Diagenetic and Burial History of a Portion of the Late Triassic South Georgia Rift Basin Based on Petrologic and Isotopic ($\delta^{18}O$) Analyses of Sandstones from Test Borehole Rizer #1, Colleton County, SC*

James M. Rine$^1$, Brittany E. Hollon$^1$, Robert Fu$^1$, Nancy Houghton$^1$, and Michael Waddell$^2$

Search and Discovery Article #51016 (2014)**
Posted September 12, 2014

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Houston, Texas, April 6-9, 2014
**AAPG©2014 Serial rights given by author. For all other rights contact author directly.

$^1$Weatherford Laboratories, Houston, Texas (james.rine@weatherfordlabs.com)
$^2$University of South Carolina, Columbia, South Carolina

Abstract

A diagenetic and burial history of a portion of the Late Triassic South Georgia Rift Basin (SGRB) was reconstructed based on petrologic and isotopic ($\delta^{18}O$) analyses of sandstone samples from conventional core and selected rotary side wall cores within test borehole Rizer #1, Colleton County, SC (2600ft to 6200ft). The original objective of this study was to assess the capability of sandstones with the SGRB to sequester CO$_2$. Due to the poor reservoir quality of the sampled interval (average porosity $>$3.4% and permeability $>$0.065mD to air), this objective was replaced with the goal of determining why the reservoir properties of this portion of the SGRB are so poor. Although porosity reduction within these lithic arkoses to arkosic litharenites is largely due to compaction, a complex diagenetic scenario added to destruction of reservoir quality. Early cements consisted of poikilotopic calcite spar or evaporites (gypsum/anhydrite). Within some portions of the sequence, these early cements remained in significant volume to inhibit compaction. Feldspar grains were also replaced during this early stage of calcite cementation, a phenomenon that reoccurred with a later stage of calcite cementation. Sphene cements (1-2% by volume) were also relatively early and preceded even early quartz cementation. Pore-rimming chlorite followed the dissolution of some of the early calcite and evaporite cements. For some sandstone within the SGRB, the chlorite-rimmed, secondary pores were partially filled with quartz overgrowths (within less than 6500ft of burial). This quartz cement was formed in sufficient volumes that the remaining intergranular porosity was preserved. For other sandstones, dissolution of these early cements resulted in compaction and pressure/solution. Subsequently for both groups of sandstone, at least two additional stages of quartz and a late stage of calcite cementation occluded the remaining pores. Based on $\delta^{18}O$ measurements (SIMS) of the quartz cements and modal petrographic
analysis of compaction indices, burial depths attained depths at least 7000ft to 10000ft deeper than present. Based on past regional studies, the SGRB strata were intruded by numerous igneous dikes and sills during the Early Jurassic. This was followed by inversion of this portion of the basin and subsequent erosion of thousands of feet of SGRB strata until the Late Cretaceous, when the SGRB was overlain by coastal plain strata.

References Cited


Diagenetic and Burial History of a Portion of the Late Triassic South Georgia Rift Basin Based on Petrologic and Isotopic ($\delta^{18}O$) Analyses of Sandstones from Test Borehole Rizer #1, Colleton County, SC

James M. Rine, Brittany E. Hollon, Robert Fu, Nancy Houghton, and Michael Waddell
General view of South Georgia Rift Basin (SGRB) showing location of interpreted reprocessed SEISData6 line.

All figures modified from Akintunde et al. (2013).
Modified from Withjack et al. (2013)
Litho Log of Upper Triassic Strata in Test Borehole Rizer #1

- Relationship of test borehole Rizer #1 with other boreholes in the area and study-related seismic line (blue).

- **Core Depth (ft)**
  - 0 to 250

- **Lithology**
  - Core Gamma Ray (API)

- **Legend**
  - Sandstone (SG)
  - Silt & Muds
  - Siltstone
  - Tuff

- **108 RSWC**
- **103 RCA**
- **52 TS, etc.**

- **57.2’ CC**
- **29 RCA**
- **10 TS, etc.**
Cross-bedded, medium-to coarse-grained sandstone within a braided channel setting

Very fine- to fine-grained sandstone within an alluvial overbank

Lacustrine influence
Detailed (modal) analysis was completed on 10 conventional core and 24 RSWC samples.
Sample from 4610.5 ft (RSWC)

Abundant Stylolites
Modified from Withjack et al. (2012)

Modified from Withjack et al. (1998)
RSWC from 4037.0 ft
Porosity = 12.4%
Perm. = 5.39 mD

Results of RCA of 103 RSWC
Avg. Porosity (Ambient) = 3.4%
Avg. Perm. (to Air) = 0.049 mD

RSWC from 5444.0 ft
Porosity = 2.9%
Perm. = 0.0045 mD

RSWC from 4037.0 ft
Porosity = 12.4%
Perm. = 5.39 mD
Project objectives changed when reservoir properties within Rizer #1 were judged insufficient to sequester CO$_2$

1. Why is reservoir quality so poor?
2. Can we predict reservoir quality in other portions of SGRB?
New objectives pursued along two avenues:

Contact Index (CI) & Tight Packing Index (TPI)

From Pettijohn et al. (1972)

δ¹⁸O values of quartz cements

From Hiatt et al. (2007)
Contact Index (CI) & Tight Packing Index (TPI)

RSWC from 5338.0 ft
CI: 2.52    TPI: 1.60

RSWC from 5444.0 ft
CI: 4.62    TPI: 3.52
Contact Index (CI) & Tight Packing Index (TPI)

RSWC from 5338.0 ft
CI: 2.52   TPI: 1.60

RSWC from 5444.0 ft
CI: 4.62   TPI: 3.52
Bulk % $\delta^{18}$O (SMOW) values of quartz

From Blatt (1987)

Precision *in situ* $\delta^{18}$O measurements of quartz & calcite by secondary ion mass spectrometry (SIMS)
Steps preparing for $\delta^{18} O$ measurements with SIMS

Selection of samples

CL SEM delineation of cements

Polished thin section with quartz standard
Photomicrographs of the sample from 5702.5 ft (R37) with \( \delta^{18} \text{O} \) (SMOW) values

\[ \delta^{18} \text{O} \text{ SMOW} \]
Photomicrograph of the sample from 5702.5 ft (R37) with \( \% \delta^{18} \text{O (SMOW)} \) values
Photomicrographs of the RSWC sample from 5152.5 ft (R26) with \( \% \delta^{18} O \) (SMOW) values
Temperatures calculated using the equation of Clayton et al. (1972). Geothermal gradient of 40°C/km from Tseng et al. (1996).
Photomicrographs of the sample from 3674.0 ft (R8) with δ¹⁸ O (SMOW) values
Plot of $\delta^{18}O$ values of primarily calcite cements versus depth from study by Milliken et al. (1981; blue diamonds) from well samples of Frio Fm (Oligocene) in Brazoria County, Texas. $\delta^{18}O$ values of primarily calcite cements from Rizer #1 samples are plotted with red squares. Modified from Milliken et al. (1981).
Other diagenetic characteristics of Rizer #1 sandstones

Early chlorite clay
Other diagenetic characteristics of Rizer #1 sandstones

Authigenic sphene, anhydrite, pyrite...
Metasomatic alteration (?) associated with basal basalt

6140.0 ft (RSWC 1-107R)
A. BURIAL MODEL FOR SOUTH GEORGIA RIFT BASIN STUDY INTERVAL (5000 FT - 6000 FT)

B. DIAGENETIC MODEL

TERMINATION OF SUBSIDENCE, BEGINNING OF BASIN INVERSION

EARLY

LATE

Compaction
Cutan Clays / Hematite
Calcite Cement / Replacement
Evaporite Cement
Dissolution of Calcite/Evaporite Cement
Authigenic Illite/Chlorite
Sphene Cement
Quartz Cement
Pressure/Solution
Isolated Metasomatism

Burial and Diagenetic Model for Rizer #1 portion of SGRB
Conclusions:

1. SGRB strata experienced complex diagenetic history

2. Study interval buried up to 8200 ft (2.5 km) deeper than present

3. SGRB strata within Rizer #1 fault block has poor reservoir quality due to compaction and cementation
Thanks to...

This material is based upon work supported by the Department of Energy under Award Number DE-FE0001965.

Special thanks to Robert M. Reed & Kitty Milliken

Special thanks to Kouki Kitajima & John W. Valley

Special thanks to John Fournelle

DOE/NETL Acknowledgment: This material is based upon work supported by the Department of Energy under Award Number DE-FE0001965.

DOE/NETL Disclaimer: This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.