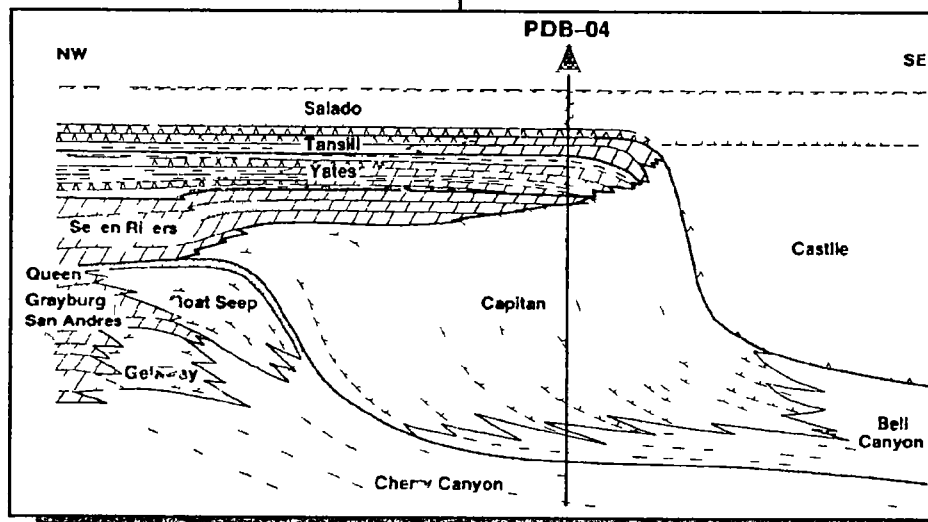
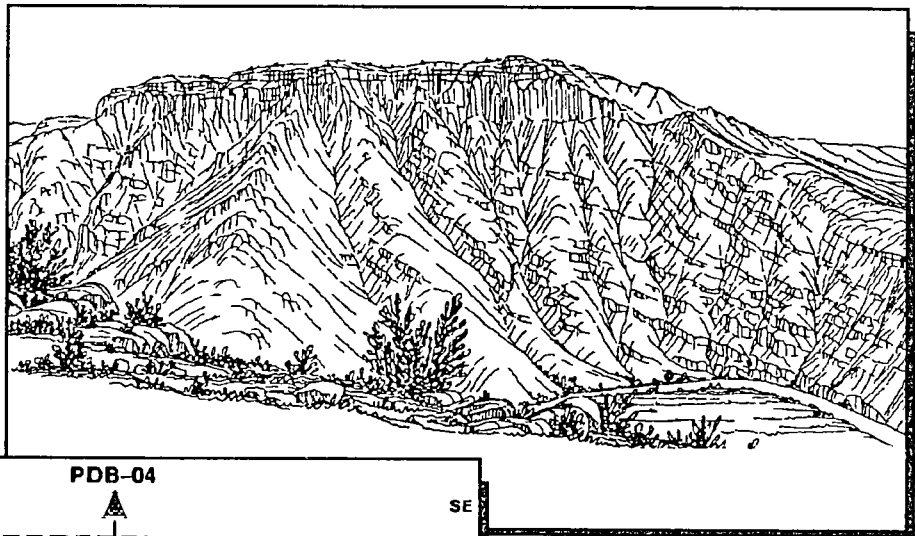


10/10/15

# Subsurface and Outcrop Examination of the Capitan Shelf Margin, Northern Delaware Basin



SEPM Core Workshop No 13  
San Antonio, April 23, 1989

OCD Case# 15307  
Oasis Water Solutions LLC  
September 17 2015  
Ex# 14

# Subsurface and Outcrop Examination of the Capitan Shelf Margin, Northern Delaware Basin

Organized and Edited

By

**Paul M Harris**

and

**George A Grover**

SEPM Core Workshop No 13  
San Antonio, April 23, 1989

## TABLE OF CONTENTS

### PART 1

- GEOLOGY OF THE CAPITAN SHELF MARGIN - SUBSURFACE DATA FROM  
THE NORTHERN DELAWARE BASIN  
By R A Garber, G A Grover, and P M Harris 3

### PART 2

- LATERAL VARIABILITY OF THE CAPITAN REEF COMPLEX, WEST TEXAS  
AND NEW MEXICO  
By L C Pray 273

- CHARACTERIZATION OF AN UPPER GUADALUPIAN BARRIER-ISLAND COM-  
PLEX FROM THE MIDDLE AND UPPER TANSILL FORMATION (PERMIAN),  
EAST DARK CANYON, GUADALUPE MOUNTAINS, NEW MEXICO  
By M J Parsley and J K Warren 279

- STACKED ISLAND FACIES IN TANSILL OUTER-SHELF PLATFORM, DARK  
CANYON, GUADALUPE MOUNTAINS, NEW MEXICO  
By S J Mazzullo, W D Bischoff, and C L Hedrick 287

- PERITIDAL FACIES OF THE GUADALUPIAN SHELF CREST, WALNUT CAN-  
YON, NEW MEXICO  
By D G Neese 295

- DEPOSITIONAL FACIES AND CYCLES IN YATES FORMATION OUTCROPS,  
GUADALUPE MOUNTAINS, NEW MEXICO  
By J M Borer and P M Harris 305

- SHALLOW MARINE SHEET SANDSTONES, UPPER YATES FORMATION,  
NORTHWEST SHELF, DELAWARE BASIN, NEW MEXICO  
By M P Candelaria 319

- FACIES MOSAIC OF THE LOWER SEVEN RIVERS FORMATION,  
MCKITTRICK CANYON, NEW MEXICO  
By N F Hurley 325

- STRATIGRAPHY AND SEDIMENTOLOGY OF THE BACK-REEF UPPER QUEEN-  
LOWER SEVEN RIVERS STRATA, GOAT SEEP-CAPITAN REEF COMPLEXES  
(MIDDLE-LATE GUADALUPIAN, PERMIAN), SOUTHEAST NEW MEXICO  
By J F Sarg 347

- STRATIGRAPHY AND SEDIMENTOLOGY OF THE SHATTUCK MEMBER (QUEEN  
FORMATION) AND LOWERMOST SEVEN RIVERS FORMATION (GUADALUP-  
IAN), NORTH MCKITTRICK AND DOG CANYONS, GUADALUPE MOUNTAINS,  
NEW MEXICO AND WEST TEXAS  
By C Wheeler 353

# TABLE OF CONTENTS (contd )

## PART 2 (contd )

THE MASSIVE FACIES OF THE CAPITAN LIMESTONE, GUADALUPE MOUNTAINS, TEXAS AND NEW MEXICO By J A Babcock and D A Yurewicz	365
GOAT SEEP - PRECURSOR TO THE CAPITAN By G A Crawford	373
LARGE-SCALE CHANNEL DEVELOPMENT WITHIN THE CAPITAN REEF COMPLEX - EVIDENCE FROM CARLSBAD CAVERNS By G M Harwood	379
DIAGENESIS OF THE CAPITAN LIMESTONE, UPPER PERMIAN, MCKITTRICK CANYON, WEST TEXAS By D H Mruk	387
DOLOMITIZATION MODEL FOR THE FOREREEF FACIES OF THE PERMIAN CAPITAN FORMATION, GUADALUPE MOUNTAINS, TEXAS-NEW MEXICO By L A Melim and P A Scholle	407
AN INVESTIGATION OF THE USE OF PALEOMAGNETIC TECHNIQUES IN A CARBONATE TERRANE - THE CAPITAN REEF COMPLEX, SOUTHWESTERN U S A By G Darke	415
SIMULATION OF THE CAPITAN SHELF MARGIN (LATE PERMIAN, GUADALUPIAN) OF WEST TEXAS/NEW MEXICO, A RESPONSE TO EUSTATIC CHANGE AND AN EXAMPLE OF THE USE OF SEDPAK By C G St C Kendall, J Strobel, J Tang, P Moore, R Cannon, J Bezdek, and G Biswas	423
SUBAQUEOUS GRAVITY FLOWS IN THE RADER MEMBER, CAPITAN REEF COMPLEX (PERMIAN), DELAWARE MOUNTAINS, WEST TEXAS By E C Lawson	427
CARBONATE SEDIMENTOLOGY OF THE MANZANITA MEMBER OF THE CHERRY CANYON FORMATION By B D Hampton	431
DEPTH EVOLUTION OF THE DELAWARE BASIN - CASTILE/SALADO TRANSITION By S D Hovorka	441
SHALLOW-WATER GYPSUM IN THE CASTILE FORMATION - SIGNIFICANCE AND IMPLICATIONS By A C Kendall and G M Harwood	451
THE GEOLOGY OF LECHUGUILLA CAVE, NEW MEXICO By D H Jagnow	459

TABLE OF CONTENTS (contd )

PART 2 (contd )

THE EVOLUTION OF THE DELAWARE BASIN - PRELIMINARY RESULTS  
By C A Hill 467

THE ROLE OF HYDROGEN SULFIDE IN THE EVOLUTION OF CAVES IN  
THE GUADALUPE MOUNTAINS OF SOUTHEASTERN NEW MEXICO  
By H R DuChene and J S McLean 475

THE ROLE OF HYDROGEN SULFIDE IN THE EVOLUTION OF  
CAVES IN THE GUADALUPE MOUNTAINS OF SOUTHEASTERN NEW MEXICO

HARVEY R DuCHENE  
Marsh Operating Company  
1625 Broadway, Suite 2100  
Denver, CO 80202

JOHN S McLEAN  
U S Geological Survey  
Box 25046, MS 406  
Denver Federal Center  
Denver, CO 80225

Part of the Permian Capitan Reef Complex is exposed in the Guadalupe Mountains of southeastern New Mexico and western Texas (Fig 1) The reef complex includes the Capitan Limestone and the carbonate backreef beds of the Artesia Group that comprise a lithosome called the Capitan aquifer (Hiss, 1976) This lithosome contains well-developed solution openings that range from microscopic to voids the size of Carlsbad Cavern This solution porosity was once thought to be caused by weak carbonic acid in the phreatic zone within the Capitan aquifer (Bretz, 1949) During the last 15 years, however, workers have obtained evidence indicating that sulfuric acid may be a major cause of carbonate dissolution (Egemeier, 1973, Jagnow, 1977, Palmer et al, 1977, Maslyn, 1979, Davis, 1980 Kirkland, 1982, and Hill, 1987) Sulfuric acid is generated when oxygen ( $O_2$ ) is introduced into solutions containing dissolved hydrogen sulfide ( $H_2S$ ) gas (Hill, 1987)

Hydrogen sulfide is common in subsurface formations in southeastern New Mexico (Bjorklund and Motts, 1959, Hinds and Cunningham, 1970, pp 4 and 7) In southeastern New Mexico and elsewhere along the subsurface trend of the Capitan reef,  $H_2S$  is present in accumulations of oil and gas and in associated saline water (Schram, 1956a, p 103, and 1956b, p 307, Wilson, 1956, p 179 and Roswell Geological Society Symposium Committee, 1956a, p 181, and 1956b, p 291)

Hydrogen sulfide results from the metabolic reduction of sulfate by bacteria in the presence of hydrocarbons (Feely and Kulp, 1957 Davis and Kirkland, 1970) This process also causes the fractionation of sulfur isotopes  $^{32}S$  and  $^{34}S$ , resulting in enrichment of  $^{32}S$  in the more mobile phase each time metabolic reduction or oxidation occur Because of this enrichment in  $^{32}S$  sulfur that has been metabolized has a distinct isotopic signature that allows it to be distinguished from nonmetabolized, primary sulfur compounds (Kirkland, 1982, Hill, 1987)

The concept of solution by sulfuric acid within the Capitan aquifer is supported by an abundance of secondary gypsum that is enriched in  $^{32}S$  in caves of the Guadalupe Mountains (Kirkland, 1982, Hill, 1987) Gypsum is precipitated when limestone is dissolved by sulfuric acid and the resulting solution becomes supersaturated with gypsum (Hill, 1987, pp 71-72) Gypsum is present in these caves as massive deposits on the floors of large rooms,

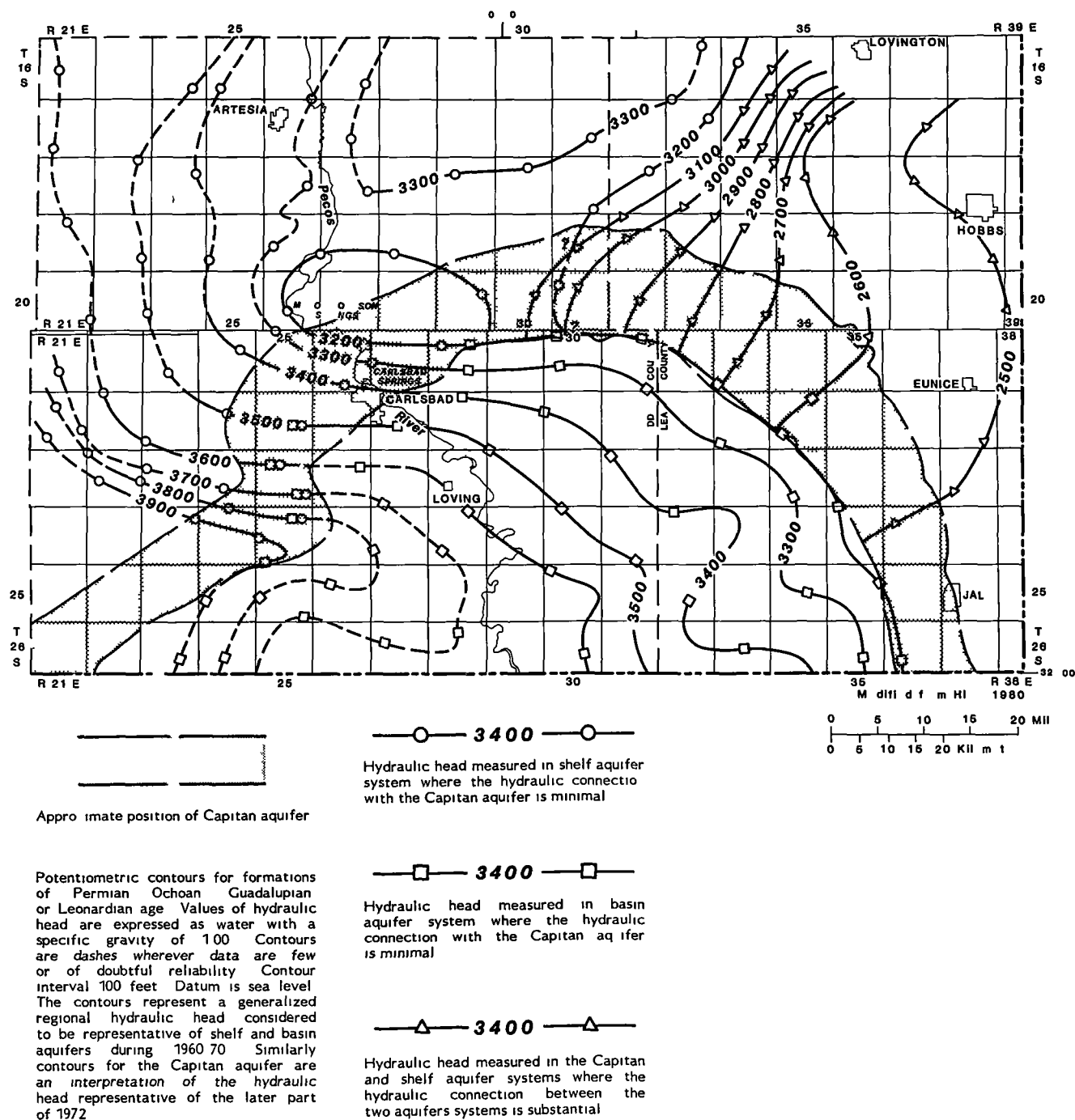


Figure 3 Potentiometric surface of the Capitan aquifer and associated deposits