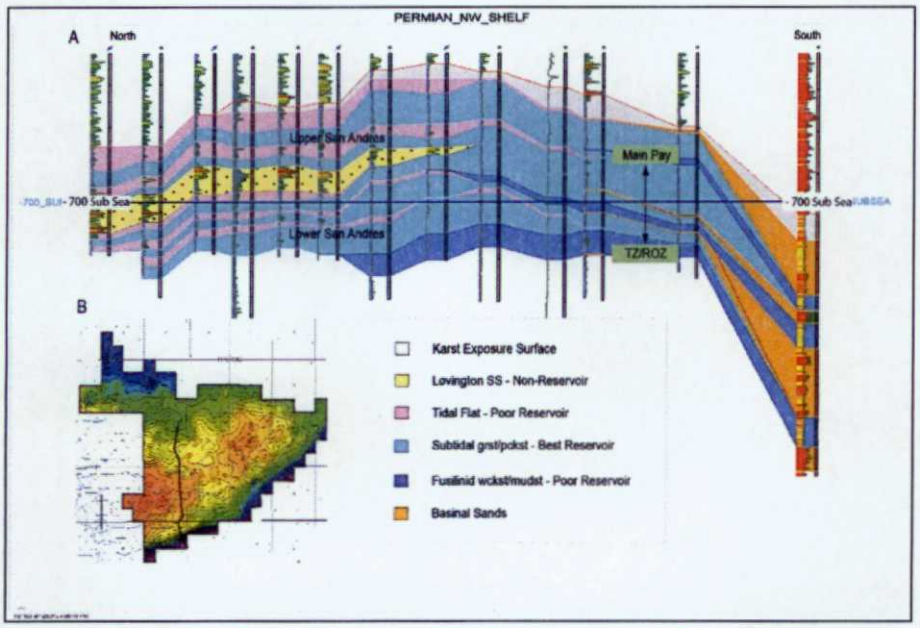

Figure 2 – Cross Section of EVGSAU Producing Formations

3. Reservoir Diagenesis and Porosity

Primary depositional lithofacies and fabrics strongly control the diagenetic sequence within the EVGSAU San Andres reservoir during burial and subsurface diagenesis. The diagenetic history was documented to consist of: 1) intense dolomitization of the existing carbonate material accompanied by some leaching of

calcareous skeletal grains, 2) precipitation of very fine to medium grained dolomite cement, 3) differential and locally intense replacement and cementation of carbonate by anhydrite, 4) authigenic quartz overgrowth on detrital terrigenous clastic lithofacies, 5) dissolution of unstable dolomite crystal cores and partial replacement of anhydrite to gypsum, and 6) the formation and occurrence of dead oil (Siemers, 1996). Anhydrite is the primary factor that determines reservoir quality due to its abundance, but is differentially distributed throughout the reservoir.

Porosity development within the reservoir occurred during three periods, each forming distinct pore groups within the subtidal, grain-rich lithofacies: 1) primary porosity that was preserved at the time of deposition and enhanced by early-stage dissolution, 2) grain-moldic, vuggy and intercrystalline porosity resulting from dolomitization of the original carbonate lithofacies and 3) secondary grain-moldic, vuggy and dolomitic porosity formed during late-stage burial diagenesis and dissolution (Siemers, 1996). The high-quality grain-rich lithofacies have an average porosity of 13% while permeability averages around 95 md. Solution enhancement of the pore system is more pervasive in the Upper San Andres section and may be further enhanced by the leaching of anhydrite during waterflooding.

I have examined the available geologic and engineering data and have found no evidence of open faults or any other hydrologic connection between any underground sources of drinking water and the injection zone for the proposed injection wells.

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Date