

## Introduction and General Comments from a Variety of Attendees

The Permian Basin is an example of an oil province where the Basin formations are replete with oil shows. The general term adopted for zones with the shows of oil are residual oil zones (ROZs). In particular, it was stated several times by the experienced professionals in the audience that, when porosity was encountered in the San Andres formation, it was likely accompanied by oil shows. What has changed in recent years is that on-going CO<sub>2</sub> EOR projects are demonstrating the commerciality of several fields with very large ROZs. Understanding the origins and distribution of these shows is what is being addressed by this RPSEA study.

## ROZ Related Papers

The small group (~6-7) in this session first discussed Bill Lemay's papers on the Tatum Basin San Andres. Bill thought the dip on the OWCs averaged 34 ft/mile though the New Mexico portion of the trend.

Discussion proceeded to some of the zonation work of the San Andres accomplished by Vince Kelly of the University of New Mexico (1960's?). Two individuals expressed some limitations of using his surface outcrop zonation work as folks tried to extend it into the subsurface.

USGS publications in late '80s/early '90s. – in what context was this discussion?

## Logs

Bill LeMay talked about the depth of penetration into the ROZ with the methodology used of the ratio of the Guard Log to the FORXO (microlaterolog) and called it the Guard/FORXO ratio. A 4/1 ratio meant mostly oil, 3/1 high oil with water, 2/1 mostly water and 1/1 all water.

Dave Percy – Sulfur H<sub>2</sub>O zones always looks more (wet than they are? – or vice versa?) saline from the logs than it is. Calculated resistivity doesn't match w/logs at all. Apparent H<sub>2</sub>O resistivity does not match water analysis data because of NaCl and other constituents. This is confusing – need to clarify with what he said/meant?

## SHR/Bitumen/Gilsonite

Gilsonite as seen in the Slaughter trend included some sulfur in it and many believed that gilsonite and pyrite (perhaps) suggested oil had moved through the intervals.

Presence of bitumen => water washing

Tar Mats – as the base of the ROZ  
Solid hydrocarbons seen in cores, grains covered w/tar  
(at the orig (paleo?) o/w contact)

NE Texas – you see tar mats.

## **SADR Fields**

Discussion took off into the age of the San Andres production in the Slaughter trend and Melzer showed a slide illustrating the northern ROZ (Slaughter) trend with the geologically oldest San Andres reservoirs there [proceeding to younger San Andres reservoirs as one moves to the more southerly trends (prograding {receding} shorelines). There are 5-6 different pay sections with the P1 being the top one just beneath the "P1" marker (a radioactive siltstone in the L. San Andres).

Scott Beatty talked about the modern seismic allowing discrimination of the individual zones and illustrating the deck of cards or shingled nature of them.

Ed Matchus pointed out that the oldest San Andres producing zone in the Slaughter/Levelland area was farthest north in the Yellowhouse field. All the fields can be considered stratigraphic in nature with the updip pinchout to the north into anhydrite ultimately transitioning to salt even further north.

Bill Lemay talked about the P3 in NM being mostly likely completely flushed (all ROZ).

Lanny Schoeling: Yates Field has few deep penetrations. Effectively no data exists on original tilt to OWC. Yates Field – there appears to be 200' thick ROZ/TZ from the scant data available.

At Means Unit the lower San Andres is more productive on a per foot basis. The CO<sub>2</sub> flood at Means has larger spacing for flooding in the lower San Andres than the upper San Andres – may have same porosity, but you have better permeability in the lower SA.

Lynch, Wilson, Keyes Fields produce from Capitan intervals in closed structures.

### **Shows and Frustrating Completions:**

Wayne Helms: Gaines County San Andres – lots of places where core looks productive of oil, but always makes water. Core looks by every feature that it should make oil, but doesn't.

ROZ is as an Exploration play.?? What was meant here?

Some discussion followed regarding the Capitan Reef complex and its extension into the 7-Rivers reef. The Capitan is limestone and the 7-Rivers is dolomitic with oil shows and production (Lynch, Wilson, Keyes fields) in closed structures.

There is minor production from the 7 Rivers reef in the Mag Sealy of Ward and Winkler.

Not much was done low in the section to stay out of the water so the deep knowledge of the ROZ is poor.

For a good CO<sub>2</sub> flood 35-40% oil saturation is a good target

ROZ's: 20-40% oil saturation

As a result of meteoric flow,  
Why does it trap oil here but not there?

In ROZ's –

What is left after the meteoric flushing?

What do you see on mud logs?

-shows-

Florescence

Odor

Cut

Oil in samples, cores, etc.

Transition Zones without primary production zones? The point was made that how can that be?

Run DST's and then discover it is sulfur H<sub>2</sub>O instead of oil.

USGS publications in late '80s/early '90s. – in what context was this discussion?

If you could find old handwritten Midland scout information.....you would get lots of data; or if you could get a hold of a Company's Sample Logs.

**Anything specific to Artesia Fairway (Area 2)?**

Chevron is very interested in TZ/ROZ in their fields. Late last year or early this year, they cored thru the ROZ until they didn't see any more oil saturation. Don't know if Chevron would release any of these findings. Found a CO<sub>2</sub> Flood Expansion where they flooded the main pay in the Vacuum Field of 300'-400' thick; a Transition Zone of 150'....so that commingled project is 450'. Below the Transition Zone ...if you get deeper than the oil saturation....it gets lower and lower you have to define where the economic limit is. It looks like oil saturation existed 150' below the Transition Zone. In our fields the TZ/ROZ is about 350'.

### **Water and Salinity Issues:**

Phil Eager: Salinity needs to remain low to maintain bacteria for sulfur generation.

H<sub>2</sub>O is full of sulfur because of aenerobic bacterial action. An accumulation of hydrogen sulfide to an intense concentration can retard the further generation. Therefore, dissemination into the pore fluids is a necessity for continued generation.

Characteristics of sulfur water: Hydrogen sulfur odor and blackness to the H<sub>2</sub>O.

Bill Lemay mentioned the salt water encroachments that occurred in the San Andres aquifer providing water to Roswell. The wells were artesian in places and some were allowed to flow with geysers for many years. The implication is that the salt water encroachment came from the deeper parts of the aquifer to the east.

-Best Source for H<sub>2</sub>O chemistry?

USGS Data Set

Lynch, Wilson, Keyes Fields produce from Capitan in closed structures. All producing zones had black sulfur water beneath them.

### **Tilted O/W Contacts:**

Mark Maddox: San Andres in Reeves Field may have been a tilted O/W contact.

Dane Cantwell: Itch Field, Seward, Kansas – tilted O/W contact.

Robert Campbell – top of transition zone may be curved: Midland Farms had a curved OW contact.

Bill LeMay thought the dip on the OWCs averaged 34 ft/mile though the Tatum Basin San Andres trend.

Curiously perhaps, there seemed to be a lot of discussion related to the OWC tilts being explained stratigraphically. This may be left over from the days when hydrodynamics were not a part of the discussion.

The Levelland field was stated to have a 25'/mile dip on the OWC to the SE while the Slaughter field has a 25'/mile dip to the south.

The base of oil saturation drops 1000' west to east at McElroy. They have had 5-10' bit drops there when drilling. The implication here is that tectonic, post entrapment reservoir tilting (Type 1 ROZ) in the south part of the Central Basin Platform may be as important to ROZ development as hydrodynamics are in the north.

The Capitan is limestone and the 7-Rivers is dolomitic with oil shows and production (Lynch, Wilson, Keyes fields) in closed structures. All producing zones had black sulfur water beneath them. Comments were made that the OWC was indeed gradational in nature.

Becky Tupman with Hess spoke out ...it is the discretion of the geologist to define how tilted the field is and how it is defined. They are finding it difficult in defining BOZO – bottom of the residual oil zone. One of the things she found interesting from the meeting that morning was the chloride profile. If that demonstration is true, then we need to be redoing the log calculations taking the RW (water resistivity) into account. So what is actually happening, any TD is given, but any changes are water saturation.

Hess kept all of their old card files....have Steve contact Joaquin Martinez.

Check the publications of King Hubbard....a lot of tilted stuff he wrote.  
Is tilted oil water contact fairly common in the PB....would you more often see them than not?  
The answer seemed to be yes in most eyes.

Check the West TX Geological Society information.

Anarge Field (?) is that being checked out? The water table is really tilted in that field.

In the Panhandle Field of Texas, the O/W is very tilted. A recent AAPG publication (3-4 years ago) discussed the tilted GWC in the Hugoton Basin and linked the hydrodynamics there back to the Panhandle field.

**Dolomitization (conversion of calcite to dolomite w/ accompanying porosity increase):**

Jimmy Hawkins commented that it was his observation that there was more porosity and better reservoirs in ROZs.

### Dolomitization

Limestone -> mg H<sub>2</sub>O -> dolomite

Robert Campbell – San Andres commonly see lower as LS & the dolomitization above is the better reservoir rock. The reservoir main pay is the best reservoir, which is higher in the San Andres section in Gaines and Crane Counties, and on the platform.

Middle San Andres always has good porosity and permeability.

Dave Percy: In Winkler County you have beautifully dolomitized San Andres, but no production. Someone should be looking at Winkler County's lack of production from the San Andres.

In San Andres it is very common. Areal distinctions – open hole logs that have a PE curve you should be able to distinguish between the reservoirs ....the PE will help distinguish between dolomite and limestone....on the log it may not be exact.

The lower SA is pretty much limestone, there are areas of the San Andres that are all limestone, but, in general if there is oil in the San Andres it will always be dolomitic.

### Corrosive Zones:

Mark Maddox: Clearfork in Glasscock County – casing dissolved in 30 days, highly corrosive. The caliper at the bottom of the hole went off scale. They ended up putting a nickel plated liner in it. The hole exhibited a bad caliper, but no caverns. The location was fairly close to the shelf edge.

In the Northern Midland Basin the San Andres is very corrosive - Dawson and Borden Counties. 200' of good SA with 15-20% porosity is not productive on primary.

You had better cement the pipes if you want them to last more than a year or two. The zone consists of high H<sub>2</sub>S and Salinity. You see fields with high iron pyrite having lots of corrosion. You see this regionally in the central part of.....

Red is dead - No hydrocarbons

Gray is pay – high sulfides – with hydrocarbons

### Sulfur Concepts:

Phil Eager: the sulfur deposits in the Delaware Basin mined areas are found in the evaporite section.

Comment: sulfur crystals are always found below the H<sub>2</sub>O contact in reservoirs.

Examples cited at Goldsmith, McElroy, SSAU.

Phil Eager: At the sulfur mined areas, fluids moved up through the anhydrite and formed sulfur a couple of million years ago. He believes there were artesian springs there and formed chimneys for sulfur deposits.

The Bell Canyon was the major aquifer in the Delaware Basin.

Phil Eager: Sulfur mine is located in the Rustler Hills at the Culberson/Reeves County lines. 50 million tons of sulfur, a calculated volume of 500 million tons required bacterial oil consumption – direct evidence of flushing.

The study is looking for water chemistry data – Martin Water Labs was suggested.

Are there particular locations vertically or geographically where sulfur is found?

Vertically – Sulfur water is more dominant shallow than it is deeper in the San Andres.

Sources of primary prior to development of respective fields: – McNeal's Data

..Sinclair.....early DST....did the early hydrodynamics of the Permian Basin.....Published in the old AAPG, Memoir One – that will be the best data you can find.

USGS published some stuff for New Mexico....but not historic information.

Hess had a geologic model built with cores at Seminole ...with as much information that they could include on the ROZ ....and it has 6" to 12" written descriptions..... We are talking about in some areas very detailed. Becky is trying to recall ever seeing elemental sulfur .....she is going to find out. (Becky Tupman with Hess)

### **Tectonic History:**

Phil mentioned that he thought that the most dynamic period was in the Cretaceous. He has done a lot of work in the Cretaceous/Tertiary.

### **Capillary Pressure/Wettability Issues:**

#### Wettability

George Hirashi (?)

80% of Carbonates ( partially) oil wet

Correlation with oil wet and ROZ? Much to be learned here.

Capillary pressure data is a direct function of wettability.

Larry Long: Wettability can be a function of pore throat size.

Phil Eager: Late stage dolomitization may have caused change in wettability.

Lots of potential for researching the properties of reservoir rocks and how they pertain to wettability – most papers are 50 to 60 years old that are found in the literature.

Comment: Capillary and wettability tests are expensive and people are averse to sharing that data.

## **Oil Gravity**

The API gravity of the oil in the Slaughter Fairway trend get lower to the west; 30 gravity in Slaughter and down to 29 and even heavier to the west into NM.

Bill Lemay was asked about oil chemistry difference in oil between main pay and ROZ and thought there was not a lot of difference (same observation as seen on the Central Basin Platform (Melzer)

## **Other Zones Comments:**

Robert Campbell: commented on the Glorieta and Abo – Glorieta is highly corrosive in the Gaines County area.

Steve Pontius – Hobbs Field on top of the structure the Glorieta looked oil productive, but always watered out.

Jim Gillespie, Chevron: Terry County, Kingdom Abo has a 100' change in oil/H<sub>2</sub>O contact from NW to SE.

Devonian comments: Most Devonian that people had worked has been sweet oil (however, some is marginal (Heluma field in Upton County (Melzer) – all signs point to late geologic stage hydrodynamics in the field there).

Mitchell County Clearfork: FMS's read non-resistant. Oil wet reservoir.

Comments on Clearfork: Haven't figured out how to waterflood it yet, let alone Tertiary flooding. Exceptions exist of course (Fullerton, Anton Irish, Wasson South – Melzer)

Yates Field – drops of entire joints, up to 3 joints of pipe dropping has been documented.

The Tubb formation has lots of corrosion problems in Crane County.

Food for thought.....Ellenberger.....if you are seeing anomalies in your log data, where you haven't actually gone in and tested...if you are seeing anomalies in log data it may be that change in chloride concentration so that your RW is flat...you may be seeing pockets of sulfur water. You are seeing higher oil saturation because it is fresher. You might be able to conclude it exists just from?

Your thoughts/edits are encouraged: For commenting further, please contact Edith Stanton at [info@residualoilzones.com](mailto:info@residualoilzones.com).