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

[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

Akintunde, O.M., C.C. Knapp, J.H. Knapp, and D.M. Heffner, 2013, New constraints on buried Triassic basins and regional implications for subsurface CO_2 storage from the SeisData6 seismic profile across the Southeast Georgia coastal plain: Environmental Geosciences, v. 20/1, p. 17-29.

Blatt, H., 1987. Oxygen isotopes and the origin of quartz: Journal of Sedimentary Petrology, v. 57, p. 373– 377.

Clayton, R.N., J. R. O'Neil, and T.K. Mayeda, 1972, Oxygen isotope exchange between quartz and water: Journal of Geophysical Research, v. 77, p. 3057-3067.

Hiatt, E.E., T.K. Kyser, M. Fayek, P. Polito, G.J. Holk, and L.R. Riciputi, 2007, Early quartz cements and evolution of paleohydraulic properties of basal sandstones in three Paleoproterozoic continental basins: Evidence from in situ $\delta^{18}O$ analysis of quartz cements: Chemical Geology, v. 238, p. 19-37.

Milliken, K.L., L.S. Land, and R.G. Loucks, 1981, History of burial diagenesis determined from isotopic geochemistry, Frio Formation, Brazoria County, Texas: AAPG Bulletin, v. 65, p. 1397-1413.

Pettijohn, F.J., P.E. Potter, and R. Siever, 1972, Sand and sandstone: New York, Springer-Verlag, 618 p.

Tseng, H.-Y., T.C. Onstott, R.C. Burruss, and D.S. Miller, 1996, Constraints on the thermal history of Taylorsville Basin, Virginia, U.S.A. from fluid inclusion and fission track analyses: Implications for subsurface geomicrobiology experiments: Chemical Geology, v. 127, p. 297-311.

Withjack, M.O., R.W. Schlische, and P.E. Olsen, 1998, Diachronous rifting, drifting, and inversion on the passive margin of central eastern North America: An analog for other passive margins: AAPG Bulletin, v. 82, p. 817-835.

Withjack, M.O., R.W. Schlische, M.L. Malinconico, and P.E. Olsen, 2012, Rift-basin development: Lessons from the Triassic-Jurassic Newark basin of eastern North America, in Conjugate Divergent Margins: Geological Society, London, Special Publications 369, p. 301–321.

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

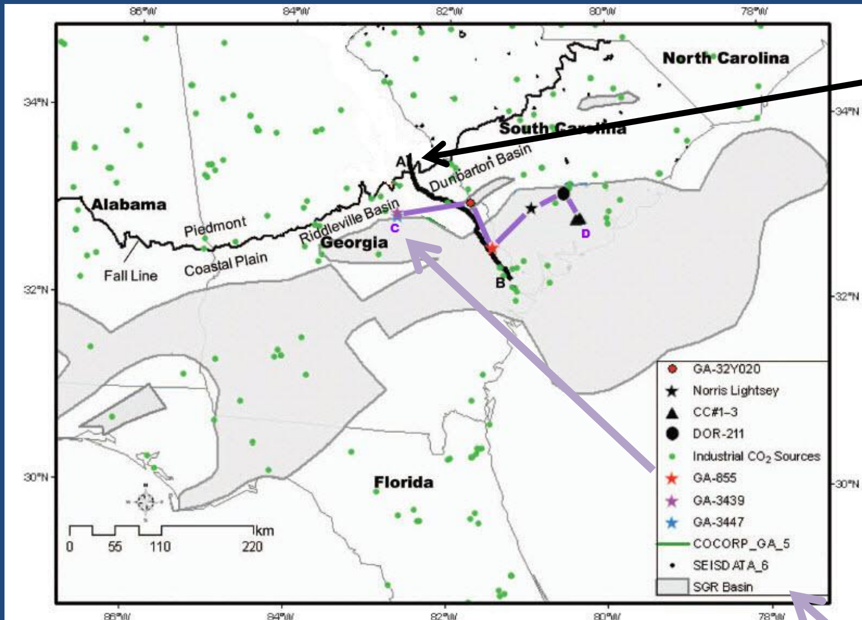
Weatherford LABORATORIES

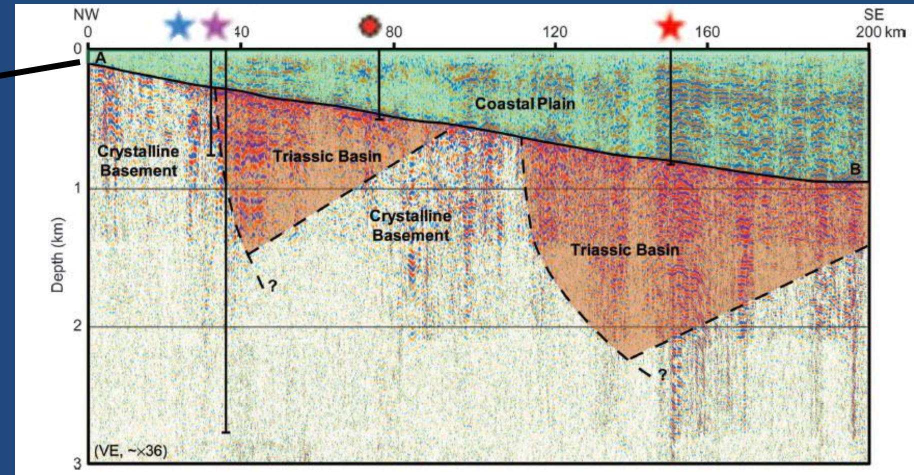
Geologic Characterization of the South Georgia Rift Basin for Source Proximal CO_2 Storage

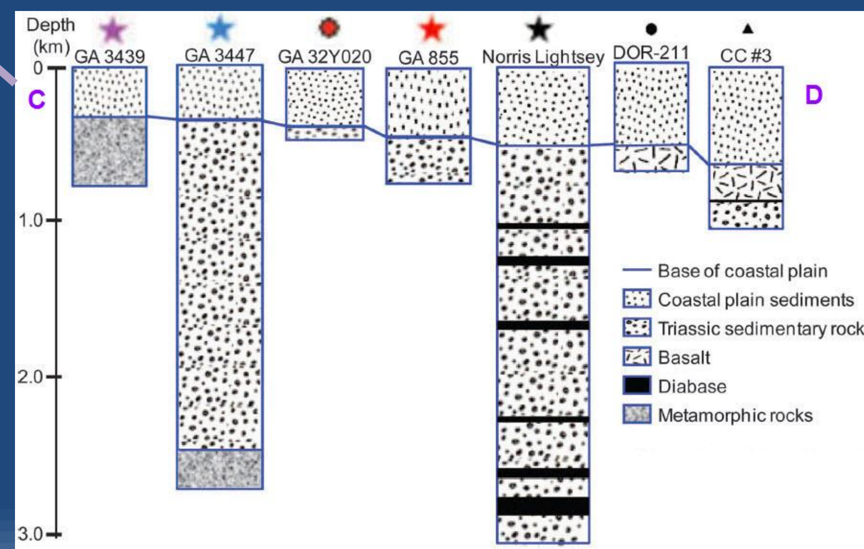
U.S. Department of Energy, National Energy Technology Laboratory

UNIVERSITY OF SOUTH CAROLINA

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

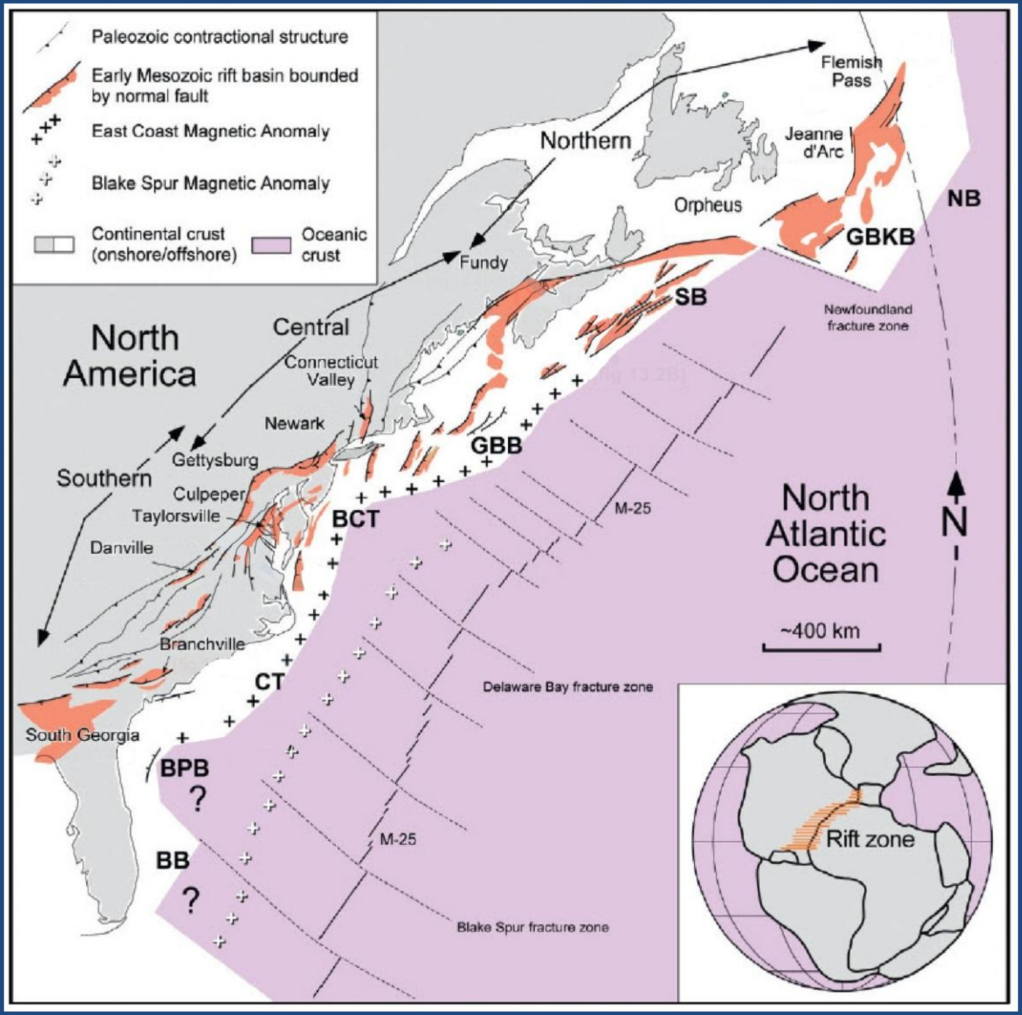




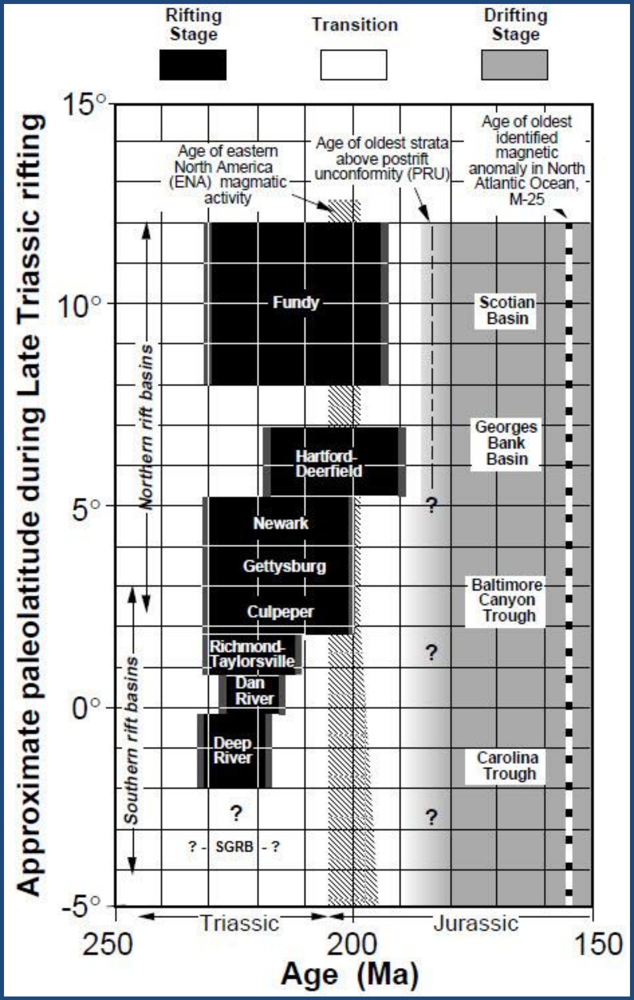


General view of South Georgia Rift Basin (SGRB) showing location of interpreted reprocessed SEISData6 line.

All figures modified from Akintunde et al. (2013).

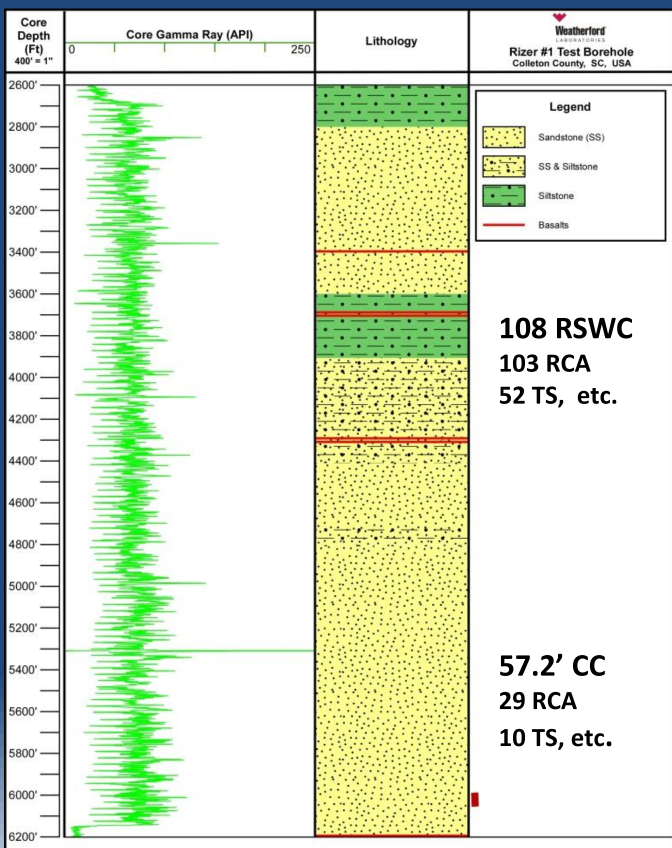


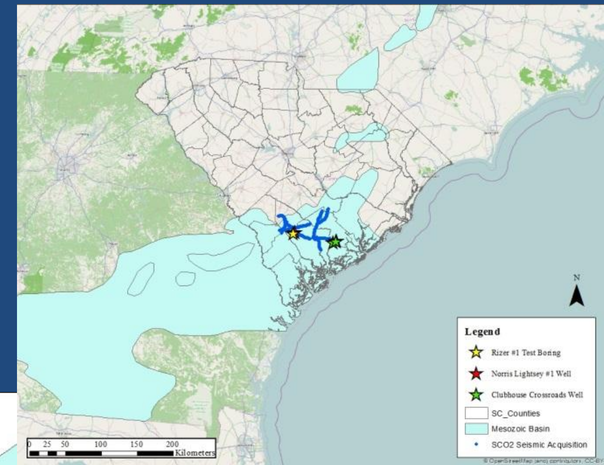
Modified from Withjack et al. (2013)

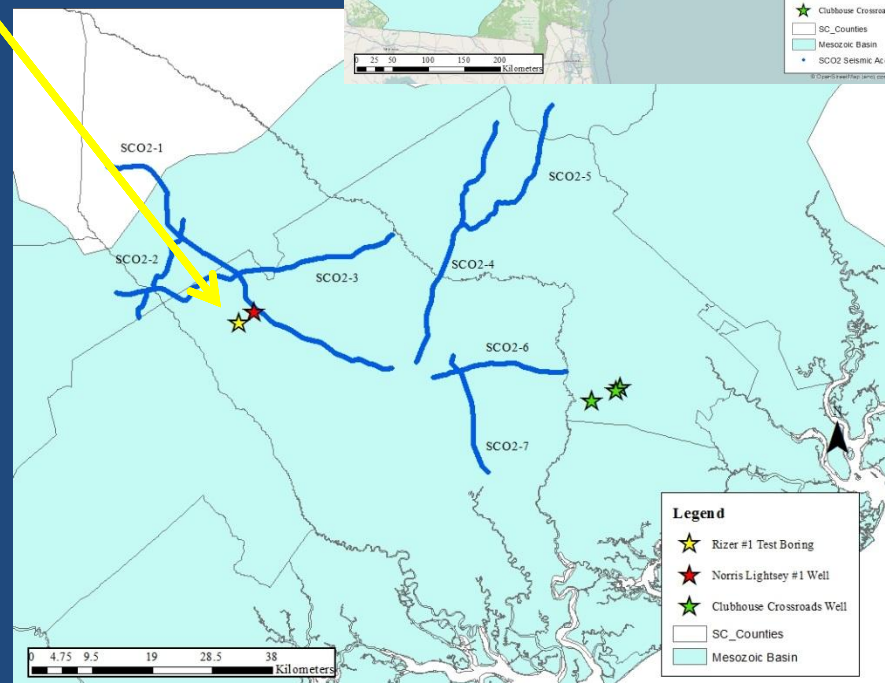


Modified from Withjack et al. (1998)

Litho Log of Upper Triassic Strata in Test Borehole Rizer #1

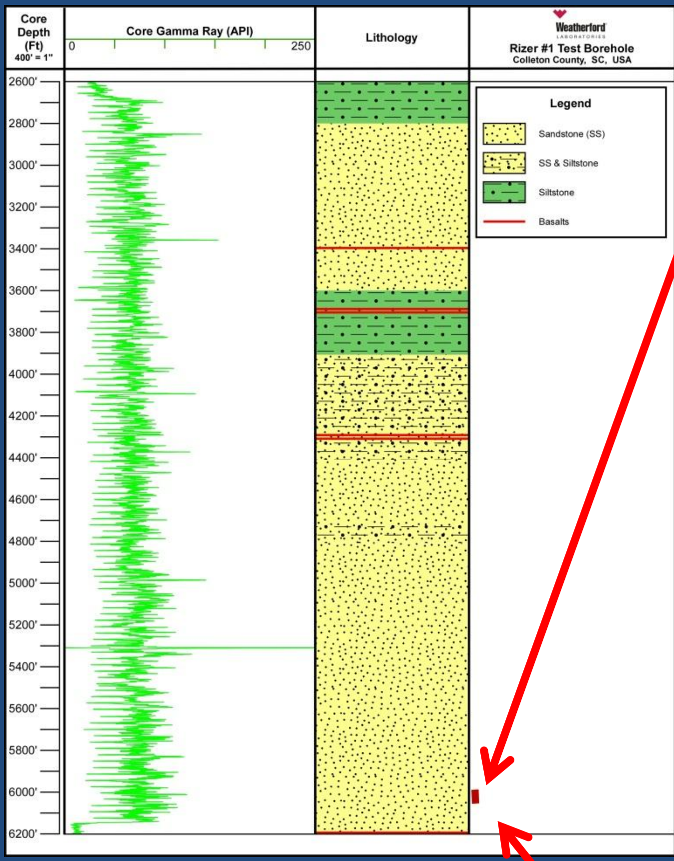


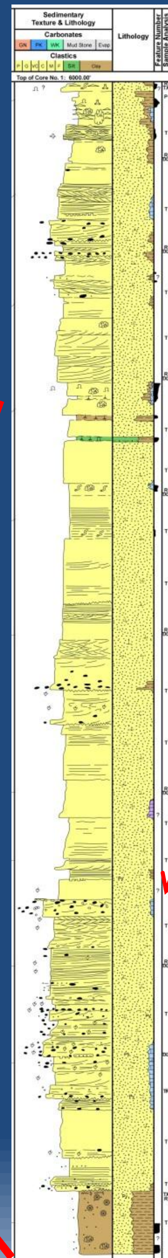


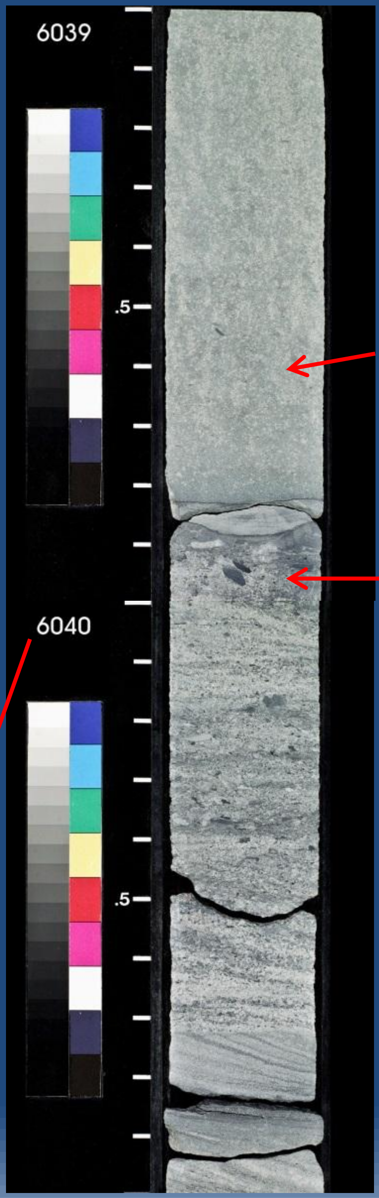


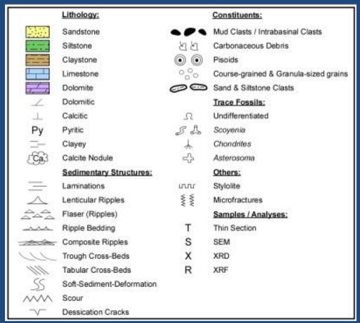
Relationship of test borehole Rizer #1 with other boreholes in the area and study-related seismic line (blue).

Litho Log of Upper Triassic Strata in Rizer #1





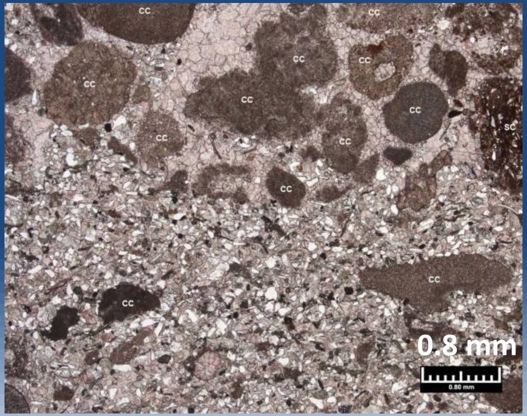


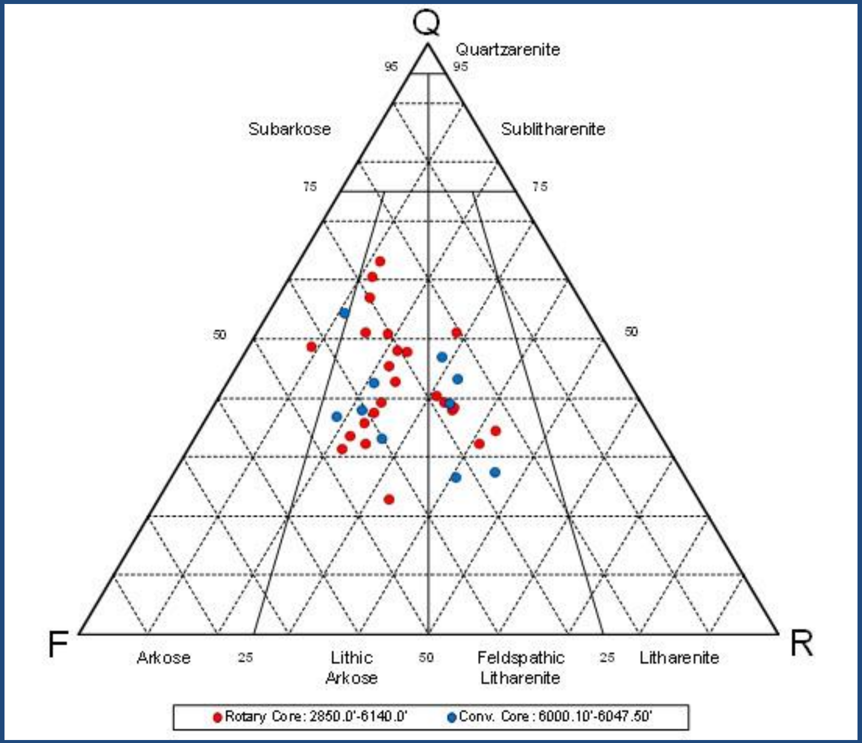


Very fine- to fine-grained sandstone within an alluvial overbank

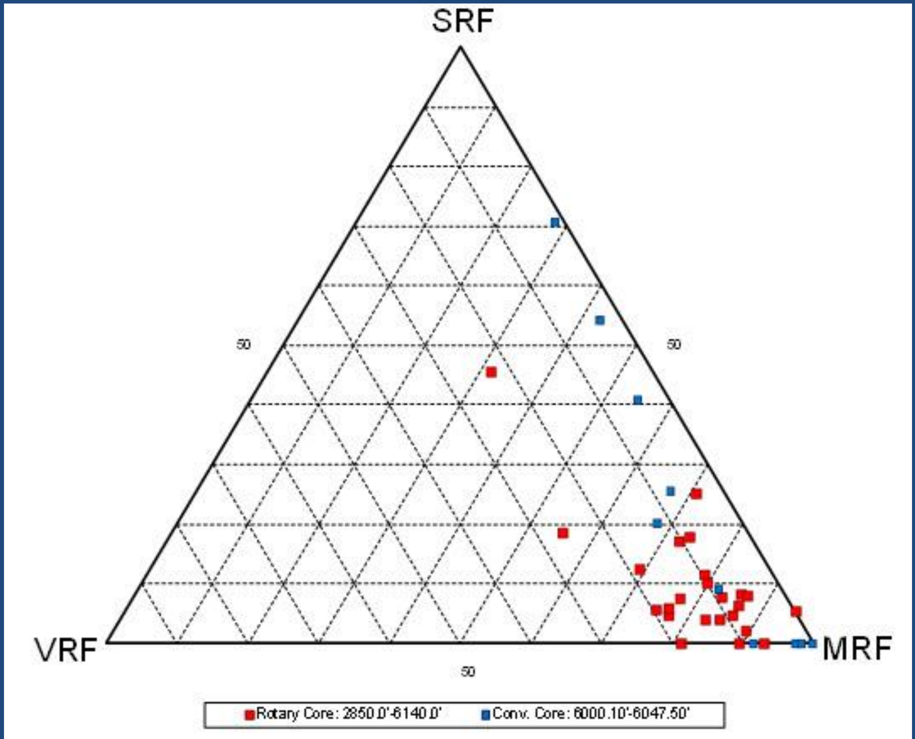
Cross-bedded, medium- to coarse-grained sandstone within a braided channel setting

Lacustrine influence



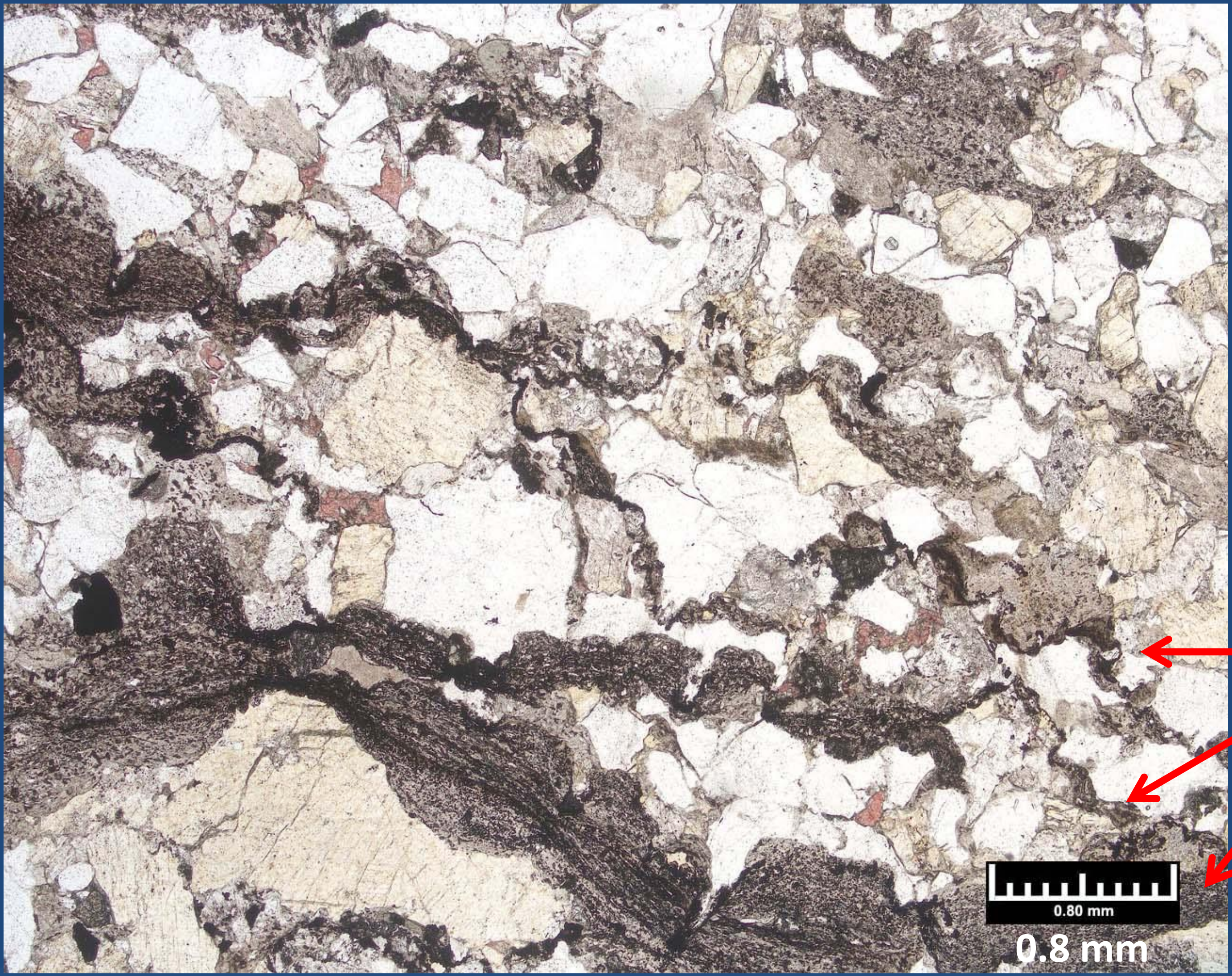


Quartz – Feldspar – Lithics (QFL)



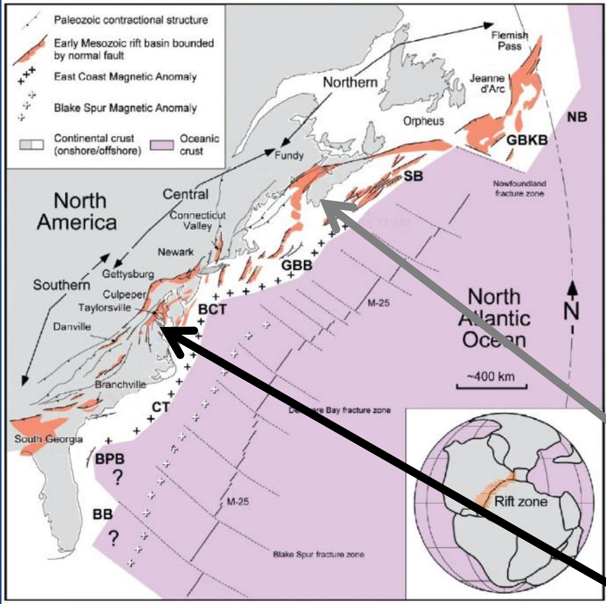
Lithics

Detailed (modal) analysis was completed on
10 conventional core and 24 RSWC samples

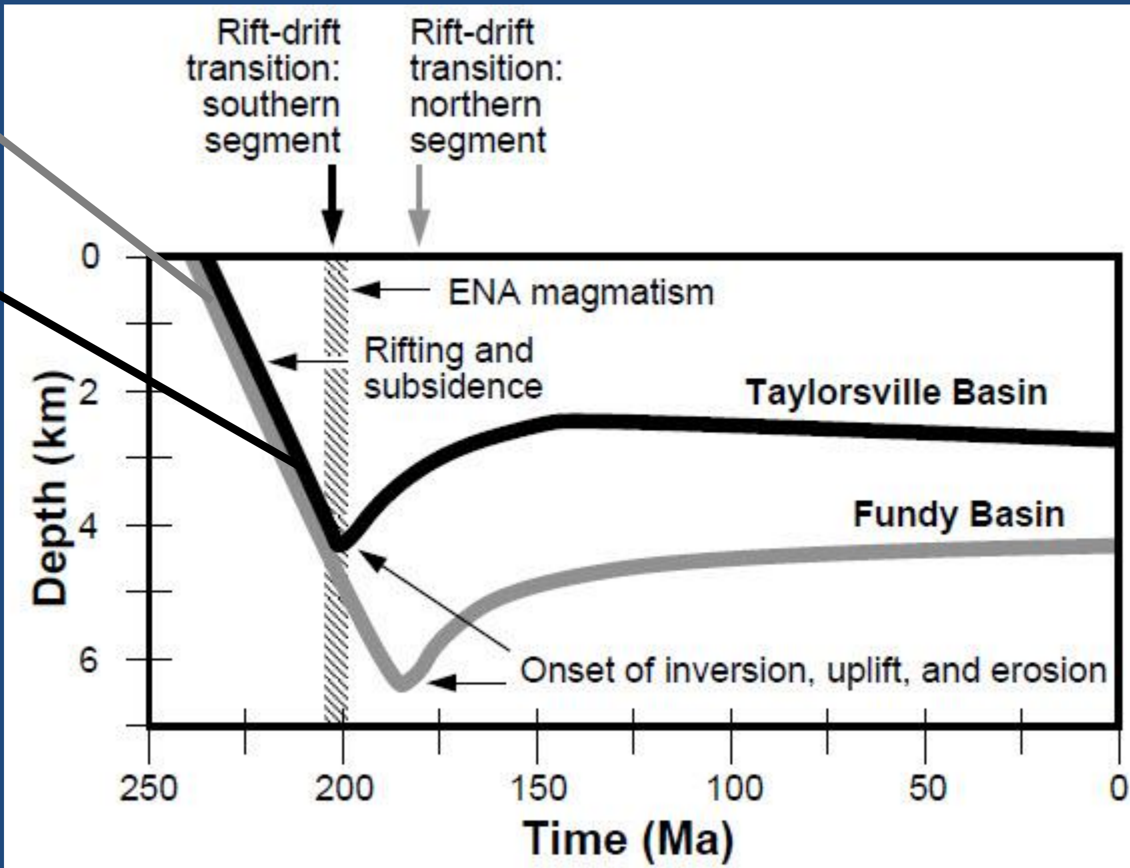


Sample from 4610.5 ft (RSWC)

Abundant Stylolites

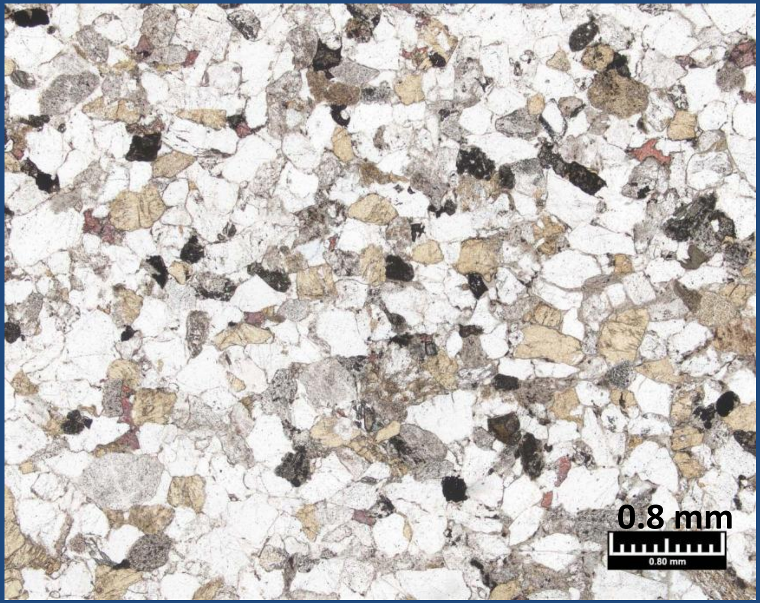


Modified from Withjack et al. (2012)

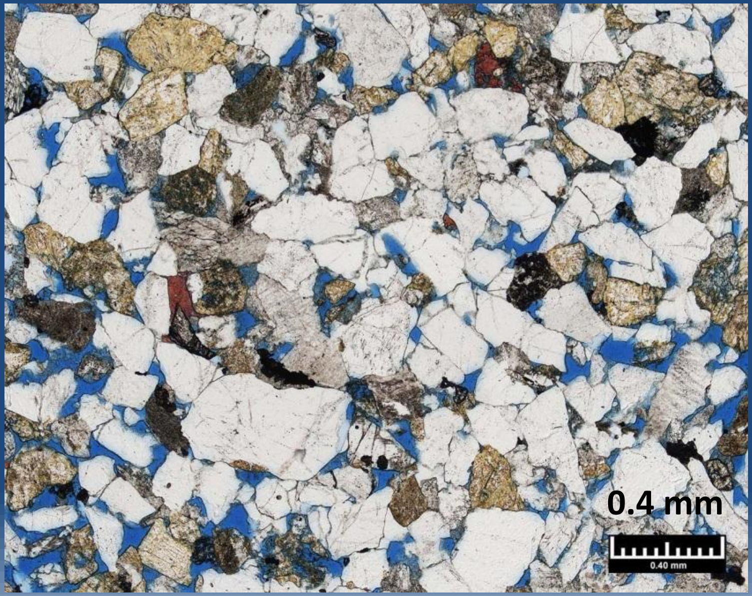


Modified from Withjack et al. (1998)

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



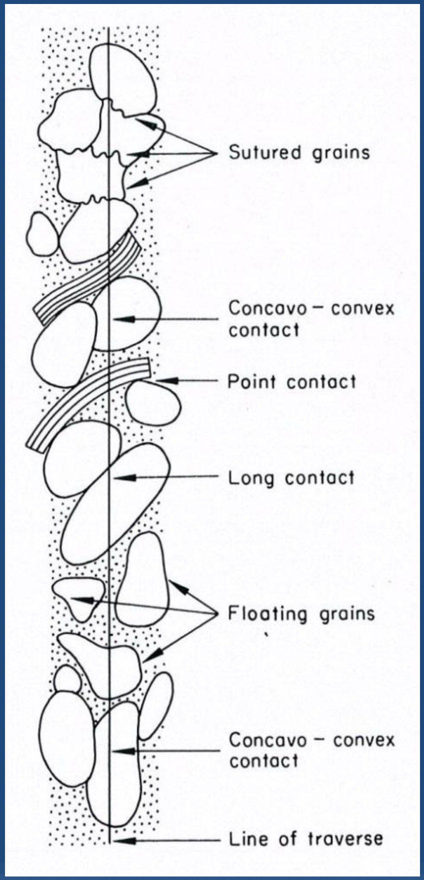
RSWC from 4037.0 ft
Porosity = 12.4%
Perm. = 5.39 mD

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?

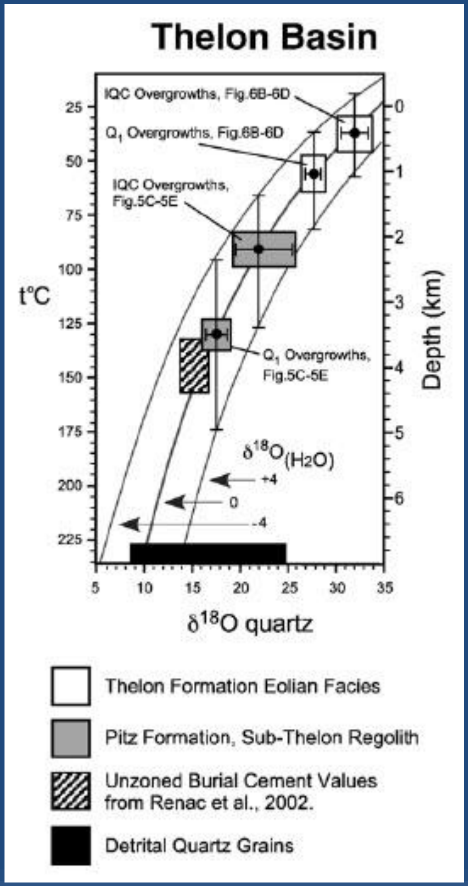
New objectives pursued along two avenues:

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



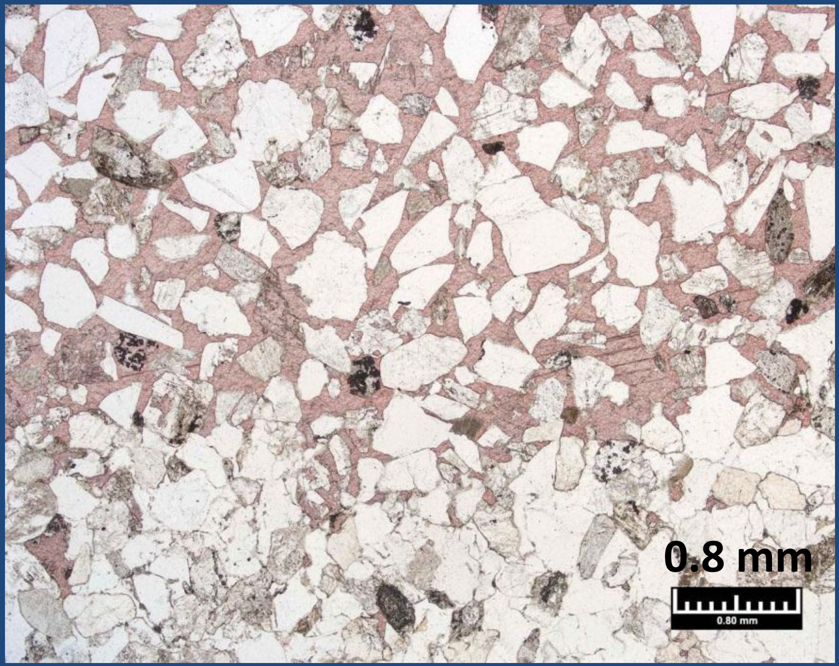
From Pettijohn et al. (1972)

δ^{18} O values of quartz cements

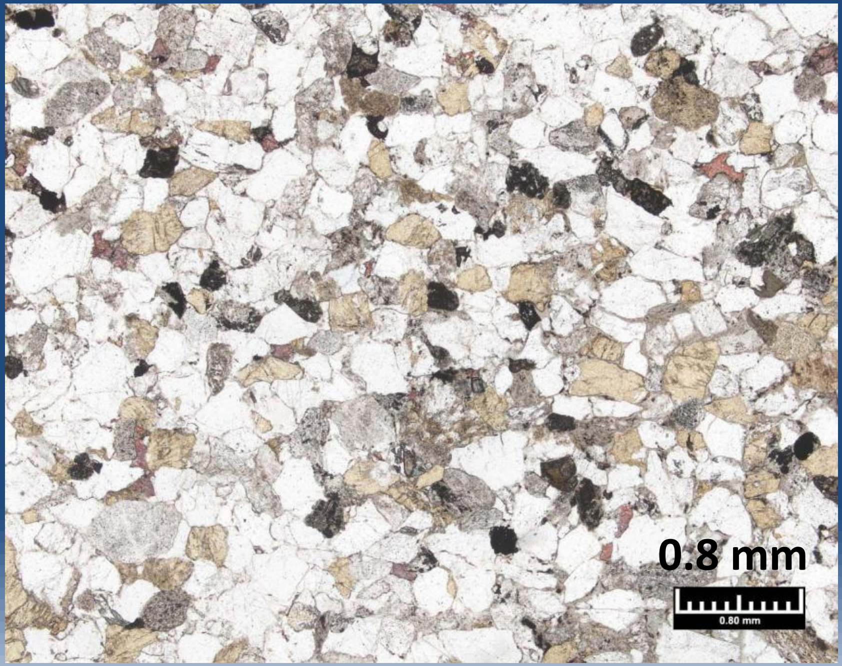


From Hiatt et al. (2007)

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

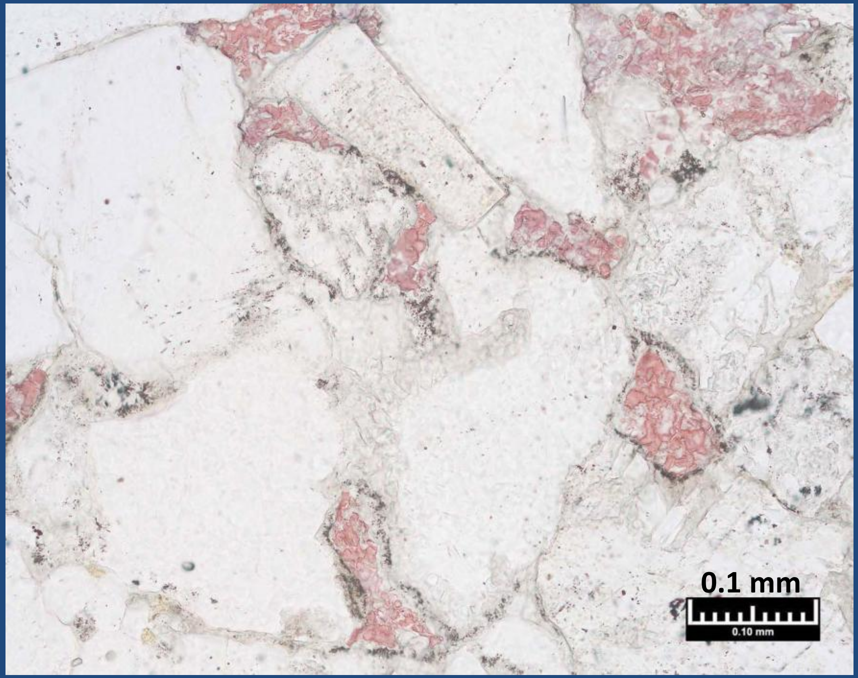


RSWC from 5338.0 ft
CI: 2.52 TPI: 1.60

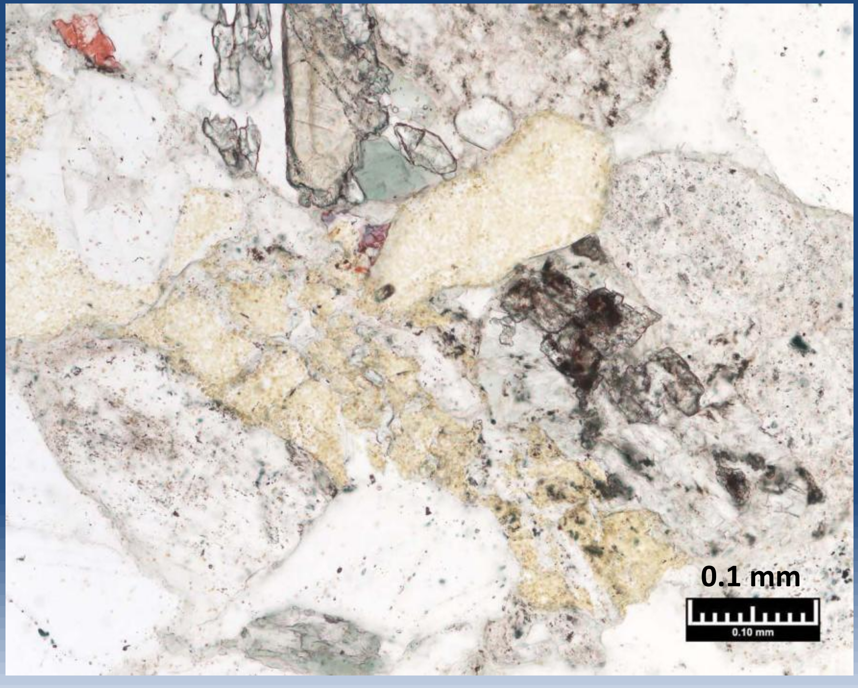


RSWC from 5444.0 ft
CI: 4.62 TPI: 3.52

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

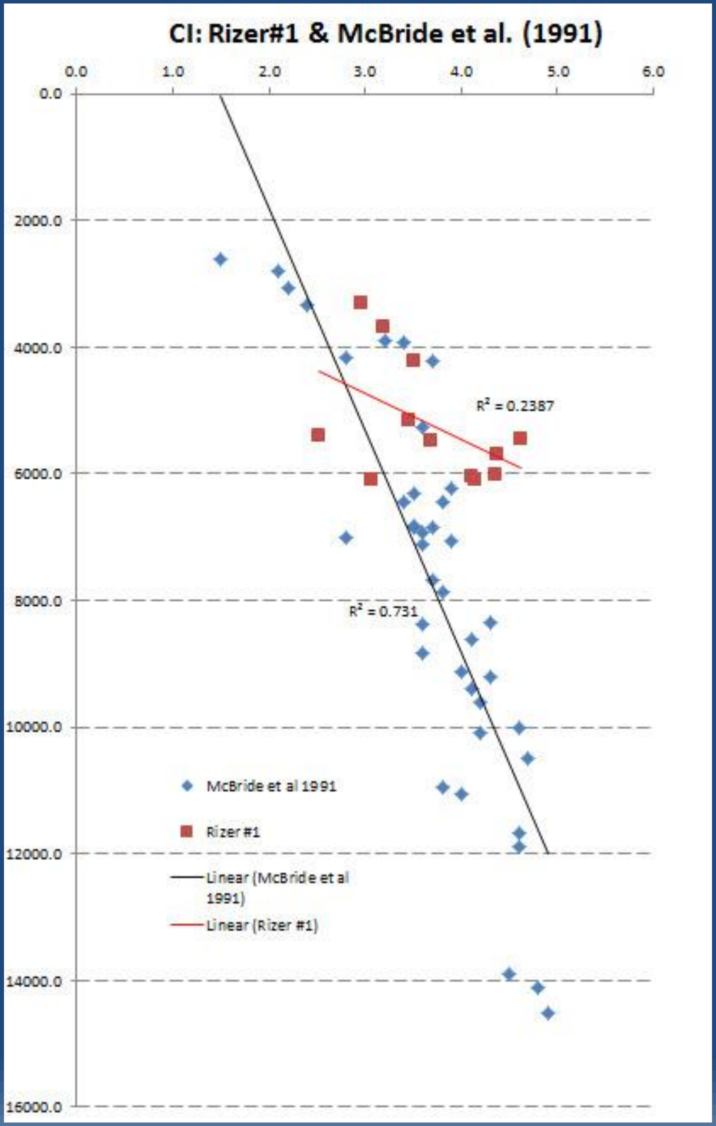


RSWC from 5338.0 ft
CI: 2.52 TPI: 1.60

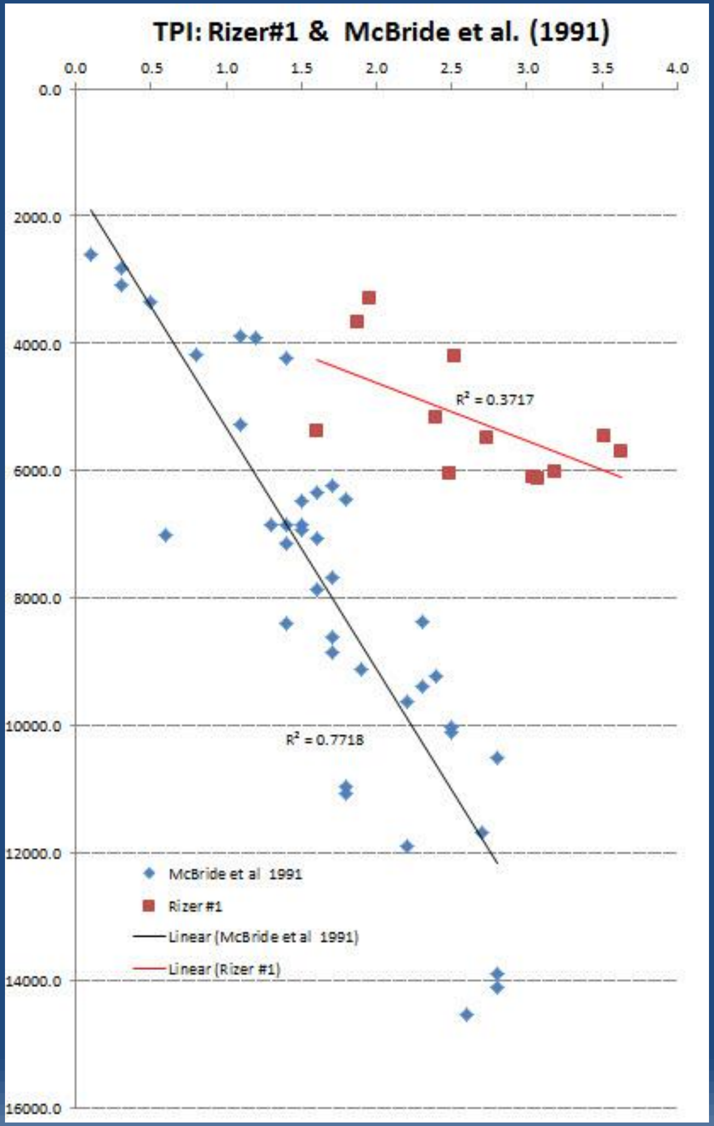


RSWC from 5444.0 ft
CI: 4.62 TPI: 3.52

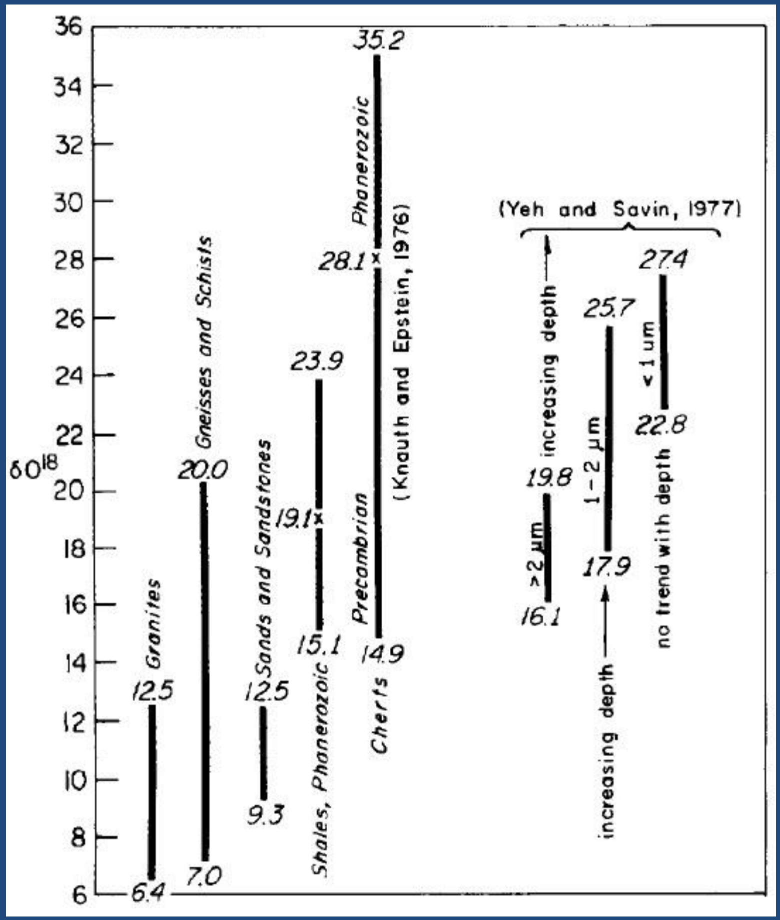
Contact Index (CI)



Tight Packing Index (TPI)



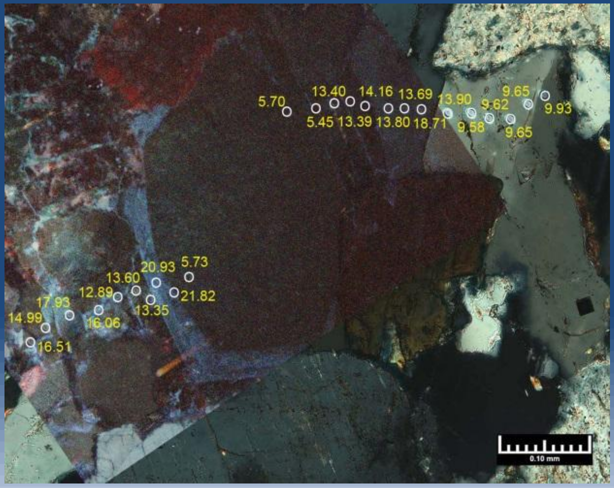
Bulk ‰ δ^{18} O (SMOW) values of quartz



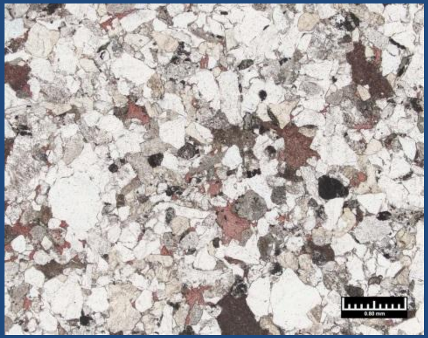
From Blatt (1987)

The Wisconsin
Secondary Ion Mass Spectrometer
LABORATORY

Precision *in situ* δ^{18} O measurements of quartz & calcite by secondary ion mass spectrometry (SIMS)

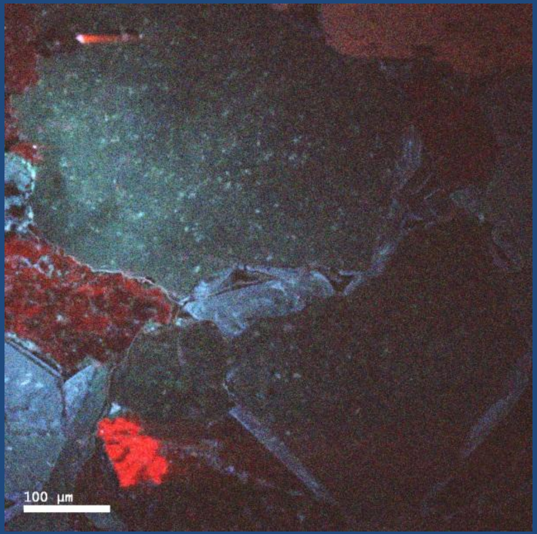


Steps preparing for δ^{18} O measurements with SIMS



Selection of samples

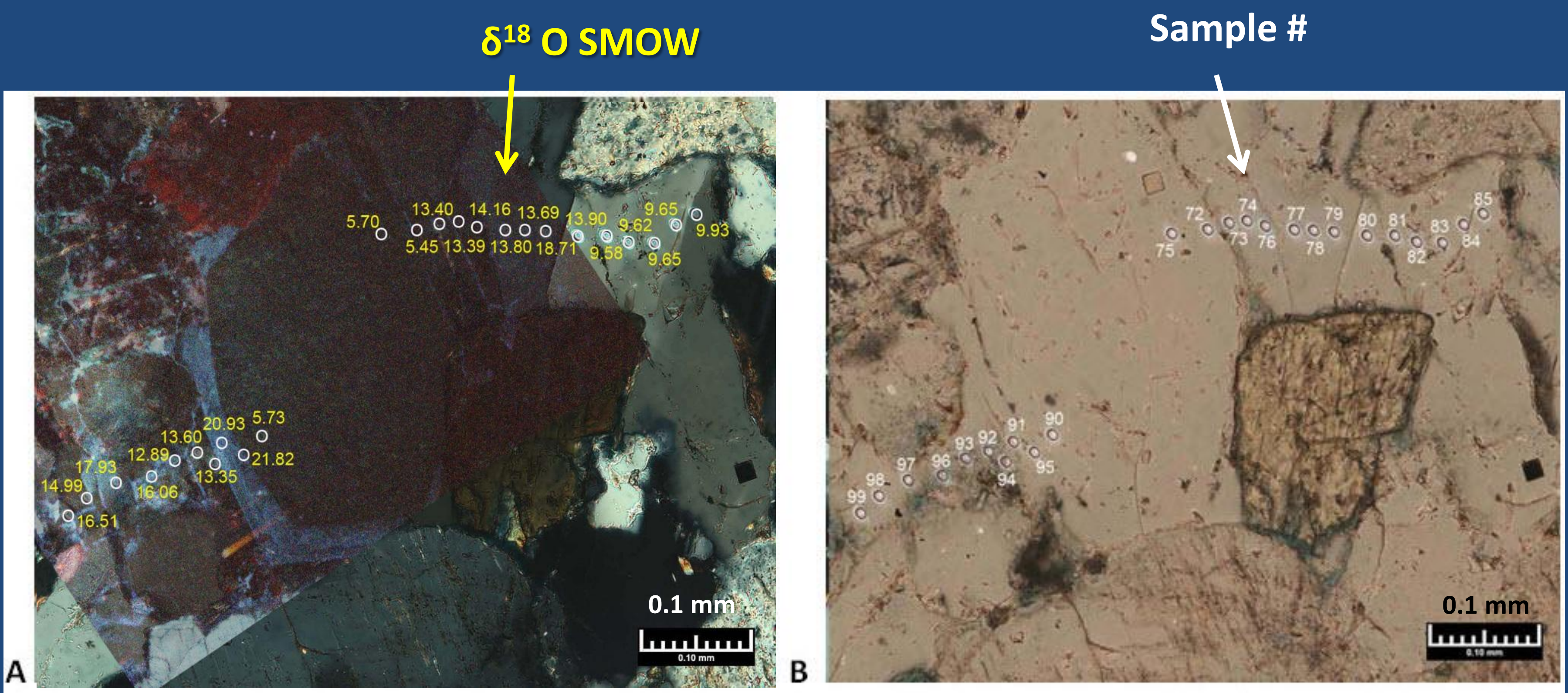
CL SEM delineation of cements



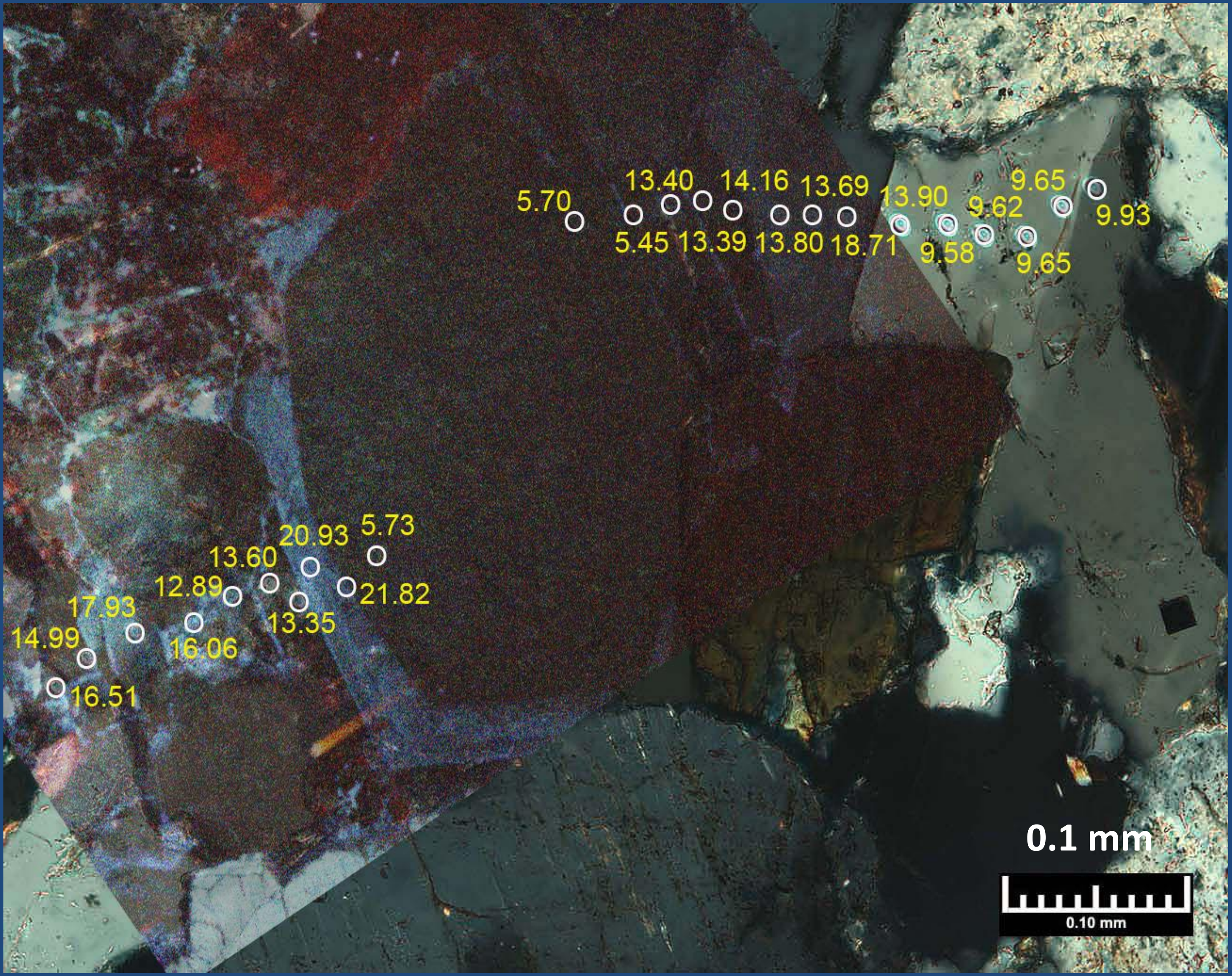
BUREAU OF ECONOMIC GEOLOGY

Polished thin section with quartz standard

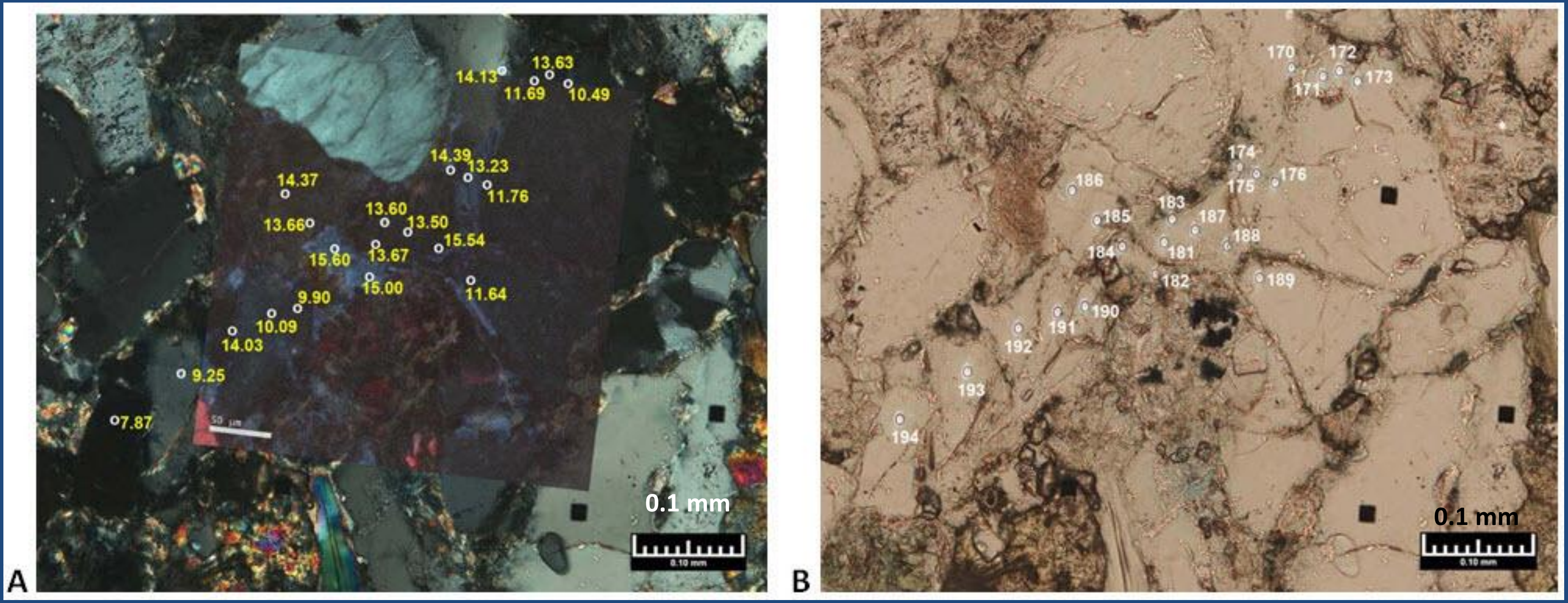
The Wisconsin Secondary Ion Mass Spectrometer LABORATORY



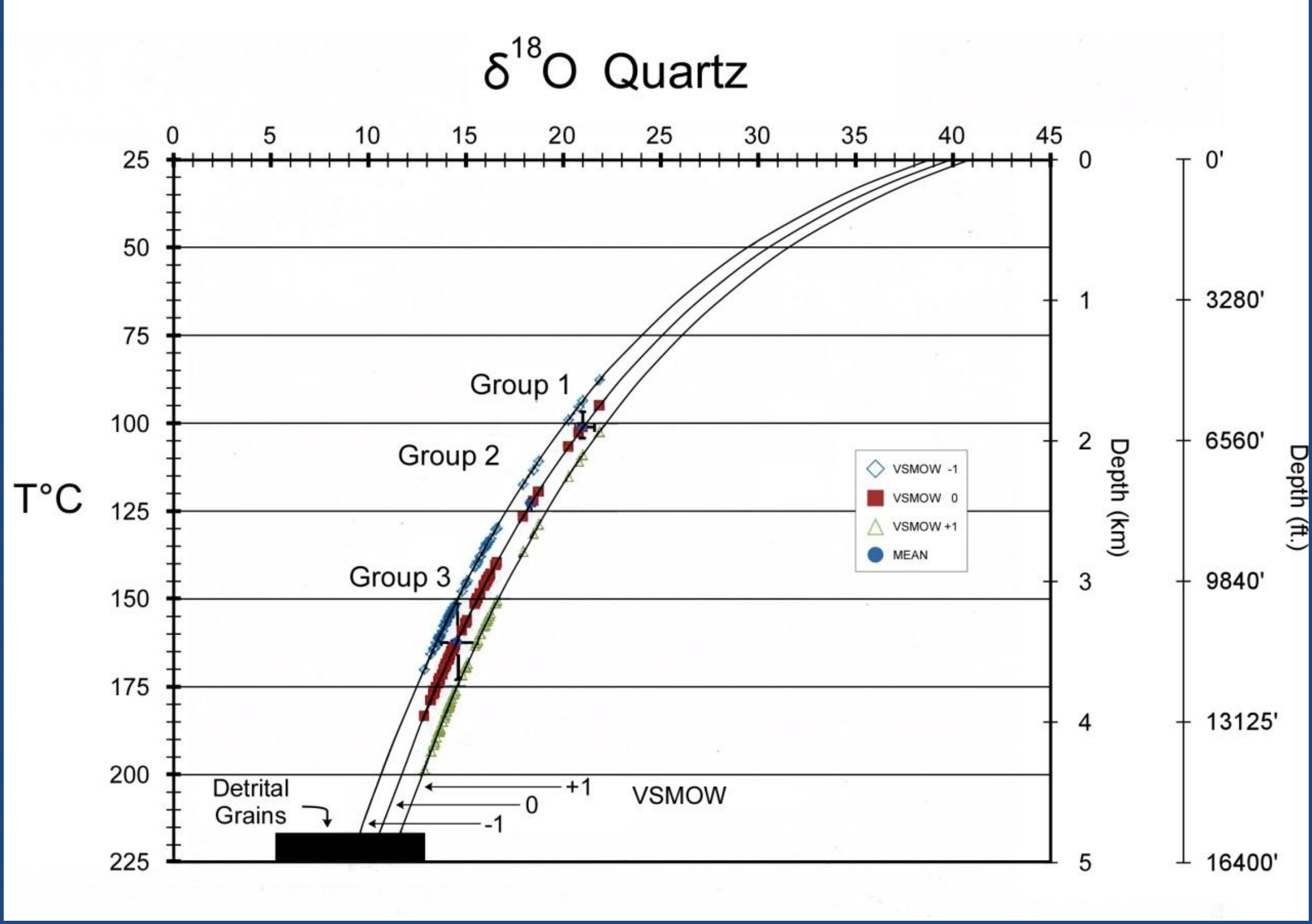
Photomicrographs of the sample from 5702.5 ft (R37) with ‰ δ^{18} O (SMOW) values



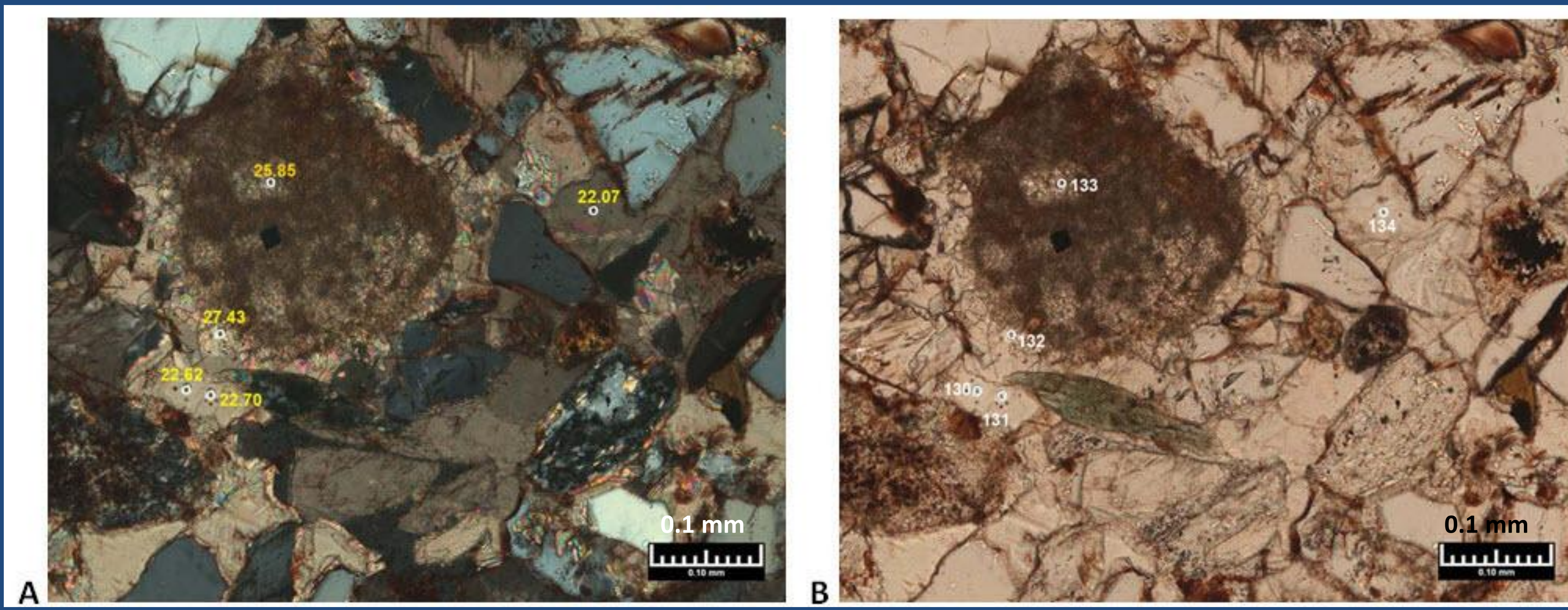
Photomicrograph of the sample from 5702.5 ft (R37) with ‰ δ^{18} O (SMOW) values



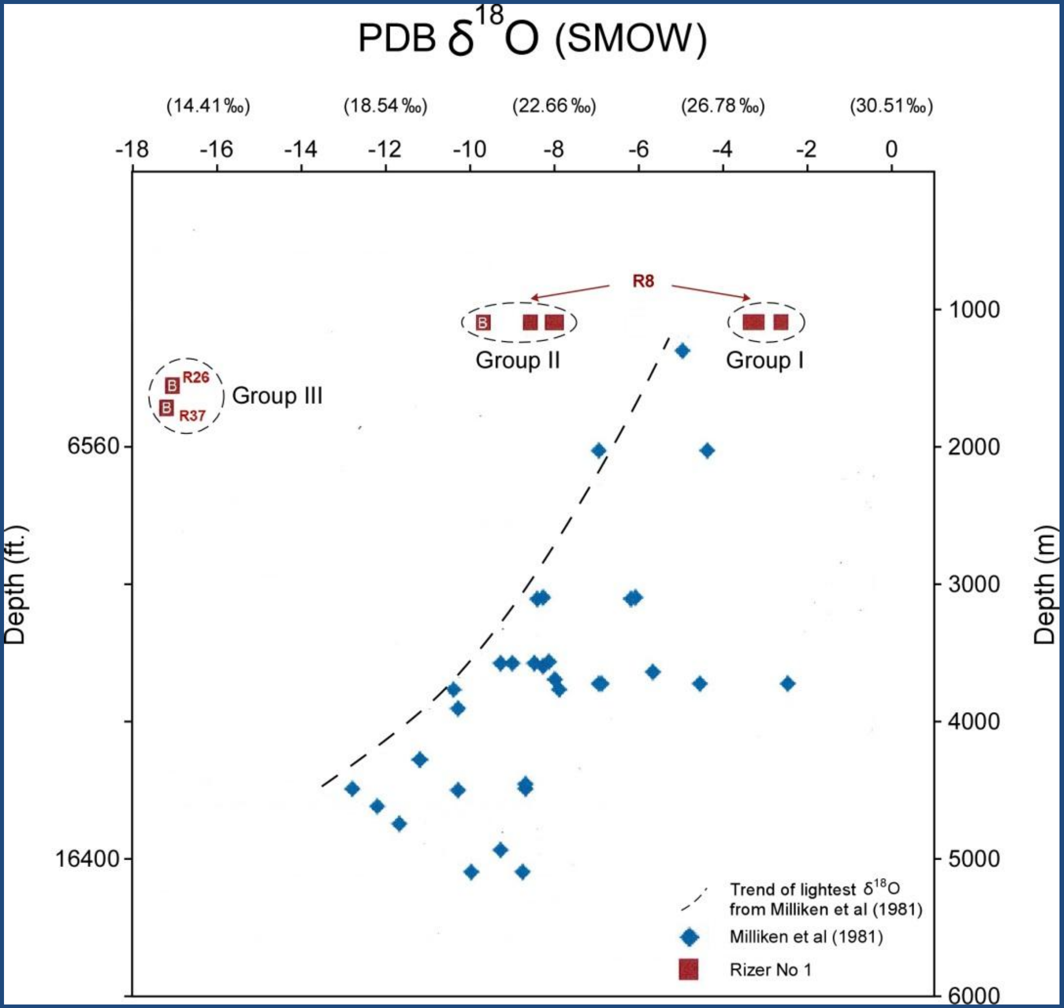
Photomicrographs of the RSWC sample from 5152.5 ft (R26) with ‰ δ^{18} O (SMOW) values



Temperatures calculated using the equation of Clayton et al. (1972).
Geothermal gradient of 40°C/km from Tseng et al. (1996).

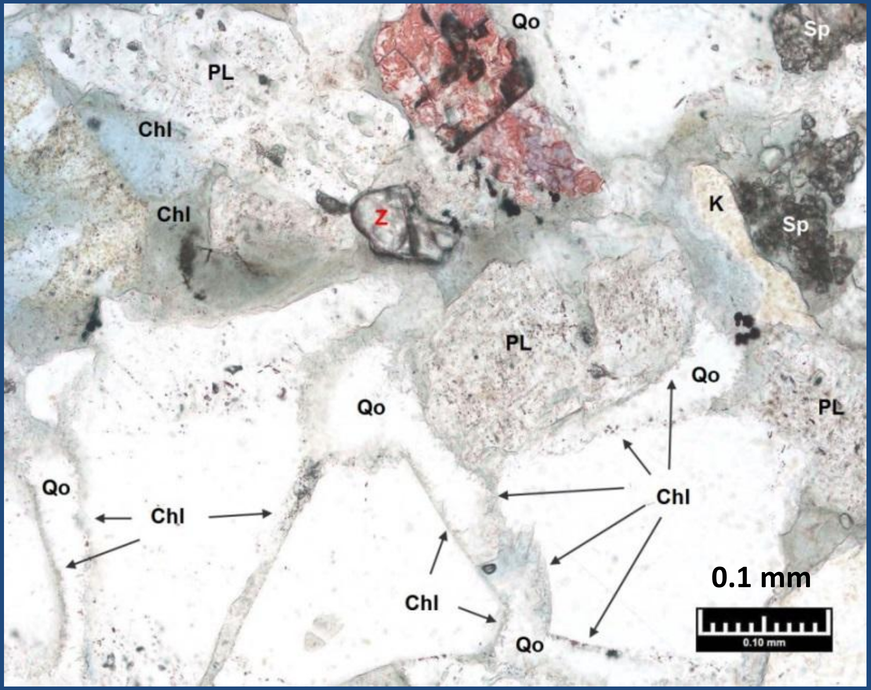


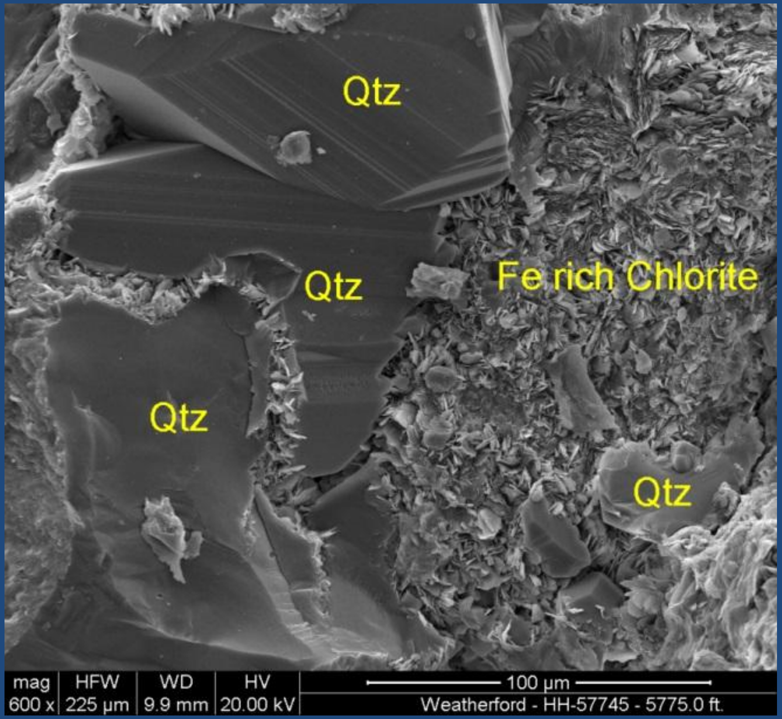
Photomicrographs of the sample from 3674.0 ft (R8) with ‰ δ^{18} O (SMOW) values



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).

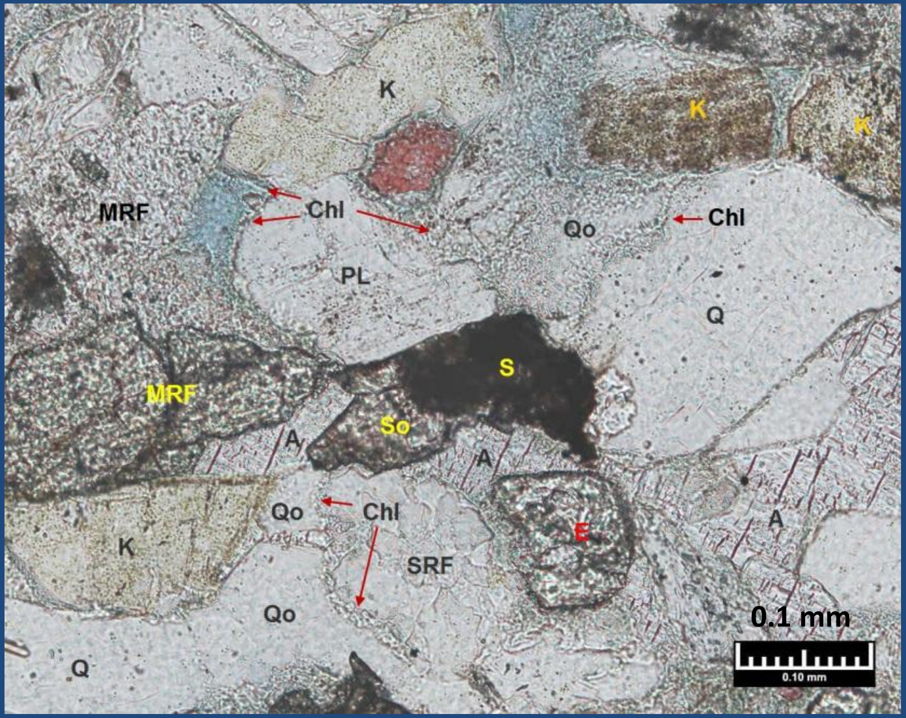
Other diagenetic characteristics of Rizer #1 sandstones

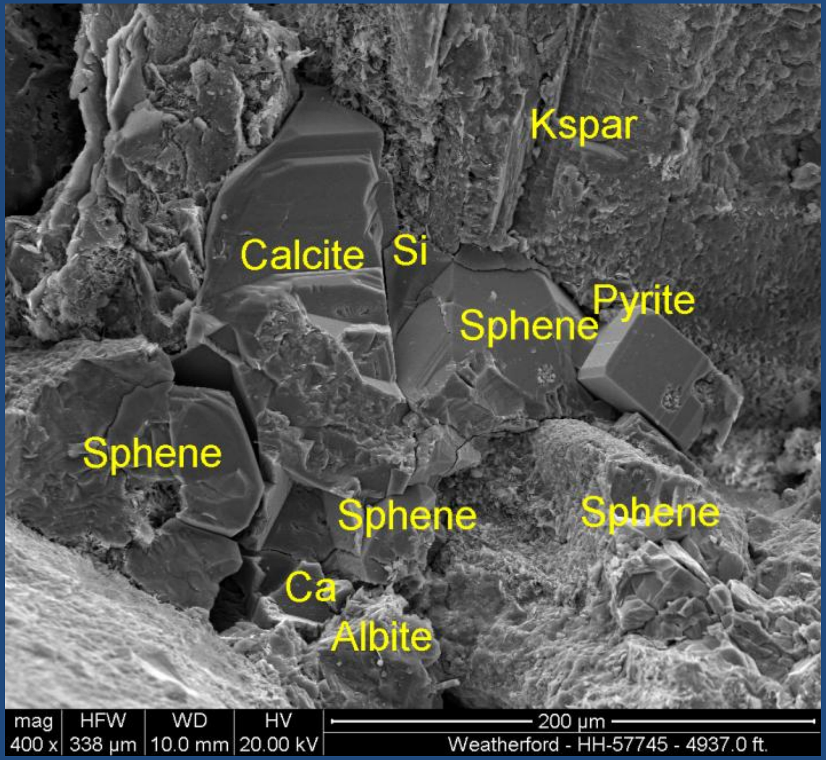




Early chlorite clay

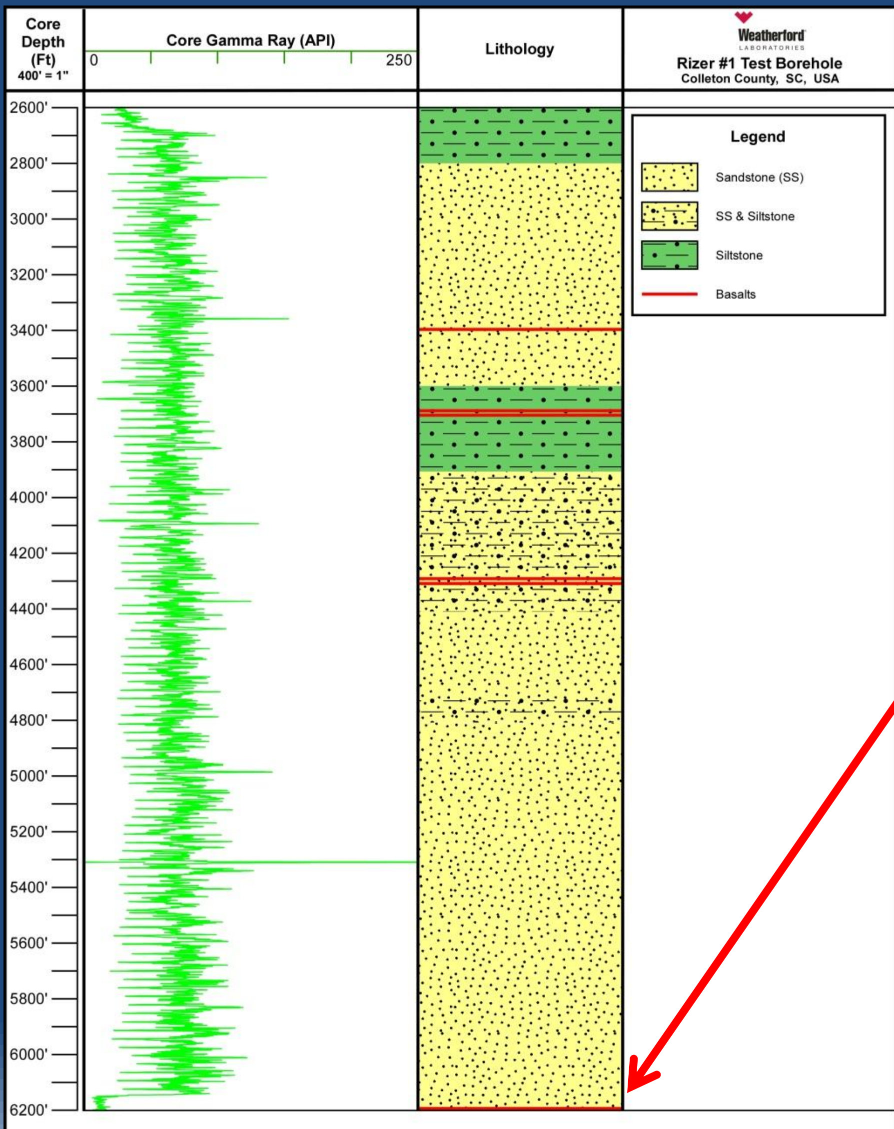
Other diagenetic characteristics of Rizer #1 sandstones

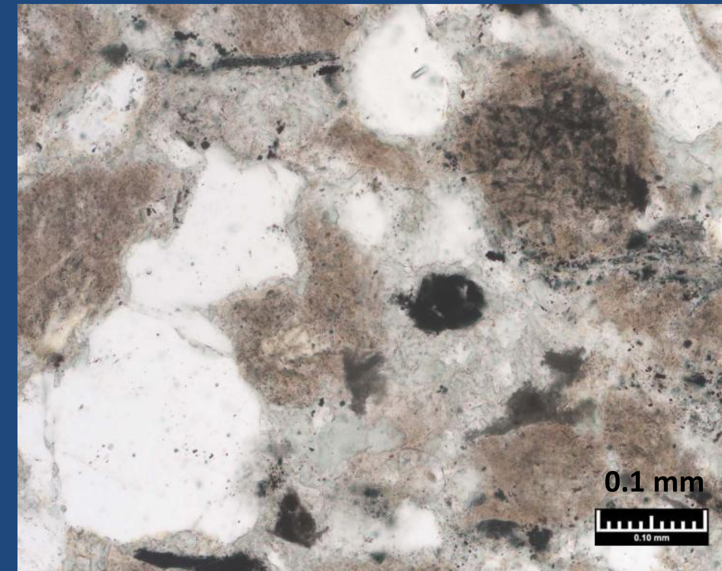




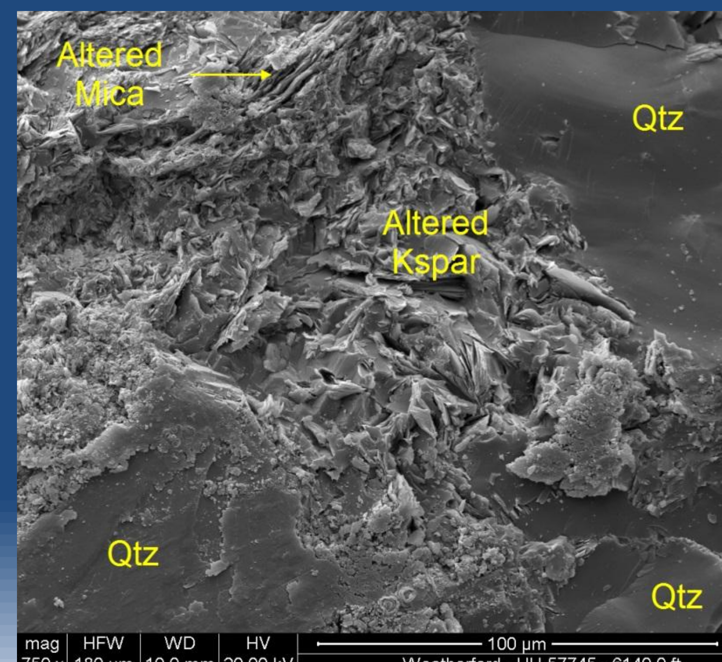
Authigenic sphene, anhydrite, pyrite…

Metasomatic alteration (?) associated with basal basalt



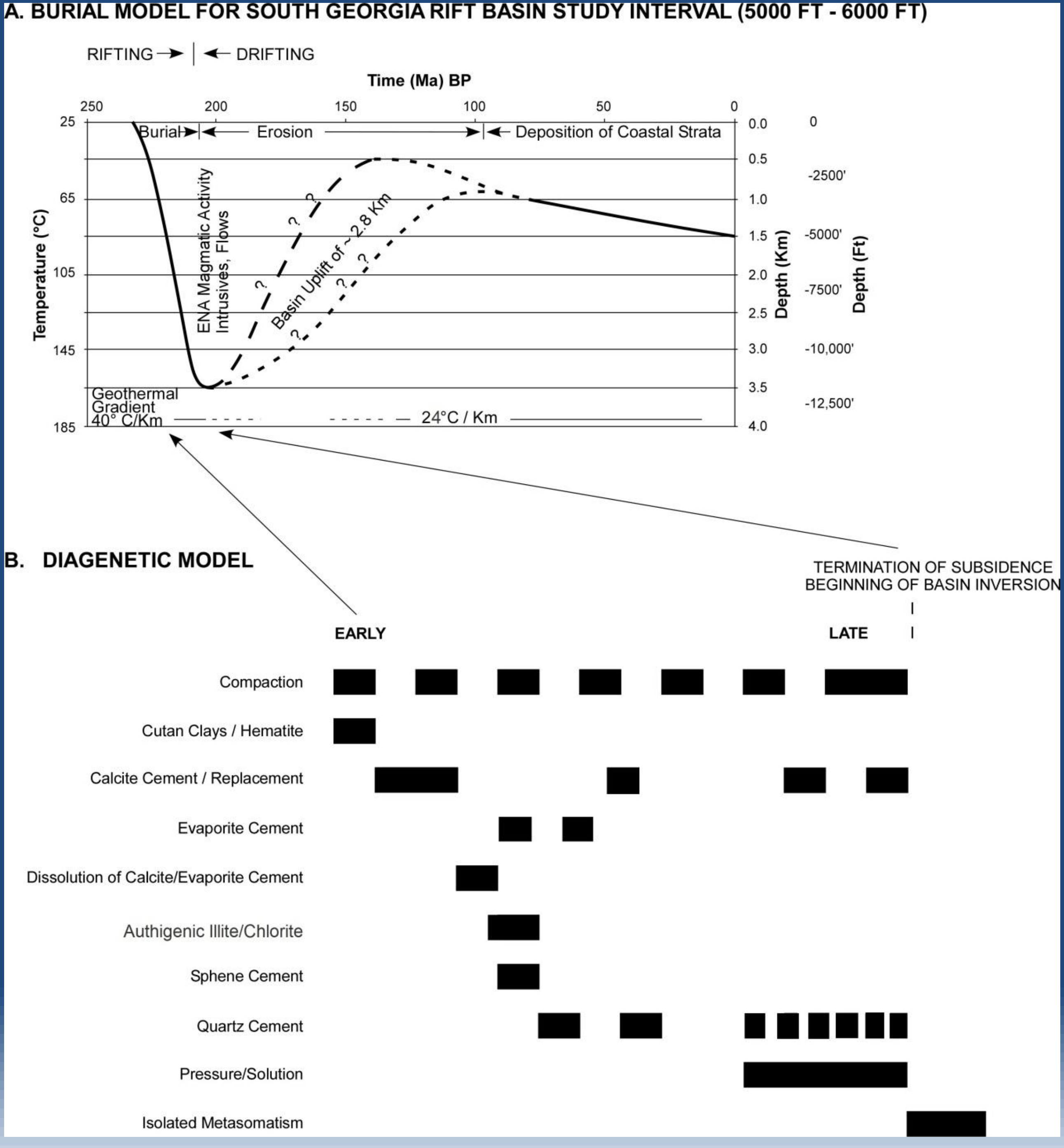


6140.0 ft (RSWC 1-107R)



Weatherford LABORATORIES

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

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