

Secondary Anhydrite From a Sabkha, Northwest Gulf of California, Mexico

Godfrey P. Butler
Esso Production Research Company
Post Office Box 2189
Houston, Texas

ABSTRACT

Sediments derived from the Colorado River and from outwash fans make up an extensive supratidal flat or sabkha in the northwestern corner of the Gulf of California. Gypsum, anhydrite and halite are found associated with reddish silty quartz sands, silts and clays. Development of the calcium sulphate minerals is restricted to a narrow zone at the landward margin of the supratidal flat, where they occur within the upper 10 to 15 cm of sediment.

Anhydrite, associated with gypsum and bassinite, is found within the upper 5 cm of sediment. It occurs as small (≤ 3 mm) irregular nodules and as blebs of felty crystal aggregates in layers 1 to 2 cm thick.

In August 1968, surface temperatures of 51°C were recorded in the gypsum and anhydrite sediments. Temperatures at a depth of 15 cm were between 38°C and 40°C. Two samples of brine collected immediately beneath the evaporites had chlorinities of approximately 143‰ and 145‰.

Comparison of the calcium sulphate mineral assemblage, brine chlorinity and strontium content of coexisting gypsum and anhydrite with that of similar data from a Trucial Coast sabkha in the Arabian Gulf, suggests that the anhydrite is a secondary mineral and after early diagenetic gypsum.

INTRODUCTION

This paper briefly describes an occurrence of gypsum and anhydrite in a supratidal flat or sabkha environment along the northeastern coast of Baja California. The data presented are the result of a

reconnaissance study of a small portion of the supratidal flat. However, the development of anhydrite in the area studied is considered typical of the supratidal flat as a whole.

The environment is similar in terms of the physicochemistry and hydrology to that of a Trucial Coast sabkha in the Arabian Gulf. In contrast to the Trucial Coast, the development of calcium sulphate minerals in the Gulf of California is volumetrically insignificant, and the host sediments are almost totally of continental origin. The occurrence of these minerals is of interest in that comparisons can be made between the diagenetic processes occurring in the two areas.

THE ENVIRONMENT

Description of sediments and evaporites.

The area studied is about 48 km north of San Felipe (Fig. 1). The sedimentology of the supratidal flats has been described by Walker and Thompson (1968) and Thompson (1969). The occurrence and origin of the anhydrite has been briefly discussed by Kinsman (1969, and *in* Holliday, 1968). Kinsman considered the anhydrite to have formed as an interstitial primary precipitate, although no supporting evidence was given for his conclusion.

The supratidal flats are considered to have formed by a process of depositional regression (Walker and Thompson, 1968) and in their broadest parts are up to 30 km wide. The sediments have been derived from the Colorado River and from large alluvial outwash fans debouching from volcanic and metasedimentary rocks to the west. The sediments consist of clays and silts which

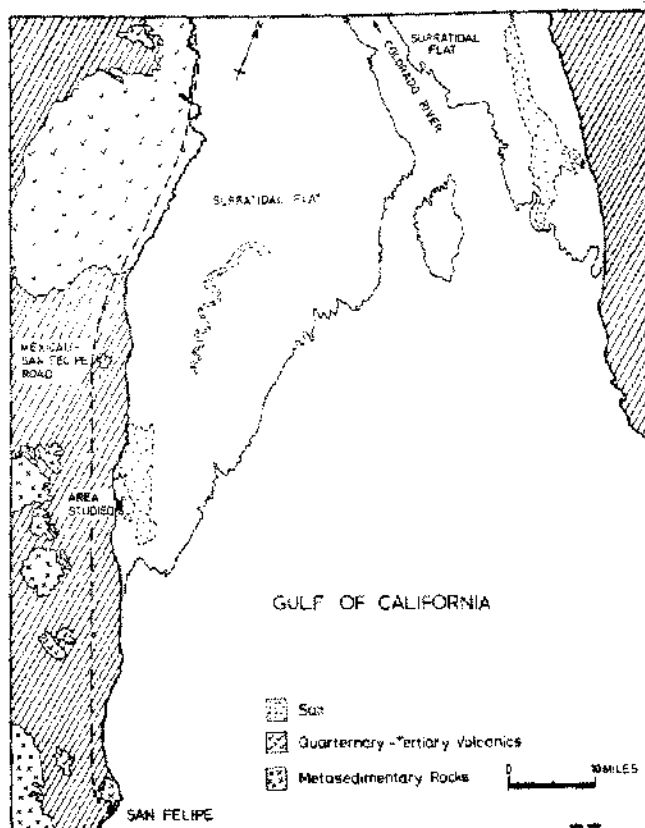


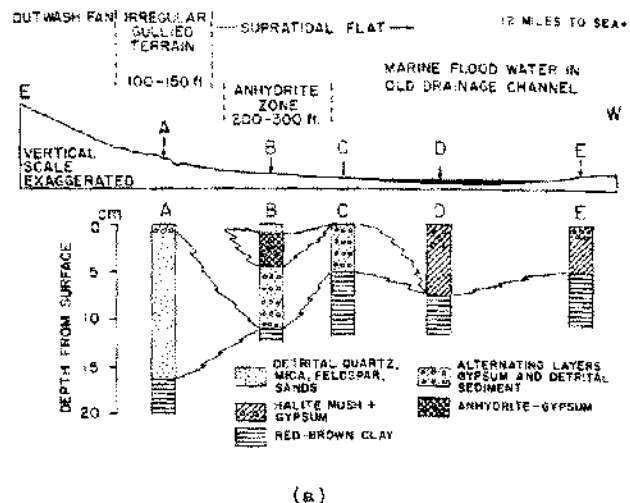
Figure 1. Location map of northern portion of Gulf of California and supratidal flats. Diagonal shading to the west indicates alluvial outwash fans; and to the east, sand dunes.

include quartz, biotite, feldspar and, in trace amounts, calcite and aragonite.

The surface of the supratidal flat is uneven and the depressions serve as catchment areas for marine floodwaters. Evaporation of these waters has given rise to surface beds of layered halite, up to 23 cm thick and covering an area in excess of 75 km² (Fig. 1).

Gypsum and anhydrite are developed within the upper 10 to 15 cm of sediment within a narrow zone at the landward margin of the supratidal flat (Fig. 2a). Gypsum occurs as 1 to 2 cm thick layers alternating with detrital sediments or dispersed in halite layers. Two habits of gypsum crystals occur. Crystals are either prismatic or discoidal and ≤ 2 mm long. In most cases they are free from inclusions but some crystals contain biotite fragments and carbonate, whereas others are zoned or made cloudy with halite.

Anhydrite is always found associated with gypsum but is patchily distributed. It occurs as



(b)

SAMPLE	pH	T°C	sp.gr	Cl%	gm/kg			mol Mg/L
					SO ₄	Mg	Ca	
B1 MARINE FLOOD WATER	7.7	42	1.198 (x 7.95)	154.0 (x 7.95)	10.91 (14.28)	18.62 (27.85)	0.933 (2.85)	2.2
B2 GROUND WATER FROM ANHYDRITE ZONE	—	—	1.183 (x 7.38)	142.8 (x 7.38)	0.98 (14.53)	14.91 (23.12)	0.788 (2.68)	31.1
B3 GROUND WATER FROM ANHYDRITE ZONE	7.0	30	1.186 (x 7.51)	155.7 (x 7.51)	9.856 (13.64)	13.60 (17.49)	1.26 (4.17)	17.9
NORMAL SEAWATER			1.024 (x 1.00)	19.45 (x 1.00)	2.712 (28.28)	1.294 (53.25)	0.413 (10.30)	5.1

Figure 2. (a). Schematic cross section and stratigraphic sections landward edge of San Felipe sabkha. (b). Analysis of surface pore water (B1, from location D, Fig. 2a) and of groundwater immediately below sediment containing gypsum and anhydrite (B2, B3). Values in parenthesis are concentrations in m.mol/kg relative normal sea water.

small (≤ 3 mm diameter) irregular nodules or blebs of felty crystal aggregates which make up near surface layers 1 to 2 cm thick (see Butler, this publication, Fig. 25a). Alternatively, it occurs as laths disseminated in gypsum layers. Anhydrite laths are commonly ≤ 2 microns long. X-ray analysis of anhydrite coexisting with gypsum indicates that bassinite is present in trace amounts.

Physicochemistry.

Surface temperatures of approximately 51° were recorded in August (1968) in sediments containing gypsum and anhydrite. Temperature ranged from 38°C to 40°C at a depth of 15 cm.

Two samples of brine collected immediately below the near surface gypsum and anhydrite had a pH of about 7, chlorinities of 142.8‰ and 145.3‰ and Mg/Ca ratios of 17.9 and 31.1. A sample of brine from a brine pond just to the seaward of the anhydrite zone had a chlorinity of 154.0‰ and Mg/Ca ratio of 23.2 (Fig. 2b).

The variability in the chemistry of groundwaters, notably with respect to Mg concentrations, may be the result of mixing of brines from episodic flooding, or to some contribution from continental drainage waters.

Strontium in gypsum and anhydrite.

Gypsum contained between 0.072 and 0.084 wt percent Sr with an average for five samples of 0.075 wt percent Sr (3.15×10^{-3} and 3.61×10^{-3} Sr/Ca; average 3.38×10^{-3} Sr/Ca). Anhydrite contained between 0.099 and 0.124 wt percent Sr with an average for five samples of 0.115 wt percent Sr (3.37×10^{-3} and 4.23×10^{-3} Sr/Ca; average 3.91×10^{-3} Sr/Ca). Analysis for Sr was made with a Perkin-Elmer Model 290 Atomic Absorption Spectrophotometer. Data are accurate to within ± 0.004 wt percent Sr.

CONCLUSIONS

The crude layering of gypsum crystals probably reflects an origin by precipitation from seawater episodically flooding the supratidal flat during storms. The compositions of brines are consistent with gypsum precipitation. Concentrations of Ca and SO_4 (relative to normal seawater) indicate that Ca has been reduced by about 9 m.mol/kg and SO_4 by about 14 m.mol/kg (Fig. 2b).

Anhydrite coexisting with gypsum has formed either as a primary precipitate, or as a secondary mineral by the reaction of gypsum with brines. Data which suggest a secondary origin for the anhydrite is as follows:

(1) Gypsum and anhydrite coexist with bassinite. A similar association has been described from the Trucial Coast (Butler, 1970) where textural relationships indicate that some gypsum alters to anhydrite via intermediary bassinite.

(2) Gypsum and anhydrite are closely associated with brines of chlorinity 142.8‰ and 145.2‰. In the Trucial Coast, gypsum and anhydrite equilibrium occurs in brines with chlorinity of approxi-

mately 145‰. Thus the supratidal anhydrite in the Gulf of California appears to have developed under marginal conditions for its formation and preservation.

(3) It has been estimated from distribution coefficients for anhydrite and gypsum and Sr/Ca ratios in brines, that at chlorinities of about 145‰, anhydrite formed by reaction of gypsum with brine should have a Sr/Ca ratio differing from the gypsum by about +15 percent (Butler, 1970). The difference in Sr/Ca ratios in coexisting anhydrite and gypsum from the Baja supratidal flat is about +13 percent.

In summary, Holocene diagenetic anhydrite of marine origin has so far been found in two areas of the world; along the Trucial Coast and along the coast of Baja California. In both environments the anhydrite appears to be of secondary origin with early diagenetic gypsum providing the bulk of the components for its formation. Anhydrite nodules are interpreted as a consequence of the alteration of gypsum to anhydrite. Furthermore, components for evaporite formation are largely derived from surface marine floodwaters in both environments.

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