Preliminary Data on the Diagenesis of Mississippian (Osagian) Strata: A Study of the Rebecca K. Bounds Core, Greeley County, Kansas

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Introduction

This report presents preliminary findings and ongoing research on the diagenetic history and fluid flow in the Mississippian (Osagian) interval of the Rebecca K. Bounds (RKB) core, Greeley County, Kansas. Core depth of the studied interval was 5,445 ft to 5,534 ft (fig. 1).

Carbonate cementation characterized by calcite and dolomite filling large vugs, channels, breccias, and fractures in the section of the core studied indicates diagenetic processes such as dissolution and reprecipitation of the Mississippian carbonates in the study area. This study focuses on the later stages of diagenetic carbonate cementation associated with the migration of subsurface fluid flow.

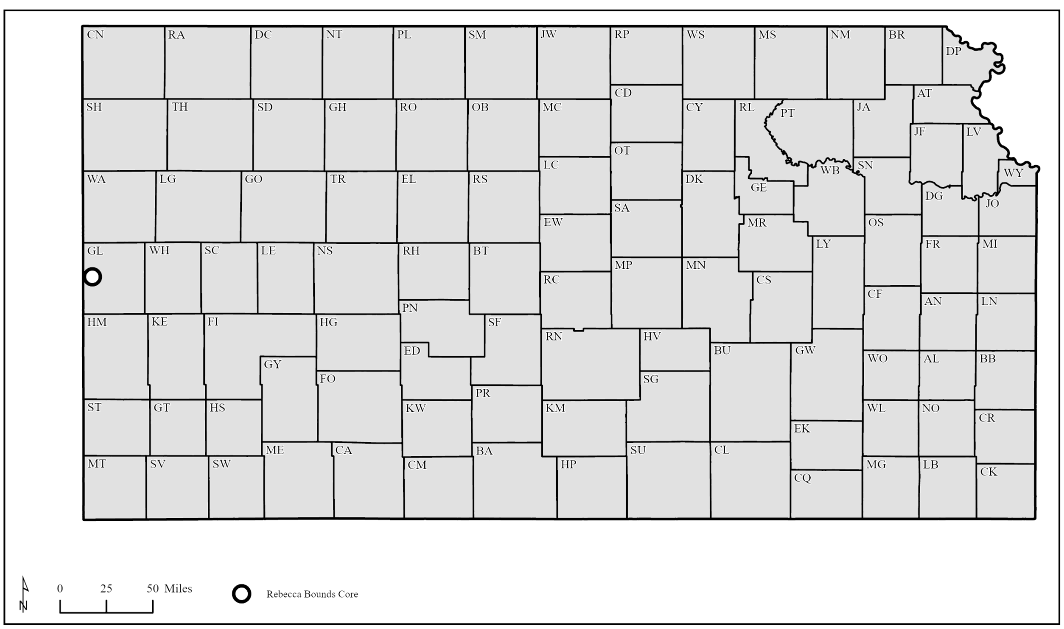

Figure 1. Location of the Rebecca K. Bounds (RKB) core sample in Greeley County, Kansas.

Geologic Setting/Background

The RKB core interval studied (fig. 2) is characterized by three main facies: (1) bioturbated mudstone-wackestone, (2) echinoderm-rich packstone-grainstone, and (3) bryozoan-rich wackestone-packstone and packstone-grainstone. The most common skeletal fragments occurring throughout the core include echinoderms, bryozoans, and bivalves. Cherty large burrows filled with echinoderm-rich packstone-grainstone facies are common in the basal portion of the core (5,531–5,517 ft). Some core areas within packstone-grainstone facies include cross bedding and apparently highly abraded skeletal grains (depths of 5,517–5,515 ft, 5,481–5,478 ft, 5,474.5–5,457.5 ft). The carbonate rocks within the RKB core were deposited during the Osagian. Kansas was located in low latitudes at roughly 20° south in a shallow-water tropical-subtropical sea during this time (Gutschick and Sandberg, 1983; Franseen, 2006). The abundance of echinoderm skeletal grains with other diverse fauna and evidence of extensive reworking by burrowing organisms within the RKB core suggest shallow-water subtidal deposition in a normal marine inner- to mid-ramp setting. Packstone and grainstone facies suggest a high-energy environment at times. Mudstone-wackestone facies indicate lower energy settings.

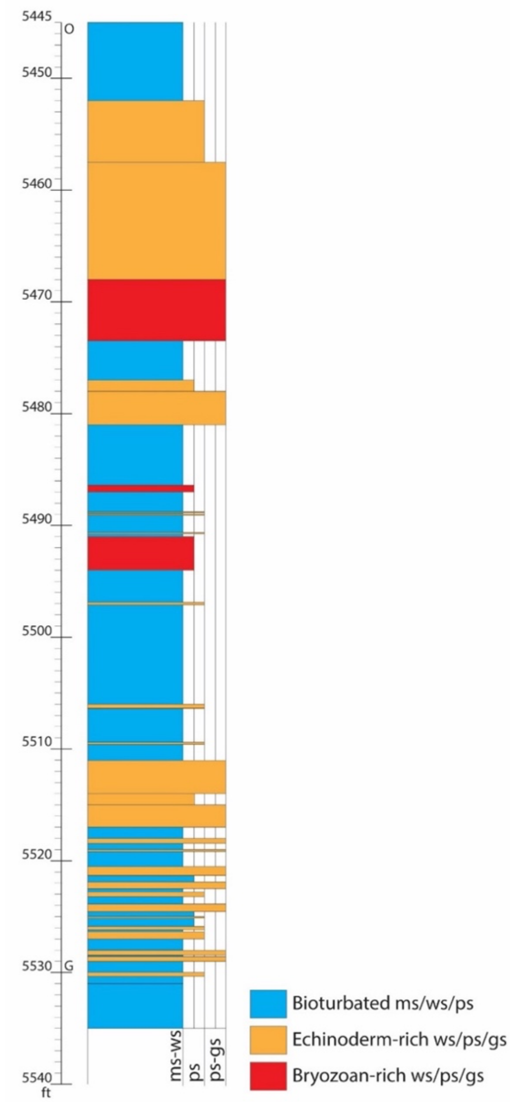

Figure 2. Core descriptions for the Rebecca K. Bounds (API: 15-071-20446) core interval studied showing depositional facies. O: Osagian Stage top (5,446 ft) and G: Gilmore City Limestone top (5,530 ft) (base of the Osagian Stage) based on the Kansas Geological Survey tops database. ms: mudstone, ws: wackestone, ps: packstone, gs: grainstone.

Endothyroids and Plectogyra are typically studied in thin sections of limestone, as their taxonomic characteristics were defined for such sections. We observed the overall shape and size of the foraminifera, noting whether they were spherical, elongated, or irregular and paying attention to the test (shell) composition, which can be either calcareous or agglutinated, and the surface texture, which may be smooth, granular, or spiny. We looked for distinctive features, such as chamber arrangement, aperture type, and wall structure. For instance, *Endothyra macra* can be identified by its coiled chambers, while *Plectogyra irregularis* may exhibit an irregular growth pattern.

Most benthic foraminifera identified in this project included species such as *Endothyra macra, Endothyra symmetrica*, and *Plectogyra irregularis*. Based on the high abundance of *Plectogyra irregularis*, the age of this rock was determined to be the Osagian Stage of the Mississippian Epoch (Zeller, 1972; Zeller, 1957) (figs. 3–5).

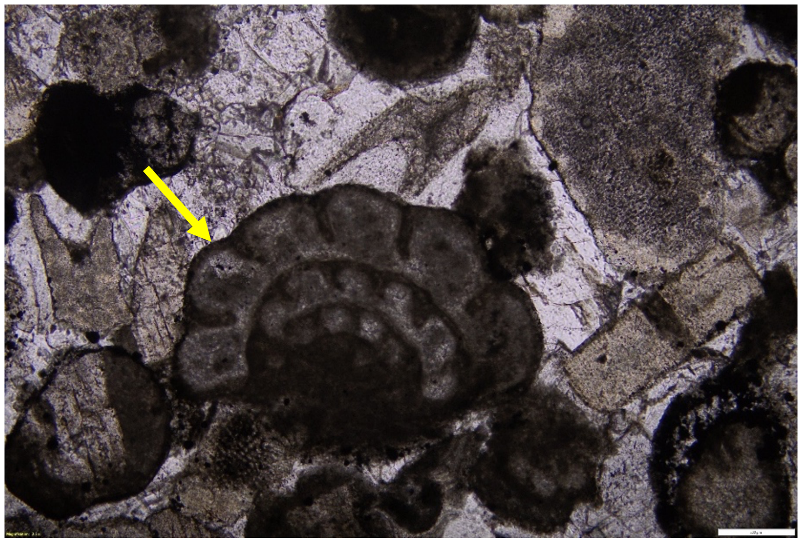

Figure 3. The yellow arrow indicates *Endothyra macra.*

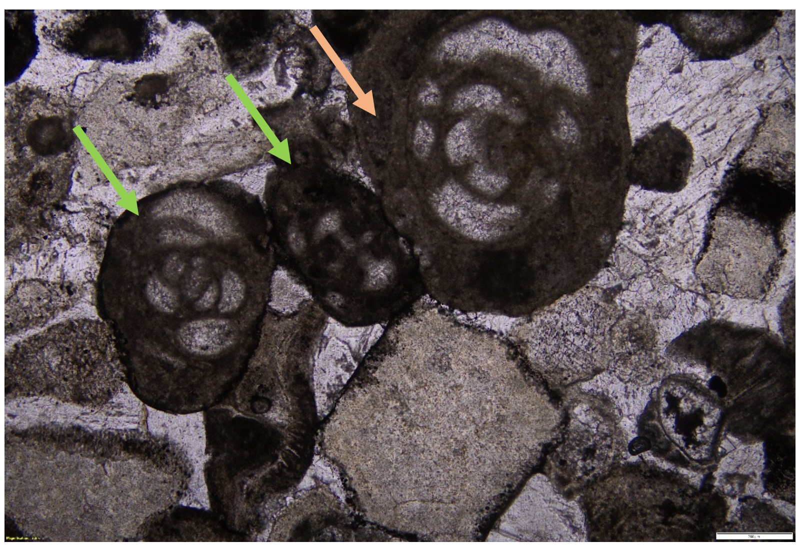

Figure 4. The light green arrows indicate *Plectogyra irregularis*, and the pink arrow indicates *Endothyra symmetrica.*

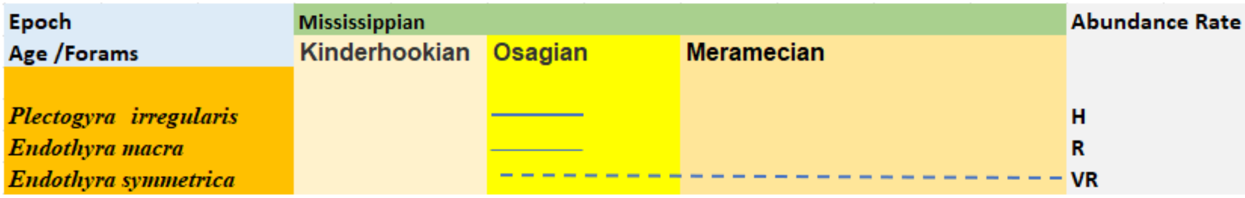

Figure 5. Age distribution of benthic foraminifera and their relative abundance. H: high, R: rare, and VR: very rare.

Methods

The authors analyzed 18 samples collected from the RKB core of the Kansas Geological Survey (KGS), specifically from the Mississippian (Osagian) strata, using the following methods:

1. **Petrography** — We conducted petrographic studies using cold-cathodoluminescence (CL) petrography with a CITL MK5-1 system mounted on an Olympus-BX53 microscope, equipped with 4X long focal distance objective lenses. Some images were stitched together using software connected to the CL microscope to enhance visualization of the paragenesis and cement stratigraphy of the core.
2. **Fluid inclusion microthermometry** — We undertook fluid inclusion studies to determine the salinity and temperature of late diagenetic fluids that precipitated the carbonate cements, including calcite and dolomite. Fluid inclusion measurements were carried out using USGS (U.S. Geological Survey) gas-flow heating/freezing stage attached to an Olympus BX53/60-MTRF-S microscope equipped with 40X and 100X long focal distance objective lenses (table 1). In addition, we conducted UV fluorescence petrography on the fluid inclusions to assess the existence of petroleum inclusion within the samples.
3. **Isotope Geochemistry:**

   The Keck-NSF Laboratory at the University of Kansas (KU) performed carbon and oxygen isotope analyses on dolomite cements filling channels and vugs. Table 2 and fig. 5 present the $\delta^{13}C$ and $\delta^{18}O$ values. Figure 6 and table 3 present the $^{87}Sr/^{86}Sr$ isotope ratios measured in late diagenetic dolomite and calcite cement using a thermal ionization mass spectrometer (TIMS) at the KU Isotope Geochemistry Laboratory (KU-IGL).

Results

Cementation Paragenesis — Blocky calcite, saddle dolomite, and quartz were observed within large vugs, channels, fractures, and breccias in 18 thin sections (figs. 6 and 7).

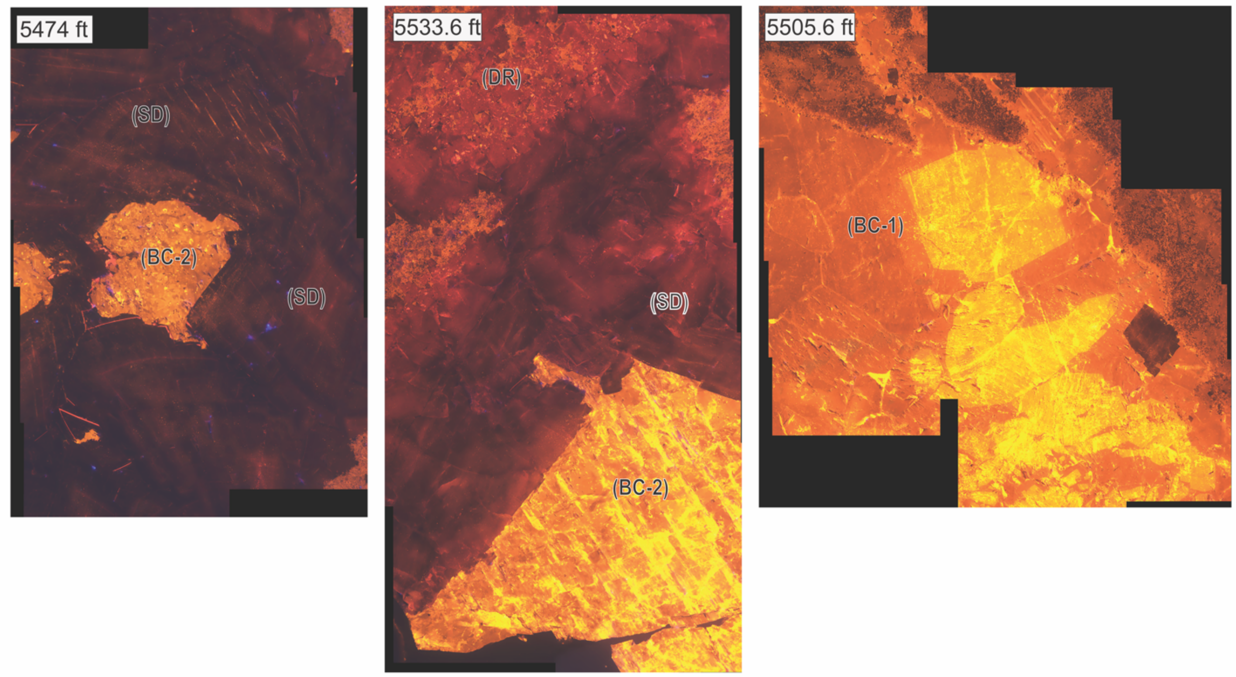

Figure 6. CL petrography of vugs and channels: filled with blocky calcite (BC-1), saddle dolomite (SD), and dolomite with recrystallization textures (DR). Note: Images do not have scales due to figure stitching. Each photomicrograph represents one thin section.

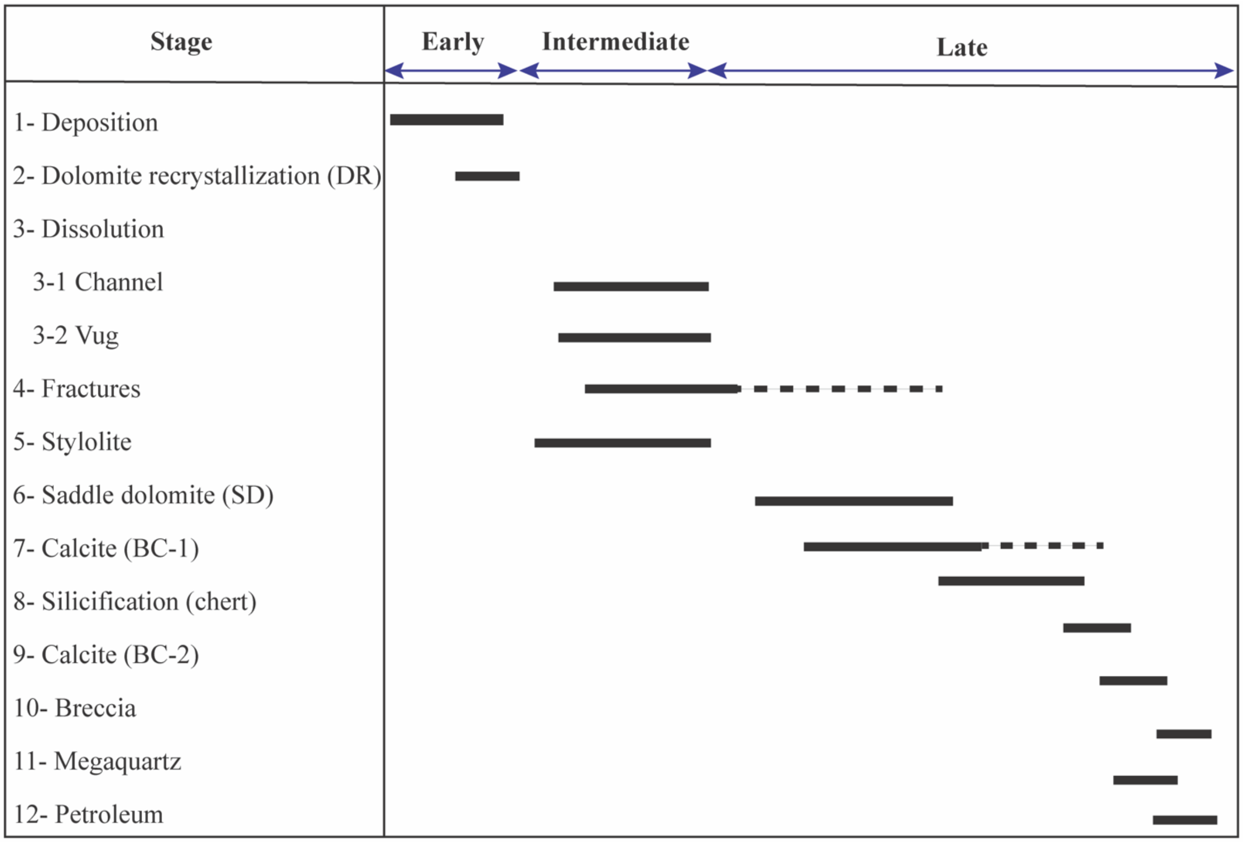

Figure 7. Paragenetic sequence in Osagian (Mississippian) strata, RKB core, Greeley County, Kansas.

Fluid Inclusion Constraints — This research identified one-phase (liquid) and two-phase (liquid-gas) primary and secondary inclusions (fig. 8). The homogenization temperature (T_h) values, representing the minimum trapping temperatures, ranged from 65°C to 126°C for dolomite cement and from 67°C to 101°C for calcite. Additionally, the ice melting temperature (T_m) ranged from -14.7°C to -21°C for dolomite and ranged from -9.3°C to -23.6°C for calcite (wt% NaCl eq) (table 1).

Fluid inclusions in saddle dolomite from samples RKB-5453, RKB-5474, and RKB-5533.6 exhibited a cream to blue color under fluorescent light, indicating the presence of petroleum inclusions (fig. 8).

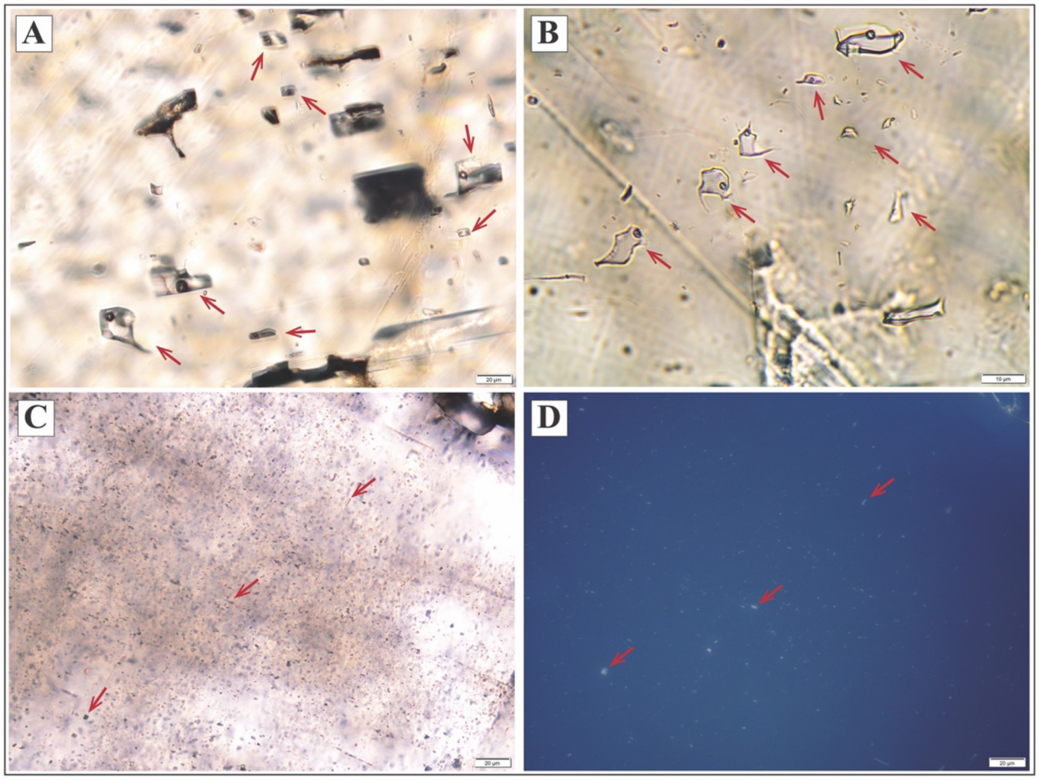

Figure 8. Photomicrographs of aqueous and oil inclusions (primary and secondary) in channel- and vug-filling saddle dolomite and calcite cements. (A) Assemblage of two-phase fluid inclusions in plane-polarized light in dolomite. (B) Assemblage of two-phase fluid inclusions in plane-polarized light in calcite cement. (C) Assemblage of two-phase oil inclusions in plane-polarized light. (D) Same sample as (C) under UV light showing oil-bearing inclusions. Red arrows indicate aqueous and oil inclusions.

Table 1. Microthermometric data for dolomite and calcite cements filling vugs, channels, and fractures in the RKB core, Greeley County, Kansas. Ass.: assemblage.

Sample ID	Mineral	Assemblage	T_h (°C)	T_m (°C)	Description
RKB-5453	Dolomite	Ass. 1	106	-16.5	Primary
			106	-16.5	Primary
			106	-16.5	Primary
			106	-16.5	Primary
			106	-16.5	Primary
		Ass. 2	93	-15.2	Primary
			93	-15.2	Primary
			93	-15.2	Primary
			93	-15.2	Primary
			93	-15.2	Primary
			93	-15.2	Primary
			93	-15.2	Primary
		Ass. 3	92	-15.2	Primary
			92	-15.2	Primary

		Ass. 4	126	-19.6	Primary
			126	-19.6	Primary
			126	-19.6	Primary
		-	109	-14.7	Primary
RKB-5474.9	Dolomite	Ass. 1	107	-18	Primary
			107	-18	Primary
			107	-18	Primary
		-	65	-	Primary
		-	107	-18	Primary
		-	111	-20	Primary
		-	121	-20	Primary
RKB-5495	Dolomite	Ass. 1	116	-20	Primary
			116	-20	Primary
			116	-20	Primary
			116	-20	Primary
			116	-20	Primary
		-	104	-20.9	Primary
		Ass. 2	124	-	Primary
			124	-	Primary
		Ass. 3	104	-	Primary
			104	-	Primary
		-	-	-20.9	Primary
RKB-5505.6	Calcite	-	79	-18.2	Primary
		-	67	-20	Primary
		-	76	-20	Primary
		-	85	-18.2	Primary
		-	85	-18.9	Primary
		-	79	-18.2	Primary
		-	79	-23.6	Primary
		Ass. 1	79	-18.2	Primary
			79	-18.2	Primary
			79	-18.2	Primary
			79	-18.2	Primary
			79	-20	Primary
RKB-5525	Calcite	Ass. 1	78	-13.5	Primary
			78	-13.5	Primary
			78	-13.5	Primary
		Ass. 2	78	-	Primary
			78	-	Primary
			78	-	Primary
			78	-	Primary
		-	76	-	Primary
		-	80	-9.3	Primary
		-	101	-19.8	Primary

Isotope Geochemistry — Carbon, oxygen, and $^{87}Sr/^{86}Sr$ isotope analyses were conducted on calcite and dolomite filling vugs and channels. Tables 2 and 3 present the data. The ratios for $\delta^{13}C$ ‰ (VPDB) and $\delta^{18}O$ ‰ (VPDB), $^{87}Sr/^{86}Sr$ isotope, and $^{87}Sr/^{86}Sr$ versus $\delta^{18}O$ ‰ (VPDB) data are plotted and illustrated in figs. 9 and 10. The $^{87}Sr/^{86}Sr$ isotope data shown in table 3 have an uncertainty of 0.000014 with a 95% confidence level.

Table 2. Carbon and oxygen isotope data (‰) from the RKB core, Greeley County, Kansas.

Sample ID	Mineral & Open Space Type	$\delta^{13}C$ ‰ (VPDB)	$\delta^{18}O$ ‰ (VPDB)	$\delta^{18}O$ ‰ (SMOW)
RKB- 5453	channel filling—saddle dolomite	2.08	-6.14	24.59
RKB- 5458.5	channel filling—saddle dolomite	1.98	-5.67	25.07
RKB- 5474.9	vug filling—saddle dolomite	1.90	-5.64	25.11
RKB- 5495	vug filling—saddle dolomite	1.46	-6.50	24.22
RKB- 5505.6	channel filling—calcite	-0.25	-9.08	21.56
RKB- 5525	vug—calcite	1.79	-9.44	21.19
RKB- 5533.4 a	channel filling—saddle dolomite	0.15	-6.14	24.59
RKB- 5533.4 b	channel filling—calcite	-0.96	-8.86	21.79
RKB- 5533.6 a	channel filling—saddle dolomite	0.57	-4.66	26.12
RKB- 5533.6 b	channel filling—calcite	-1.01	-8.69	21.96

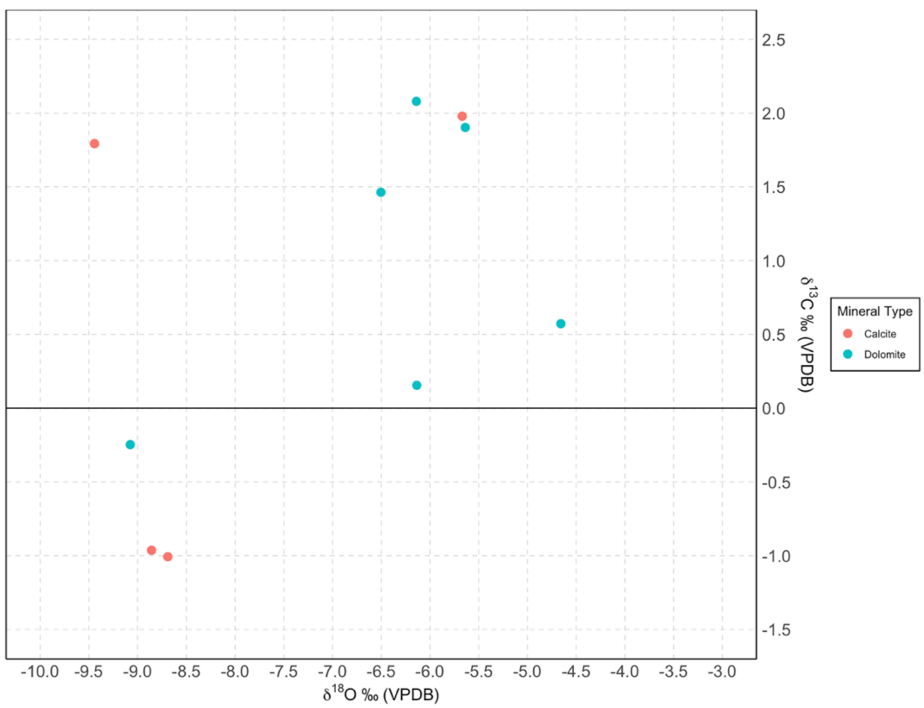

Figure 9. Carbon and oxygen isotope ratios (‰, VPDB) for carbonate cements filling vugs and channels.

Table 3. $^{87}Sr/^{86}Sr$ isotope data from the RKB core, Greeley County, Kansas.

Sample ID	Mineral & Open Space Type	$^{87}Sr/^{86}Sr$ (exp correction)	$\delta^{18}O$ ‰ (VPDB)
RKB-5453	channel filling—saddle dolomite	0.7088812	-6.14
RKB-5474.9	vug filling—saddle dolomite	0.7090068	-5.64
RKB-5495	vug filling—saddle dolomite	0.7094432	-6.5
RKB-5505.6	channel filling—calcite	0.7089503	-9.08
RKB-5525	vug—calcite	0.7111501	-9.44

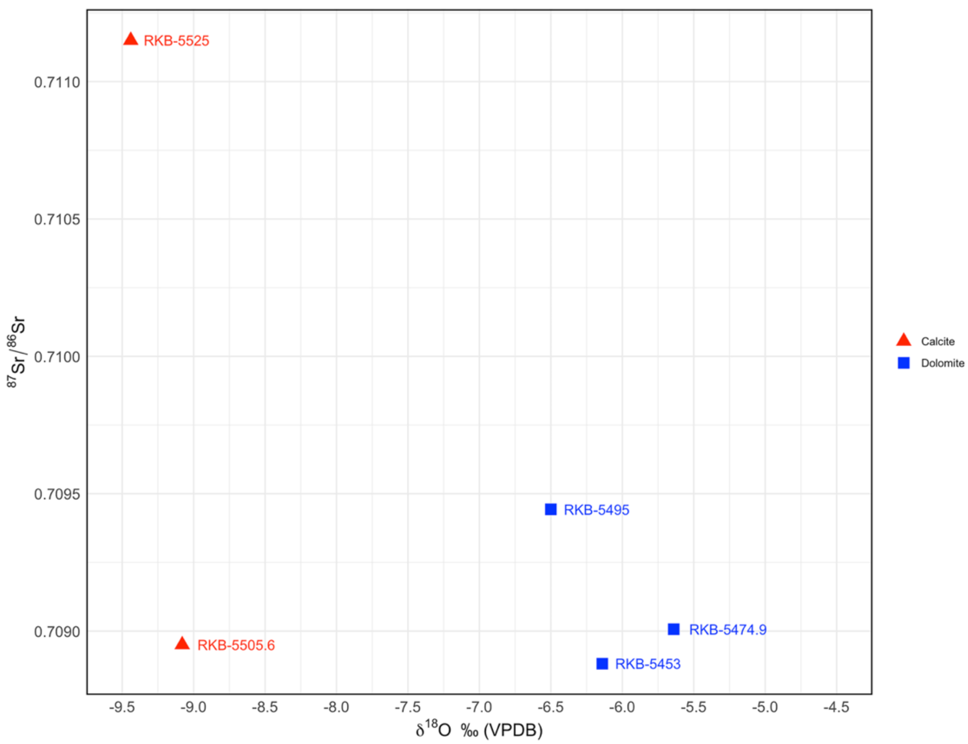

Figure 10. $^{87}Sr/^{86}Sr$ versus $\delta^{18}O$ ‰ (VPDB) data from the RKB core, Greeley County, Kansas.

Summary — A summary of preliminary data for this study indicates the following:

- Homogenization temperatures (T_h) for open-space-filling dolomite and calcite cements range from 65°C to 126°C and 67°C to 101°C, respectively. Additionally, the ice melting temperatures (T_m) for dolomite and calcite cements range from -14.7°C to -21°C and -9.3°C to -23.6°C (wt% NaCl eq), respectively. These ranges of T_h and T_m values suggest the presence of hot and highly saline fluids. Furthermore, these fluids were followed by petroleum migration, as indicated by petroleum inclusions.

- The low $\delta^{18}O$ values (-4.66 to -9.44 ‰, VPDB) suggest cement precipitation from warm fluids, while the low $\delta^{13}C$ values can be associated with sulfate reduction followed by petroleum movement.
- Elevated $^{87}Sr/^{86}Sr$ isotope ratios range from 0.708 to 0.711 ‰ observed from this interval.

References:

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