

A COMPARISON OF THE DEPOSITIONAL ENVIRONMENT  
OF THE SAN ANDRES FORMATION IN THE PALO DURO BASIN  
TO RECENT EVAPORITIC ENVIRONMENTS

by

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# A Comparison of the Depositional Environment of the San Andres Formation in the Palo Duro Basin to Recent Evaporitic Environments

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The safe storage of high-level radioactive waste in a geologic repository requires a detailed knowledge of the properties of the host rock and surrounding beds, and the continuity of these properties. One of the serious problems faced in the characterization of the deep formations under consideration is that sufficiently detailed descriptions cannot be obtained from the small number of widely spaced test holes available. The examination of modern analogs to the formation under consideration can provide important insights into geochemical characteristics and their degree of continuity.

The first step in identifying a natural analog is to adequately describe the formation of interest and to determine its environment of deposition. The formation under consideration in the Palo Duro Basin, the San Andres Formation, has been described elsewhere (Presley, 1979 a & b; 1980 a & b, 1981; Presley and Ramondetta, 1981; Ramondetta, 1981; Handford, 1981 a & b; Handford and Wiggins, 1981; Bassett and Palmer, 1981; Bassett and Roedder, 1981; Budnik and Smith, 1982; Roedder, 1982). In the Palo Duro Basin, the San Andres Formation is an evaporite sequence containing halite, anhydrite, carbonates, and mudstones. The lithology of the San Andres and the stratigraphic sequence prior to San Andres deposition indicate that the formation was deposited at the end of a long-term shift from fan-delta, marine shelf, and deep-basin environments during the Pennsylvanian to shallow marine, brine pan, and evaporite conditions during Late Permian time. A modern analog environment should be located in a relatively shallow basin that has already been filled by marine sedimentation

and is now a broad shelf undergoing long-term oceanic regression and slow subsidence.

More specifically, an analog to San Andres deposition would be found in a marine setting capable of depositing laterally and vertically extensive halite beds. Laterally extensive beds can result from continued marine regression and/or occasional high tides across areas of low topographic relief. Vertically extensive beds require a slowly subsiding basin and maintenance of arid climatic conditions over a long period of time. Another requirement for the analog environment is a continental influence, indicated both by paleogeographic reconstructions of the Permian (Handford, 1981b) and the relative humidity control on evaporite facies (Kinsman, 1976).

The San Andres evaporites define a unique environment for which there is no current equivalent. Though the San Andres halites were not deposited in a true sabkha setting, the sabkha environment is the closest modern analogy. Studies of modern sabkha environments (Butler, 1969 a & b, 1970; Kinsman, 1966) reveal many similarities in stratigraphic succession, mineralogy, and sedimentary structures between present-day sabkhas and evaporite facies in the Palo Duro Basin (Presley, 1979 a & b; Handford, 1981b). Two modern sabkhas have been examined in some detail: the Trucial Coast along the Arabian Gulf, and the Salina Ometepe near San Felipe, Mexico, along the Gulf of California. Both of these modern sabkhas are the result of advancing continental deposits with concomitant oceanic regression. The San Felipe site differs from the evaporites of the San Andres in that it is developed primarily on continental clays and silts (Butler, 1969a). Though the Trucial Coast has continental sabkhas developed on sandstones, its marine sabkhas, like the evaporites of the San Andres, are developed primarily on marine carbonates (Kinsman, 1966).

The mineralogy of the San Andres evaporites more closely resembles the Salina Ometepec sediments than those found on the Trucial Coast. The Trucial Coast sabkhas are dominated by carbonate and calcium sulfate minerals; although halite does occur, it is not abundant. Layered halite beds are characteristic of the San Felipe evaporites with volumetrically insignificant calcium sulfate minerals (Butler, 1969a).

The prominent occurrence of halite in the evaporite mineral assemblages of the San Andres and the Salina Ometepec indicates that, geochemically, the San Andres is best represented by a setting like the Salina. However, in sheer size, the Palo Duro Basin deposits are better represented by a setting like the Arabian Gulf. Estimates of the size of the combined coastal and continental sabkhas of the Trucial Coast range from 8,000 to 10,000 km<sup>2</sup> (Kinsman, 1969). The sabkhas found near San Felipe can only develop as thin coastal bands due to the high topographic relief encountered inland.

Despite the size of the Trucial Coast sabkhas, there are no areas of recent evaporite deposition that are comparable in size to the Palo Duro Basin deposits. Individual cycles in the San Andres can be traced over areas from 16,000 to 26,000 km<sup>2</sup> and are from 2 to 90 m thick (Fracasso and Hovorka, in prep.). The possible extent of evaporite environments is primarily related to the original physiography and geometry of the depositional surface: the large, shallow epicontinental seas, characteristic of the Permian, do not exist today. Laterally extensive deposits might develop in a setting such as the Trucial Coast if there were long-term fluctuations in sea level. Vertically extensive deposits would only develop through time in a slowly subsiding basin. Basin subsidence and sea-level fluctuations are difficult to judge on a geologic time scale when observing modern evaporite environments. However, if deposits similar to those of the Palo Duro Basin are currently being created, they will have

to undergo extensive growth to rival the ancient deposits in size. All modern evaporite environments studied to date are relatively thin, near-surface features and do not extend for any great depth into the subsurface.

Despite the problem of the relative sizes of the deposits, strong similarities exist between the geochemical settings of San Andres evaporite deposition, the Trucial Coast sabkhas, and the Gulf of California environment. Comparisons of a few characteristics of geochemical interest will now be examined between the San Andres Formation and modern sediments in the Salina Ometepec and the Trucial Coast.

#### Strontium in Gypsum and Anhydrite

The strontium content of gypsum and anhydrite is controlled by the Sr/Ca ratio in the solution and the distribution coefficient of strontium in each mineral. Because gypsum and anhydrite have different distribution coefficients, the amount of Sr in a sulfate mineral can be used to help determine whether anhydrite was precipitated directly from solution, or was formed diagenetically by the alteration of gypsum. Using the distribution coefficients derived by Butler (1973), and assuming a range of Sr/Ca in the mother brine between that found during dolomitization (0.010) and that found during aragonite, gypsum, and halite saturation (0.022), the range of Sr values in gypsum is found to be 400 to 1,000 ppm and the range for Sr in anhydrite precipitated from solution is 1,050 to 2,400 ppm. Anhydrite formed by the diagenesis of gypsum will usually be characterized by depleted Sr values (Kushnir, 1982).

Butler (1973) analyzed sulfates from the Trucial Coast and found Sr values ranging from 410 to 1,100 ppm, depending on grain size, for gypsum, and a value of 2,260 for anhydrite precipitating from solution. Samples from San Felipe yielded a value of 790 ppm Sr for gypsum and 1,150 ppm Sr for anhydrite

(Butler, 1973). Butler attributed the lower anhydrite value found in San Felipe to the minerals' formation in a marginally stable environment.

The Sr values found in anhydrite from the San Andres Formation from the DOE-Gruy Federal #1 Grabbe Core Test Well, Swisher County, range from 1,257 to 2,835 ppm (Bein and Land, 1982). Values from the DOE-Gruy Federal #1 Rex White Core Test Well range from 1,270 to 2,390 ppm Sr in the San Andres anhydrites. All of these values lie well within the range expected for primary anhydrite. Nineteen of the twenty-three analyses also fall between the value determined for San Felipe anhydrite and that determined for Trucial Coast anhydrite. There is a wide variation in strontium content over small depth ranges in the #1 Grabbe core (1,448 ppm in 37 feet) that may reflect changing amounts of dolomitization. An investigation into the vertical variability of strontium in anhydrites from recent sabkhas may shed more light on the subject.

#### Bromide in Halite

The bromide content of halite is widely recognized as an indicator of the salinity of the water which precipitated halite and as a clue to the possible dissolution and recrystallization of halite (Raup and Hite, 1978). Analyses performed thus far on cores retrieved from the Palo Duro Basin record bromide values generally greater than 60 ppm for halite from the Lower San Andres Formation. These values indicate that halite saturation persisted throughout deposition of the unit without significant decreases in brine salinity and that the salt beds have not undergone significant post-depositional remobilization.

No bromide values for halite from the Trucial Coast could be found, probably because investigations in that area have not centered on the ephemeral and volumetrically insignificant halite. Holser (1966) analyzed 26 halite samples from the Salina Ometepe and found a range of 100-195 ppm Br in 25

samples, and a value of 50 ppm for one sample. The low value is considered to be a recrystallized sample. The range of bromide values found in the Lower San Andres generally agrees with the range found in the Salina Ometepec. If further investigation proves that halite found in modern evaporites tends to have higher bromide values (190-300 ppm Br), it could have important implications for the possibility of past recrystallization of San Andres bedded salt.

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