TSR The Sedimentary Record
SEPM | Society for Sedimentary Geology

Lasemi, Y., & Askari, Z. (2024). Multiple Paleokarst Events in the Cambrian Potosi Dolomite, Illinois Basin. *The Sedimentary Record*, *22*(1).
https://doi.org/10.2110/001c.94133

Research Article

Multiple Paleokarst Events in the Cambrian Potosi Dolomite, Illinois Basin

Yaghoob Lasemi[1], Zohreh Askari[1]

[1] Illinois State Geological Survey, Prairie Research Institute, University of Illinois Urbana-Champaign

Keywords: Potosi Dolomite, Stratigraphic variability, Fracture/cavern porosity, Paleokarst events, Cambrian, Illinois Basin, Hypogenic basinal/hydrothermal fluids

https://doi.org/10.2110/001c.94133

The Sedimentary Record

Vol. 22, Issue 1, 2024

The Cambrian (Furongian) Potosi Dolomite (100-183 m) in Illinois is part of the Cambro-Ordovician Knox Group. It is a uniformly dolomitized unit with very low intercrystalline porosity but contains very permeable vug, fracture/cavern porosity intervals. Here, we interpret the characteristics of the widespread porous zones in the Potosi as paleokarst features formed by rising hypogenic basinal/hydrothermal fluids. The conformity bounded Potosi Dolomite is characterized by massive dolomitization, overdolomitization and occlusion of previously generated intercrystalline porosity, void filling mineralization, and extensive dissolution and formation of cavity-conduit systems. The pore spaces are typically lined with drusy quartz or are characterized by partial to complete infilling with chalcedonic silica and/or dolomite cements. Clay minerals may partially fill pore spaces; physical properties and thorium-potassium crossplot suggest chlorite as the main clay mineral present. Dolomite crystals typically are planar-s or nonplanar with open-space filling, inclusion rich saddle dolomite displaying curved and zigzag crystal faces. Void filling cement does not exhibit sign of pressure solution and in places vug porosity is developed along bedding parallel stylolite indicating post burial origin of these features.

Cavern reservoirs in the Potosi are laterally extensive and often stacked with intervening very low porosity dolomite; very low bulk density, excursion of caliper log signature from the baseline, and loss of fluid circulation during drilling in these intervals signify anomalously high porosity and permeability interpreted as being the result of cavern forming multiple paleokarst events. Post burial origin of cavities and void filling cements, association of saddle dolomite and chlorite, and occurrence of Mississippi Valley-type (MVT) ore deposits in Missouri suggest karstification by hypogenic warm basinal/hydrothermal fluids. Dissolution and mineralization likely occurred by flow of deep basinal formation waters and hydrothermal fluids (sourced from the crystalline basement underlying the Reelfoot Rift and the Illinois Basin) along numerous basement-rooted normal, reverse, and strike-slip faults, and the associated fold and fractures. Expansion and contraction because of fault-related seismicity likely developed fracture porosity in brittle host dolomite and possibly ruptured any underling impermeable units to enable large-scale upward and outward fluid movement. The Potosi fracture/cavern porosity intervals are confined by thick very low porosity dolomite intervals that could serve as effective seal. There is no report of any show of oil in the Potosi Dolomite, but the unit has an excellent potential to serve as a combined reservoir and seal for storing anthropogenic CO_2 and waste material.

INTRODUCTION

The Cambrian (Furongian) Potosi Dolomite in Illinois is part of the Cambrian-lower Middle Ordovician Knox Group (Fig. 1A) and is a relatively uniformly dolomitized unit with low siliciclastic content. Studies to date of the Potosi in the Illinois Basin have been mainly of general stratigraphic nature (e.g., Buschbach, 1975; Lasemi & Askari, 2014). The Potosi is characterized by very low intercrystalline porosity but encompasses vug and fracture/cavern porosity intervals (terminology after Chocquette & Pray, 1970) in which several hundred barrels of fluid may be lost during drilling (Lasemi & Askari, 2014, 2021; Leetaru et al., 2014). Cavernous intervals could serve as reservoirs for oil and gas, groundwater, and ore mineralization (e.g., Loucks, 1999), or serve as repositories for CO_2 and hazardous waste material. This study focuses on facies, stratigraphic variability, paleokarst features, and mineralization in the Potosi using the available subsurface data. Geophysical log suites, well samples/cores, and petrographic data are used to document the presence of caverns and open vugs, diagenetic cements, and breccias associated with cave collapse. The Potosi vug and brecciated zones at the ADM IBDP wells, Macon County, central Illinois was assumed to be the result of early vadose or phreatic karstification due to subaerial exposure at the top of the Eminence Dolomite (Leetaru et al., 2014). However, the results of this study suggest that the Potosi karstification had no genetic relationship with groundwater recharge from the upper surface of the overlying Eminence Dolomite. Here, we interpret the characteristics of the widespread porous zones in the Potosi as paleokarst features formed by rising hypogenic basinal/hydrothermal fluids that caused massive dolomitization and overdolomitization of the host carbonates, formation of dissolution porosity/permeability, and mineralization.

GEOLOGIC SETTING AND STRATIGRAPHY

The intracratonic Illinois Basin covers most of Illinois and parts of western Kentucky and southwestern Indiana. It is bordered by a series of prominent arches and domes (Fig. 1B) and overlies the northeast extension of the Late Proterozoic to Middle Cambrian Reelfoot Rift system (Kolata & Nelson, 1990) associated with the breakup of supercontinent Rodinia (e.g., Bond et al., 1984; Meert & Torsvik, 2003). Numerous folds, monoclines, and fault zones and systems are present (Fig. 1C), which show a variety of structural styles; the folds and monoclines generally overlie faults in the Precambrian crystalline basement and in several cases, the same structure has undergone deformation under more than one stress regime (Nelson, 1995). Several domes or irregular shape folds overlie Precambrian hills in southern Illinois that are unrelated to major anticlines and monoclines and in places the basal Knox carbonates directly rest on granite basement (Nelson, 1995).

The Cambrian and Lower Ordovician succession in northern Illinois consists of alternating carbonate and siliciclastic units (Fig. 1A) the upper part of which was classified as the Lower Ordovician Prairie du Chien Group (Buschbach, 1975; Kolata, 2005; Willman & Buschbach, 1975). The siliciclastic intervals thin southward and grade to carbonate dominated units in southern and deeper part of the Illinois Basin. South of 40˚ N latitude, the succession including the capping lower Middle Ordovician interval is classified as the Knox Group (Fig. 1A), which includes Bonneterre, Davis, Derby-Doerun, Potosi, Eminence, Oneota, Shakopee, and Everton stratigraphic units (Kolata, 2005) consisting chiefly of fine to coarsely crystalline dolomite (Lasemi & Askari, 2014).

The Cambrian (Furongian) Potosi Dolomite was named for the town of Potosi, Washington County, Missouri by Arthur Winslow in 1894 who mentioned drusy quartz as a distinguishing feature (in T. L. Thompson et al., 2013). The Potosi is conformably bounded by the underlying Derby-Doerun Formation and the overlying, uppermost Cambrian, Eminence Dolomite. Thompson et al. (2013) noted that the Potosi contact with the Eminence is difficult to recognize and in places the two formations are mapped as a single unit. Siliciclastic content is low compared to the underlying and overlaying units that consist of dolomite interbedded with sandstone and siltstone/shale beds (Figs. 1A and 2G). The Potosi thickness ranges from 100 feet (30 m) in northern Illinois to over 600 feet (183 m) in southern Illinois (Lasemi & Askari, 2014). In southwestern Indiana, rocks equivalent to Davis, Derby-Doerun, Potosi, and Eminence stratigraphic units of Illinois are included in the Potosi Dolomite because they are hardly distinguishable (Shaver et al., 1986; T. A. Thompson et al., 2016). The Potosi Dolomite occurs in western Kentucky, but its lower and upper contacts are difficult to recognize (Johnson & Schwalb, 2010).

LITHOFACIES AND RESERVOIR PROPERTIES

The Potosi Dolomite varies from medium bedded (10-30 cm thick) to very thick bedded (over 1 m thick) and commonly contains vug cavities that are generally lined with drusy quartz (Fig. 2A, B). Drusy quartz is a distinctive feature of the Potosi in Missouri (Palmer, 1989; T. L. Thompson et al., 2013) and Illinois (Buschbach, 1975; Lasemi & Askari, 2014, 2021). The Potosi commonly has very low porosity and, based on crystal size classification of Folk (1959), is composed of medium (0.062-0.25 mm) to coarse (0.25-1 mm) crystalline dolomite; its primary depositional fabric is destroyed but ghosts of carbonate grains (Fig. 2C, D, E) record deposition in a shallow marine setting (Lasemi & Askari, 2021). In the subsurface, well records, including geophysical log signatures, well samples, and cores may be utilized to characterize the Potosi Dolomite. Gamma ray logs commonly display a lower gamma ray response in the Potosi compared to the underlying and overlying units (Fig. 2G). The higher gamma ray response in the porous intervals is likely due to the presence of uranium. Abundant drusy quartz and chert, low siliciclastic content, fractured/vug cavities that may be partially to completely mineralized, and collapse breccia commonly characterize the Potosi.

The Potosi is a uniformly dolomitized unit in which intercrystalline porosity is typically very low or absent (Figs. 2 C through F and 3A, C, E). Low matrix porosity can be attributed to overdolomitization (cementation/recrystallization) process (e.g., Lucia, 2004). Dolomite crystals generally show wavey extinction and, according to the terminology of Sibley and Gregg (1987), typically are planar-s (subhedral to anhedral) or nonplanar anhedral type with irregular and curved boundaries (Figs. 2C and 3 A through F). Saddle dolomite (e.g., Radke & Mathis , 1980) inclusion rich void-filling cement which displays curved and zigzag crystal faces and coarse planar to nonplanar replacive dolomite are both present (Fig. 3 A through F). Primary and secondary inclusions (Goldstein, 2003; Goldstein & Reynolds, 1994) are present (Fig. 3A, C) with primary inclusions along the direction of crystal growth and secondary inclusions cutting through growth zones or occurring as isolated irregular shape; two-phase fluid inclusions consisting of bright liquid and dark spherical bubble shape gas phase (Fig. 3C) are recognized but were not measured.

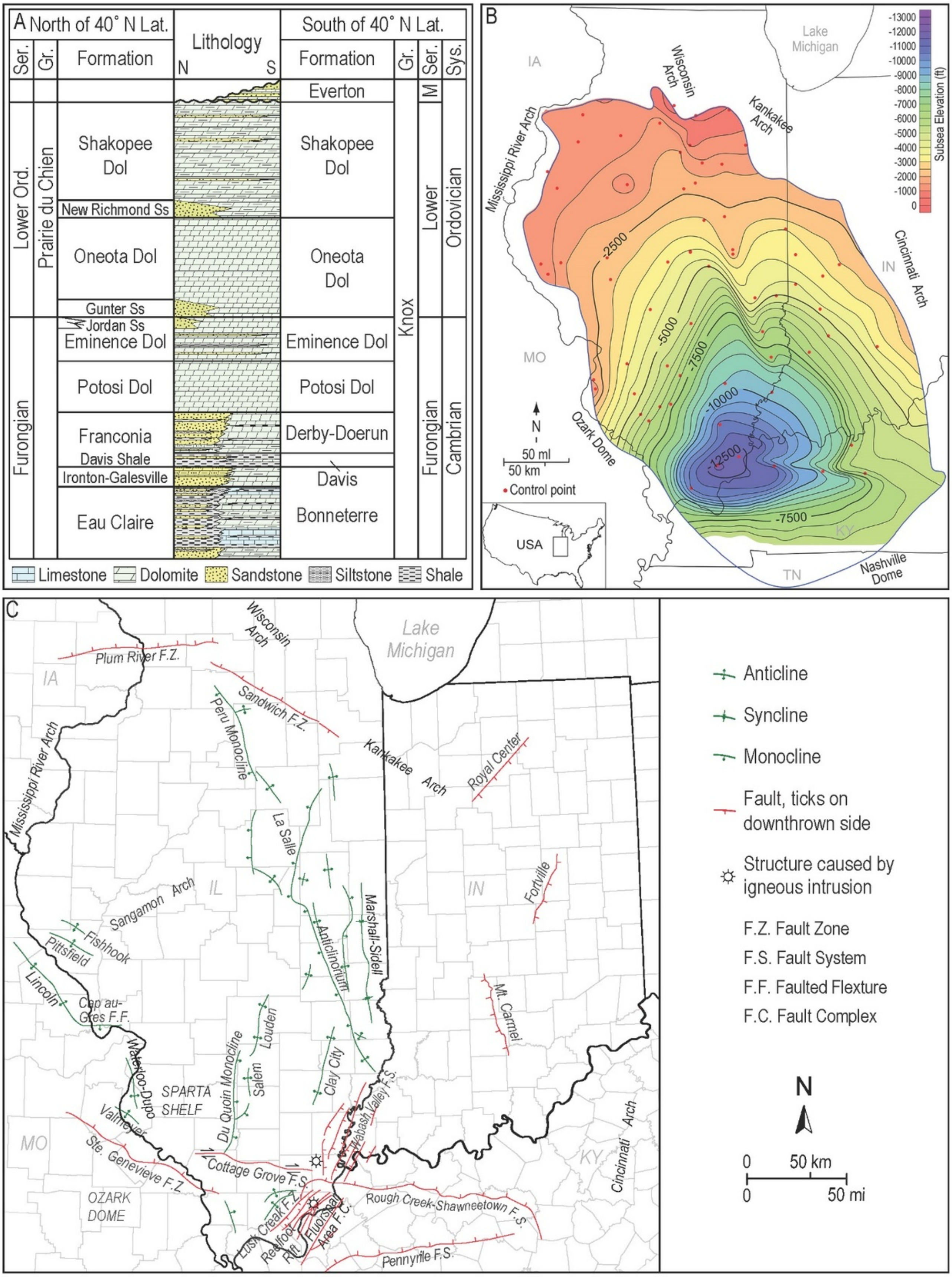

Figure 1. (A) Stratigraphic nomenclature of the Upper Cambrian through lower Middle Ordovician succession in Illinois. Note that the succession is classified as the Knox Group south of 40° N latitude (stratigraphic classification from Kolata, 2005). (B) Illinois Basin (basin outline in blue) surrounded by major structural features. Structure contour map on the top of Davis displays the Late Cambrian configuration of the basin. (C) Map showing major structural features in Illinois and the surrounding areas; the most intensely deformed area of the state is in southern Illinois (from Nelson, 1995).

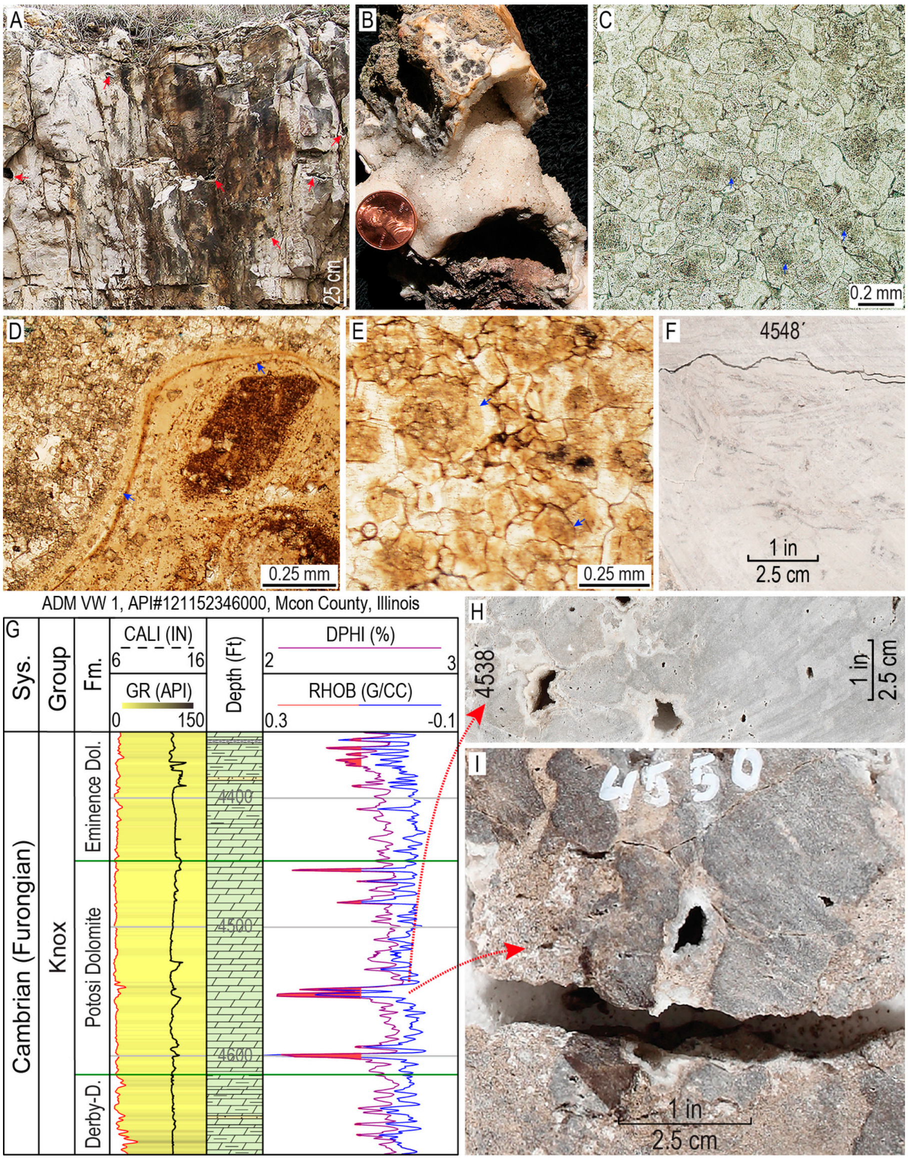

Figure 2. (A) Potosi Dolomite in a road cut, junction Route 21 and 47, Washington County, Missouri showing fractures and voids lined with drusy quartz (arrows). (B) Close up of drusy quartz lined cavities in the Potosi Dolomite, Washington County, Missouri. (C) Photomicrograph in PPL of a well sample from Macon County Well API#121152346000, depth 4490 ft (see well log in 2G) displaying medium (0.062-0.25 mm) to coarse (0.25-1 mm) crystalline planar-s to nonplanar dolomite with irregular and curved boundaries; round areas with inclusions in the crystals (arrow) resemble original peloid. (D, E) Photomicrographs in PPL of partially silicified dolomite samples from Gallatin County Well API#120592489400. Note brachiopod shells with preserved fibrous ultrastructure (blue arrow) in D (depth 12340 ft) and ghost of ooids (blue arrow) in E (depth 12350 ft). (F) Core sample photograph of dolomite interval (depth 4548 ft) displaying very low porosity (see well log in 2G). (G) Type log of Archer Daniels Midland Co. VW 1, Macon County, Illinois showing lithology, gamma ray, bulk density, and density porosity log signatures. Note that curves highlighted in red show highly porous fracture/cavern porosity intervals (for lithologic symbols see Fig. 1A). Note also that the Potosi is less radioactive and relatively pure dolomite compared to Eminence and Derby-Doerun formations (Abbreviations: CALI, caliper; DPHI, density porosity; GR, gamma ray; RHOB, bulk density). (H, I) Core samples from the well shown in 2G. (H) Breccia and vug cavities partially to completely infilled with silica and dolomite (depth 4538 ft). (I) Core sample within a cavernous interval (depth 4550 ft) displaying fractures, collapse breccia and partially filled cavities. Cavern porosity is too large-scale to be visible here but can be inferred by fluid loss (372 barrels of mud was lost in this zone). Note that chalcedonic silica, drusy quartz, and dolomite cement partially fill fracture and cavern porosity. Note also partial infilling by silt size internal dolomite sediment.

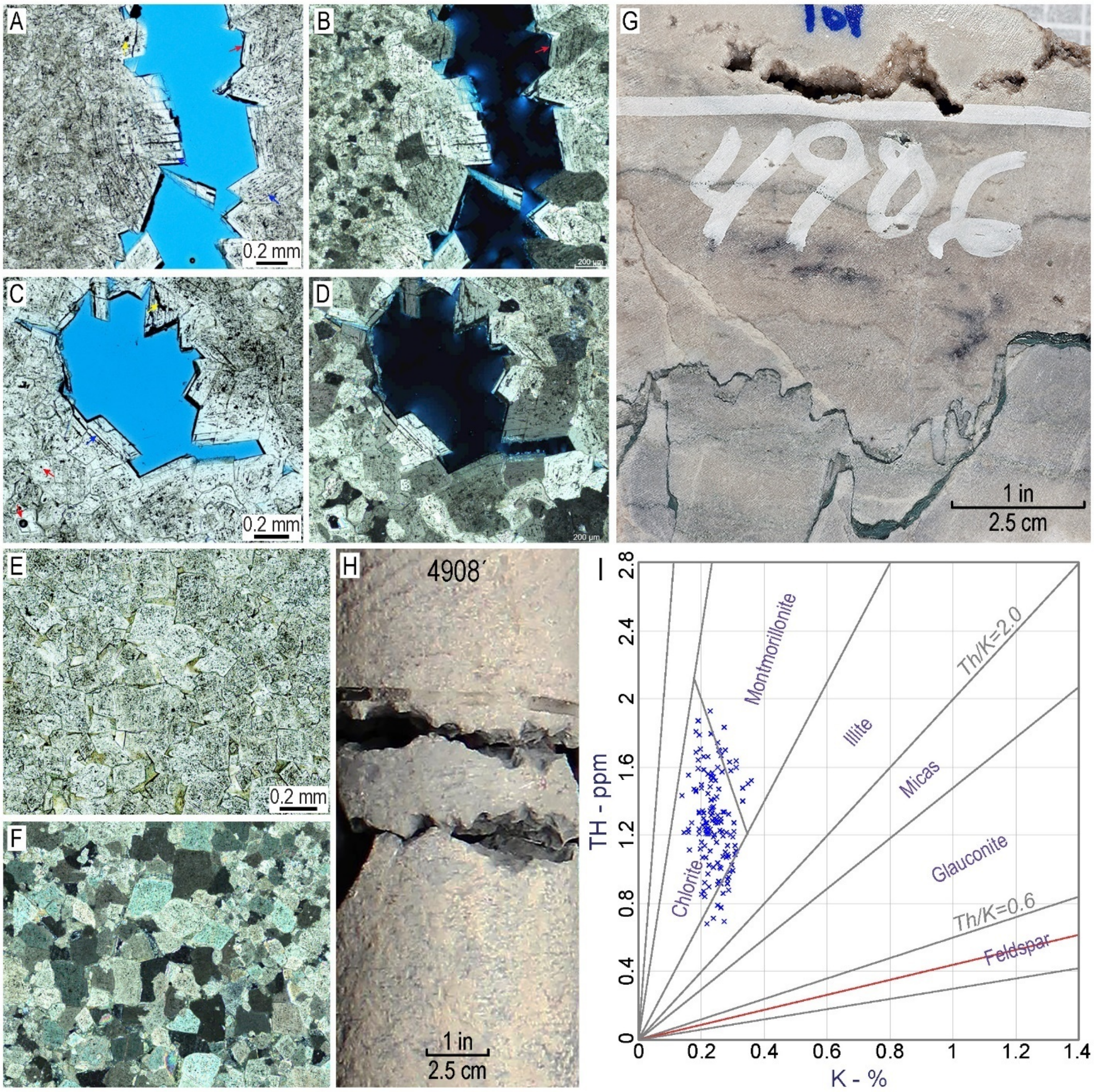

Figure 3. (A through D) Photomicrographs in PPL and XPL (blue is porosity) from core samples in Macon County well API#121152346000 showing replacive planar to nonplanar and void-filling zoned saddle dolomite with curved and zigzag crystal boundaries (sample depth in A 4487 ft and in C 4477 ft, see well log in Fig. 2G). Note a complete saddle in the upper right in A (red arrow). Note also abundant primary inclusions along the direction of crystal growth (blue arrow) and secondary inclusions that are isolated and irregular shaped or cut across growth zones (yellow arrow). The lower left corner of C displays two zoned dolomite crystals containing bright and spherical bubble shape dark inclusions (red arrow) suggesting two phase liquid and gas inclusions. The crystal that underlies the larger spherical inclusion is isotropic and may represent a solid phase inclusion. (E, F) Photomicrographs in PPL and XPL from core sample in McLean County well API#121132537300 (sample depth 3382 ft, see well log in Fig. 5) showing planar and nonplanar matrix-replacive and void-filling saddle dolomite crystals with curved and zigzag crystal boundaries. Pore spaces are partially filled with chlorite as physical properties and thorium-potassium crossplot in 3I suggest. (G, H) Photographs of core samples showing development of vug porosity along bedding parallel stylolite from well API#121892494700, Washington County, Illinois (sample depth in A 4906 ft and in H 4908 ft; for well location see index map in Fig. 5). (I) Thorium-potassium crossplot indicating chlorite as the dominating clay mineral present from McLean County, Illinois well API#121132537300, depth 3345 to 3415 ft (see well log in Fig. 5).

The Potosi Dolomite encompasses vug, fracture and cavern porosity intervals confined by very low porosity host dolomite (Figs. 2G, H, I, 3A, C, G, H, 4, and 5). The cavities are typically lined with drusy quartz (Fig. 2B) or are characterized by partial to complete infilling with chalcedonic silica and/or dolomite cements (Figs. 2H, 3A, C, G, and 4B, D). Void filling cements do not exhibit any sign of pressure solution and in places vug porosity is developed along bedding parallel stylolite (Fig. 3G, H) indicating that these features postdate pressure solution. Silt size internal dolomite sediment may partially fill fracture and cavern porosity (Fig. 2I). Clay minerals may partially fill pore spaces (Fig. 3E); physical properties and thorium-potassium crossplot (Fig. 3I) suggest chlorite as the main clay mineral cement present. In central and southern Missouri, in addition to dolomite and silica, the Potosi contains fault and fracture-controlled Mississippi Valley-type (MVT) ore deposits including commercial barite and sub-economic galena and sphalerite (Gregg & Shelton, 2012; He et al., 1997; Palmer et al., 2012).

Cavern reservoirs in the Potosi are laterally extensive and often stacked with many passages having lateral blind terminations; individual cavern reservoirs are up to 14 feet (4 m) thick (Fig. 5). They display dark conductive patches in FMI log (see for example Macon County Well API#121152346000 in Fig. 5) and show very low bulk density with caliper log signature departing from the baseline (Figs. 2G and 5) indicating enlarged drill hole diameter; fluid circulation may be lost during drilling in these intervals signifying anomalously high permeability. Throughout the Illinois Basin, lost circulation intervals are encountered when drilling the Potosi Dolomite (Bell et al., 1964). Well record data indicates loss of several hundred barrels of drilling fluid during drilling in cavern porosity zones (see for example well API#121152346000 in Fig. 5). About 60 miles east of this well, a chemical waste disposal well, the Cabot Corporation Cabot-Tuscola #2 (API#120412122000) in Douglas County, IL, has injected over 50 million metric tons of CO_2 equivalent of liquid chemical wastes into the Potosi (Leetaru et al., 2014). Many wells have tested the Potosi in the Illinois Basin for petroleum, but no commercial production has been achieved.

DISCUSSION AND CONCLUSION

The characteristics of widespread stacked porous and permeable zones in the Potosi is interpreted as being the result of cavern forming multiple paleokarst events that caused massive dolomitization and overdolomitization of the host carbonates, formation of dissolution enlarged porosity/permeability, and mineralization. Paleokarst may be the result of deep hypogenic processes by which, unlike epigenic karst, upward moving dissolving fluid is recharged from below giving rise to dissolution-enlarged permeability structures (e.g., Klimchouk, 2017, 2022). In the Potosi, Karstification was likely controlled by basinal and/or hydrothermal fluid flow through earlier formed pore systems (e.g., Gregg & Shelton, 1989; Klimchouk, 2017). An early porosity network formed by seawater dolomitization at certain intervals may have driven the initial flow of basinal and hydrothermal fluids (Lasemi & Askari, 2021).

Contrary to an earlier suggestion (Leetaru et al., 2014), it is unlikely that the Potosi vug and brecciated zones had any genetic relationship with groundwater recharge from the upper surface of the overlying Eminence Dolomite. The lithologic and petrographic characteristics of the Potosi Dolomite do not support vadose/phreatic karstification. Aside from the major sub-Tippecanoe unconformity, which developed a highly irregular erosional surface on the Lower Ordovician carbonates, in part the consequence of a karst topography in Illinois and the neighboring states (e.g., Lucia, 2012; Overstreet et al., 2003; Willman & Buschbach, 1975), there is no notable internal unconformity in the Knox succession of the Illinois Basin. In addition, the possibility of epigenic karstification was minimal because arid conditions prevailed during late Cambrian and Early Ordovician as evidenced by presence of arid climate indicators (e.g., Harrison & Grammer, 2012; Overstreet et al., 2003; Witzke, 1990). It is unlikely that the fracture/cavern porosity intervals of the Potosi and the underlying Derby-Doerun Formation that, in the deeper part of the basin, occur at depth greater than 2,000 m below the sub-Tippecanoe unconformity was controlled by epigenic fluid flow from the unconformity surface. Any early epigenic karst, if it existed, was heavily modified by later hydrothermal fluids.

The Potosi Dolomite in Illinois, like the host carbonates of the Cambro-Ordovician MVT ore deposits in Missouri (e.g., Gregg & Shelton, 2012), is characterized by massive dolomitization, overdolomitization and occlusion of previously generated intercrystalline porosity, extensive dissolution and formation of void-conduit systems, and void filling mineralization. MVT deposits are precipitated by saline basinal/hydrothermal mineralizing fluids having temperatures in the range of 60 to 250°C (e.g., Gregg & Shelton, 2012). Aside from MVT ore deposits, the Potosi records similar diagenetic, dissolution, and mineralization history in both Missouri and Illinois suggesting a widespread event that was possibly controlled by the same fluid source and regional flow regime.

In the Illinois Basin, post burial origin of cavities and void filling cements, presence of nonplanar dolomite, and void-filling inclusion rich saddle dolomite (Figs. 2C and 3 A through F) suggest karstification and mineralization by hypogenic warm basinal/hydrothermal fluids (e.g., Gregg & Shelton, 1989, 1990; Radke & Mathis , 1980; Warren, 2019). This interpretation is supported by thorium-potassium ratios and the association of saddle dolomite and chlorite cement. Chlorite is a common high-temperature hydrothermal alteration mineral (Fulignati, 2020) and thorium, in contrast to the generally held view, is highly mobile at temperature 175-250°C and commonly incorporates into the structure of carbonate-bearing minerals precipitated from or modified by hydrothermal fluids (Nisbet et al., 2019, 2022). However, future work on geochemical and fluid inclusion analyses of the Potosi Dolomite may shed more light on the origin of fluids for karstification in the Illinois Basin.

Regional late dolomitization and MVT mineralization in the Bonneterre and Davis formations of Missouri were interpreted as being related to migration of warm basinal fluids from the Arkoma and Illinois basins and the underlying granitic basement (Gregg & Shelton, 1989). Keller et al. (2000) concluded that the Reelfoot Rift was a potential source of hydrothermal fluids because of basinward fluid flow at the time of mineralization. The Illinois Basin is the northeast extension of Reelfoot Rift system, and its underlying crystalline basement is similar to the exposed igneous rocks of the Ozark Dome (Keller et al., 2000; Nelson, 1995) whose boundary with the Illinois Basin is along

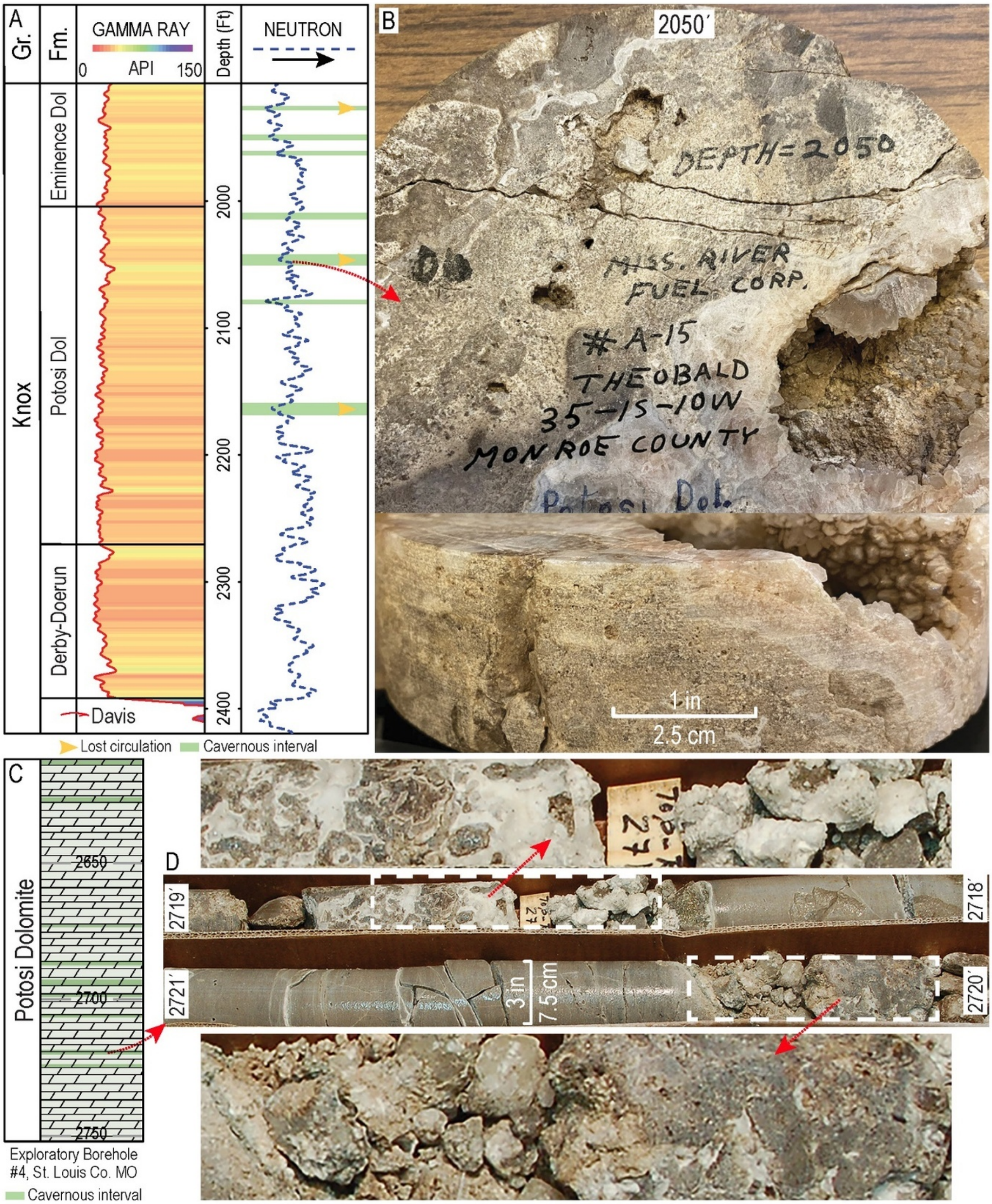

Figure 4. (A) Gamma ray/neutron log of Mississippi River Fuel Corp. Theobald A-15 in Monroe County, Illinois well API#121330002800 showing major cavernous intervals and lost circulation zones (for well location see index map in Fig. 5). (B) Vertical and radial cut through the Potosi core sample within a cavernous interval (depth 2050 ft) in the Monroe County well showing collapse breccia and partially cemented vug and fracture porosity. Cavern porosity is inferred because of fluid loss in this interval (modified from Lasemi & Askari, 2021). (C) Lithologic column of the Potosi Dolomite, exploratory Borehole #4, St. Louis County, Missouri showing fractured, brecciated, and vug porosity intervals (depth in feet). (D) Core box displaying four feet of interlayered dense dolomite with low intercrystalline porosity and vug and fracture porosity intervals (for well location see index map in Fig. 5).

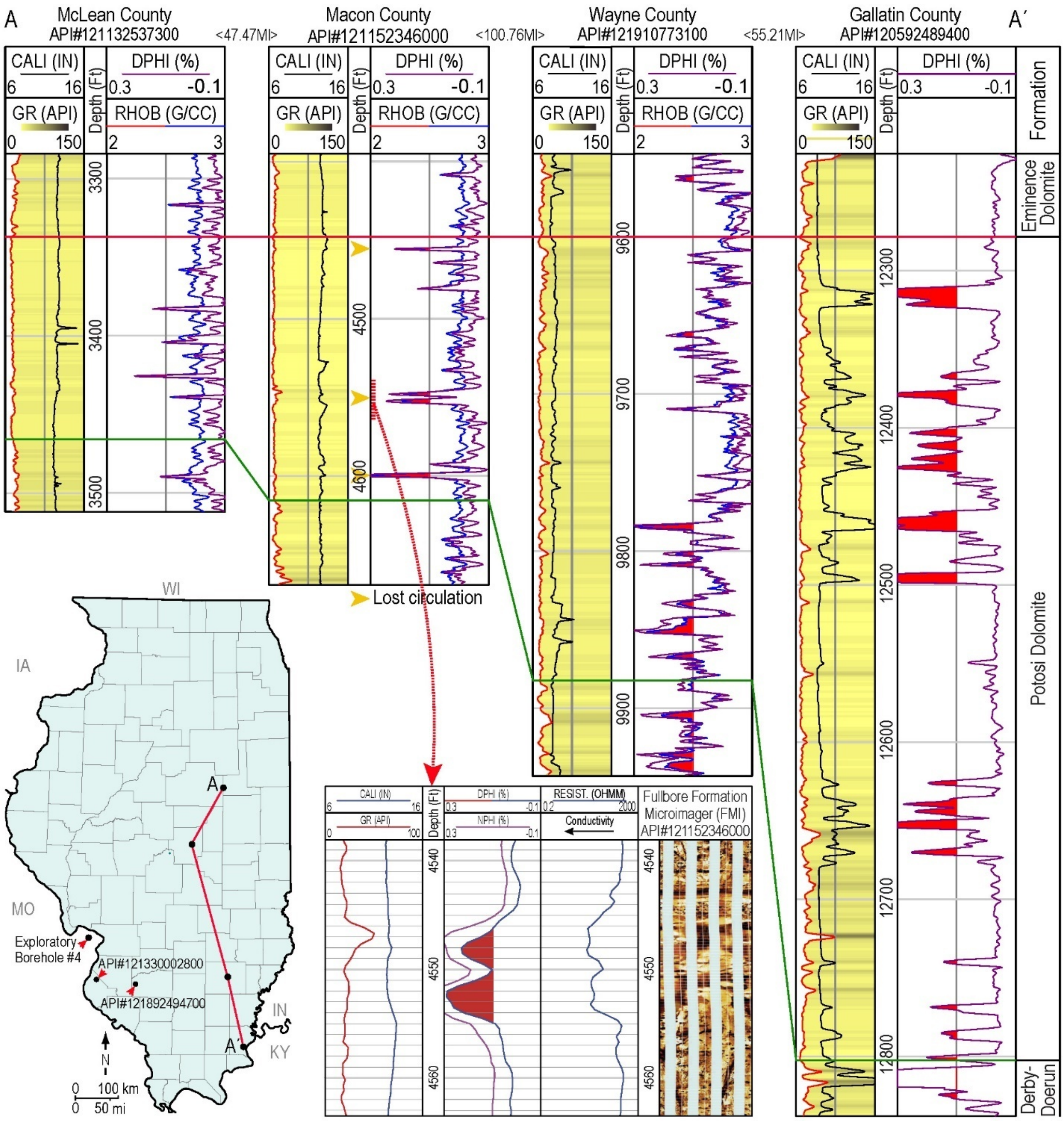

Figure 5. Geophysical log cross section AA′ showing stratigraphic variability of the Potosi and parts of the overlying and underlying units. Note that curves highlighted in red display anomalously high porosity intervals. Also note that in well API#121152346000, Macon County, several hundred barrels of drilling fluid was lost during drilling in the interval from 4548 to 4552 feet. In this well, dark conductive patches in FMI log correspond to cavern porosity intervals (Abbreviations: CALI, caliper; DPHI, density porosity; GR, gamma ray; NPHI, neutron porosity; OHMM, ohmmeter; RESIST., resistivity; RHOB, bulk density). The inset map shows cross section line and location of other wells referenced in this article.

the Ste. Genevieve Fault zone west of the southern part of the basin (Fig. 1C). Dissolution and mineralization likely occurred by flow of deep basinal formation waters and hydrothermal fluids (sourced from the crystalline basement underlying the Reelfoot Rift and the Illinois Basin) along numerous basement-rooted normal, reverse, and strike-slip faults, and the associated fold and fractures. Expansion and contraction because of fault-related seismicity likely developed fracture porosity in brittle host dolomite and possibly ruptured any underling impermeable units to enable large-scale upward and outward fluid movement. Sulfuric acid from oxidized H_2S-waters and basement sourced hydrochloric/hydrofluoric acids possibly played a role in dissolution of rocks in this process (e.g., Klimchouk, 2017, 2022). North-northwestward topography-driven brine migration due to Late Paleozoic uplift along the southern margin of the Illinois Basin (Bethke, 1986) was unlikely because the groundwater flow within the basin displays an overall north-to-south pattern and, except for northern Illinois, the Potosi void spaces are saturated with saline connate formation water (Mehnert & Weberling, 2014; Panno et al., 2017).

The Potosi fractured/cavern porosity intervals are confined by thick very low porosity dolomite intervals that could serve as effective seal. There is no report of any show of oil in the Potosi Dolomite, but the unit has an excellent potential to serve as a combined reservoir and seal for storing anthropogenic CO_2 and waste material.

ACKNOWLEDGEMENTS

We are deeply grateful to J. M. Gregg and an anonymous reviewer for their critical reviews of the manuscript. Their countless comments and constructive remarks resulted in significant improvement of the article. We thank W. J. Nelson for his helpful comments and suggestions on the first draft of the manuscript. We benefited from discussion with R. H. Goldstein on burial diagenesis and fluid inclusion of dolomite. R. R. Mumm and J. Thomas at the Illinois State Geological Survey Geological Samples Library aided with cores and samples. We thank Jeong-Hyun Lee and Jenn Pickering, the editors of SEPM TSR for editorial handling.

Submitted: January 09, 2023 CDT, Accepted: February 19, 2024 CDT

References

Bell, A. H., Atherton, E., Buschbach, T. C., & Swann, D. H. (1964). Deep oil possibilities of the Illinois Basin: Illinois State Geological Survey. *Circular*, *368*, 38.

Bethke, C. M. (1986). Hydrologic constraints on the genesis of the Upper Mississippi Valley mineral district from Illinois Basin brines. *Economic Geology*, *81*(2), 233–249. https://doi.org/10.2113/gsecongeo.81.2.233

Bond, G. C., Nickeson, P. A., & Kominz, M. A. (1984). Breakup of a supercontinent between 625 Ma and 555 Ma: New evidence and implications for continental histories. *Earth and Planetary Science Letters*, *70*(2), 325–345. https://doi.org/10.1016/0012-821x(84)90017-7

Buschbach, T. C. (1975). Cambrian system. In H. B. Willman, E. Atherton, T. C. Buschbach, C. Collinson, J. G. Frye, M. E. Hopkins, J. A. Lineback, & J. A. Simon (Eds.), *Handbook of Illinois stratigraphy: Illinois State Geological Survey, Bulletin 95* (pp. 34–46).

Chocquette, P. W., & Pray, L. C. (1970). Geologic nomenclature and classification of porosity in sedimentary carbonates. *AAPG Bulletin*, *54*, 207–250. https://doi.org/10.1306/5d25c98b-16c1-11d7-8645000102c1865d

Folk, R. L. (1959). Practical petrographic classification of Limestones. *AAPG Bulletin*, *43*, 1–38. https://doi.org/10.1306/0bda5c36-16bd-11d7-8645000102c1865d

Fulignati, P. (2020). Clay Minerals in Hydrothermal Systems. *Minerals*, *10*(919), 1–17. https://doi.org/10.3390/min10100919

Goldstein, R. H. (2003). Petrographic analysis of fluid inclusions, inn book: Fluid Inclusions: Analysis and Interpretation. In I. Samson, A. Anderson, & D. Marshall (Eds.), *Mineralogical Association of Canada, Short Course 32* (pp. 9–53).

Goldstein, R. H., & Reynolds, T. J. (1994). Fluid inclusions and their origin. In *Systematics of Fluid Inclusions in Diagenetic Minerals, SEPM (Society for Sedimentary Geology) Short course 31* (pp. 5–21). https://doi.org/10.2110/scn.94.31.0005

Gregg, J. M., & Shelton, K. L. (1989). Geochemical and petrographic evidence for fluid sources and pathways during dolomitization and lead-zinc mineralization in southeast Missouri: a review. *Carbonates and Evaporites*, *4*(2), 153–175. https://doi.org/10.1007/bf03175105

Gregg, J. M., & Shelton, K. L. (1990). Dolomitization and dolomite neomorphism in the back reef facies of the Bonneterre and Davis formations (Cambrian), southeastern Missouri. *Journal of Sedimentary Petrology*, *60*(4), 549–562.

Gregg, J. M., & Shelton, K. L. (2012). Mississippi Valley-type mineralization and ore deposits in the Cambrian–Ordovician great American carbonate bank. *AAPG Memoir*, *98*, 163–186. https://doi.org/10.1306/13331493m981487

Harrison, W. B., III, & Grammer, G. M. (2012). The Great American Carbonate Bank in the Central Michigan Basin. *AAPG Memoir*, *98*, 1049–1062. https://doi.org/10.1306/13331529m983519

He, Z., Gregg, J. M., Shelton, K. L., & Palmer, J. R. (1997). Sedimentary facies control of fluid flow and mineralization in Cambro-Ordovician strata, southern Missouri. *Society for Sedimentary Geology (SEPM) Special Publication*, *57*, 81–99. https://doi.org/10.2110/pec.97.57.0081

Johnson, W. D., Jr., & Schwalb, H. R. (2010). Geology and Structure of the Rough Creek Area, Western Kentucky. *Kentucky Geological Survey Bulletin*, *1, Series XII*, 127.

Keller, T. J., Gregg, J. M., & Shelton, K. L. (2000). Fluid migration and associated diagenesis in the Greater Reelfoot rift region, Midcontinent, United States. *Geological Society of America Bulletin*, *112*(11), 1680–1693. https://doi.org/10.1130/0016-7606(2000)112

Klimchouk, A. B. (2017). Types and settings of hypogene karst. In A. Klimchouk, A. N. Palmer, J. De Waele, A. S. Auler, & P. Audra (Eds.), *Hypogene Karst Regions and Caves of the World* (pp. 1–39). Springer. https://doi.org/10.1007/978-3-319-53348-3_1

Klimchouk, A. B. (2022). Hypogene Karst: principal features and implications for geosciences. *Highlights of Geoscientific Cave Research, Austrian Academy of Sciences*, *Vienna*, 45. https://doi.org/10.13140/RG.2.2.28859.90401

Kolata, D. R. (2005). *Bedrock geology of Illinois* [Figure].

Kolata, D. R., & Nelson, W. J. (1990). Tectonic history of the Illinois Basin. In M. W. Leighton, D. R. Kolata, D. F. Oltz, & J. J. Eidel (Eds.), *Interior Cratonic Basins. AAPG Memoir 51* (pp. 263–285). https://doi.org/10.1306/m51530c19

Lasemi, Y., & Askari, Z. (2014). *Stratigraphy of the Cambo-Ordovician Knox succession in Illinois* (No. US DOE Knox Project Cooperative Agreement No. DE-FE0002068, Topical Report No. FE0002068-12; p. 43).

Lasemi, Y., & Askari, Z. (2021). Paleokarst Development and Controls in the Cambrian Potosi Dolomite and Eminence Formation, Illinois Basin. *Kansas Geological Survey, Technical Series*, *24*, 31–33.

Leetaru, H. E., Smith, V., Adushita, Y., & Freiburg, J. T. (2014). An integrated approach to evaluating the suitability of the Potosi Dolomite as a carbon sequestration target. *Interpretation*, *2*(3), SF125–SF133. https://doi.org/10.1190/int-2013-0185.1

Loucks, R. G. (1999). Paleocave Carbonate Reservoirs: Origins, Burial-Depth Modifications, Spatial Complexity, and Reservoir Implications. *AAPG Bulletin*, *83*, 1795–1834. https://doi.org/10.1306/e4fd426f-1732-11d7-8645000102c1865d

Lucia, F. J. (2004). Origin and petrophysics of dolostone pore space. *Geological Society, London, Special Publications*, *p. 235*, 141–155.

Lucia, F. J. (2012). The great Lower Ordovician cavern system. *AAPG Memoir 98*, 83–111. https://doi.org/10.1306/13331490m980155

Meert, J. G., & Torsvik, T. H. (2003). The making and unmaking of a supercontinent: Rodinia revisited. *Tectonophysics*, *375*(1–4), 261–288. https://doi.org/10.1016/s0040-1951(03)00342-1

Mehnert, E., & Weberling, P. (2014). Groundwater Salinity within Mt. Simon Sandstone in Illinois and Indiana. *Illinois State Geological Survey, Circular*, *582*, 23.

Nelson, W. J. (1995). Structural Features in Illinois. *Illinois State Geological Survey, Bulletin*, *100*, 144.

Nisbet, H., Migdisov, A. A., Williams-Jones, A. E., Xu, H., van Hinsberg, V. J., & Roback, R. (2019). Challenging the thorium-immobility paradigm. *Scientific Reports*, *9*(1), 170351–170356. https://doi.org/10.1038/s41598-019-53571-x

Nisbet, H., Migdisov, A. A., Williams-Jones, A. E., Xu, H., van Hinsberg, V. J., & Roback, R. (2022). The solubility of thorium in carbonate-bearing solutions at hydrothermal conditions. *Geochimica et Cosmochimica Acta*, *330*, 80–92. https://doi.org/10.1016/j.gca.2021.04.035

Overstreet, R. B., Oboh-Ikuenobe, F. E., & Gregg, J. M. (2003). Sequence stratigraphy and depositional facies of Lower Ordovician cyclic carbonate rocks, southern Missouri, U.S.A. *Journal of Sedimentary Research*, *73*(3), 421–433. https://doi.org/10.1306/112002730421

Palmer, J. R. (1989). Late Upper Cambrian shelf depositional facies and history, southern Missouri. In *Field guide to the Upper Cambrian of southern Misouri; stratigraphy, sedimentology, and economic geology* (pp. 1–24).

Palmer, J. R., Thompson, T. L., Seeger, C., Miller, J. F., & Gregg, J. M. (2012). The Sauk megasequence from the Reelfoot rift to southwestern Missouri. *AAPG Memoir 98*, 1013–1030. https://doi.org/10.1306/13331527m983518

Panno, S. V., Askari, Z., Kelly, W. R., Parris, T. M., & Hackley, K. C. (2017). Recharge and groundwater flow within an intracratonic basin, Midwestern United States. *Groundwater*, *56*(1), 32–45. https://doi.org/10.1111/gwat.12545

Radke, B. M., & Mathis , R. L. (1980). On the formation and occurrence of saddle dolomite. *SEPM Journal of Sedimentary Research*, *50*, 1149–1168. https://doi.org/10.1306/212f7b9e-2b24-11d7-8648000102c1865d

Shaver, R. H., Ault, C. H., Burger, A. M., Carr, D. D., & others. (1986). Compendium of Paleozoic rock-unit stratigraphy in Indiana—a revision. *Indiana Geological Survey Bulletin*, *59*, 203.

Sibley, D. F., & Gregg, J. M. (1987). Classification of dolomite rock textures. *SEPM Journal of Sedimentary Research*, *57*, 967–957. https://doi.org/10.1306/212f8cba-2b24-11d7-8648000102c1865d

Thompson, T. A., Sowder, K. H., & Johnson, M. R. (2016). *Generalized stratigraphic column of Indiana bedrock*. Indiana Geological Survey.

Thompson, T. L., Mulvany, P. S., Palmer, J. R., Miller, J. F., & Davis, J. G. (2013). Cambrian Stratigraphic Succession in Missouri. In P. S. Mulvany & T. L. Thompson (Eds.), *Paleozoic Succession in Missouri, Part 1-Cambrian System: Missouri Geological Survey, Report of Investigations 70* (pp. 25–254).

Warren, J. (2019). Saline Dolomites: Ancient – Part 4 of 4 - Saddle dolomite, calcite and anhydrite spar burial salts. *Salty Matters*, *22*. http://www.saltworkconsultants.com

Willman, H. B., & Buschbach, T. C. (1975). Ordovician System. In H. B. Willman, E. Atherton, T. C. Buschbach, C. Collinson, J. C. Frye, M. E. Hopkins, J. A. Lineback, & J. A. Simon (Eds.), *Handbook of Illinois Stratigraphy* (pp. 47–87).

Witzke, B. J. (1990). Palaeoclimatic constraints for Palaeozoic Palaeolatitudes of Laurentia and Euramerica. In W. S. Mckerrow & C. R. Scotese (Eds.), *Palaeozoic Palaeogeography and Biogeography, Geological Society Memoir 12* (pp. 57–73). https://doi.org/10.1144/gsl.mem.1990.012.01.05