Diagenetic History of the Wolfcamp A in the Eastern Midland Basin, Texas*

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Abstract

Fluid flow and diagenesis in fine-grained reservoirs remains enigmatic. We studied the diagenetic history of lower Leonardian, toe-of-slope strata in the eastern Midland Basin (Howard County, Texas) composed of pelagic components, fine-grained clastics, and carbonate sediment gravity flow deposits (high and low density). These carbonates host highly variable macroporosity (1 to 15%) and distribution of diagenetic phases has impacted porosity location. The paragenesis includes: early dissolution; early and late calcite cement; early and late dolomite cement; displacive anhydrite; mechanical and chemical compaction; petroleum migration; late silicification; pyrite; episodes of fracturing; bitumen; and late dissolution. Extant porosity is the result of preserved primary porosity (dominantly intraparticle) and secondary porosity (vuggy, moldic, and fracture). Analysis of primary, aqueous, two-phase fluid inclusions within calcite cement in an opening-mode vein indicate initial precipitation from an ambient burial temperature, locally sourced fluid (mean Th = 78.3 °C). High salinity (mean Tmice = -20.5 °C) suggests that deep burial ambient water in the reservoir was evaporated seawater delivered through reflux in the Late Permian (e.g. Stueber et al. 1998). In contrast, later calcite precipitated from an anomalously hot, deeply sourced, hydrothermal fluid (mean Th = 154.1 °C). There are two plausible sources for these anomalously hot fluids: (1) faults cutting kilometers into and injecting fluids from underlying basement; or (2) the deep Val Verde Basin to the south where a meteoric pressure head in the elevated Marathon Mountains could have driven migration of hot fluids through a permeable unit north into the Midland Basin. The transition from locally derived fluids to hydrothermal fluids may represent progression from a relatively closed to open diagenetic system. This finding of a hydrothermal system has important exploration implications, as thermal maturation and porosity-altering diagenetic events may be localized near certain fracture systems.

References Cited

Adams, D.C., and R.G. Keller, 1996, Precambrian Basement Geology of the Permian Basin Region of West Texas and Eastern New Mexico: A Geophysical Perspective: American Association of Petroleum Geologists Bulletin, v. 80, p. 410-431.

Engle, M.A., F.R. Reyes, M.S. Varonka, W.H. Orem, L. Ma, A.J. Ianno, T.M. Schell, P. Xu, and K.C. Carroll, 2016, Geochemistry of Formation Waters from the Wolfcamp and “Cline” Shales: Insights into Brine Origin, Reservoir Connectivity, and Fluid Flow in the Permian Basin, USA: Chemical Geology, v. 425, p. 76-92

Mazzullo, S.J., 1994, Lithification and Porosity Evolution in Permian Periplatform Limestones, Midland Basin, Texas: Carbonates Evaporites, v. 9/151.

Pawlewicz, M., C.E. Barker, and S. McDonald, 2005, Vitrinite Reflectance Data for the Permian Basin, West Texas and Southeast New Mexico: US Department of the Interior, US Geological Survey, Open-File Report 2005-1171, 25 p.

Stueber, A.M., A.H. Saller, and H. Ishida, 1998, Origin, Migration, and Mixing of Brines in the Permian Basin: Geochemical Evidence from the Eastern Central Basin Platform, Texas: American Association of Petroleum Geologists Bulletin, v. 82, p. 1652-1672.

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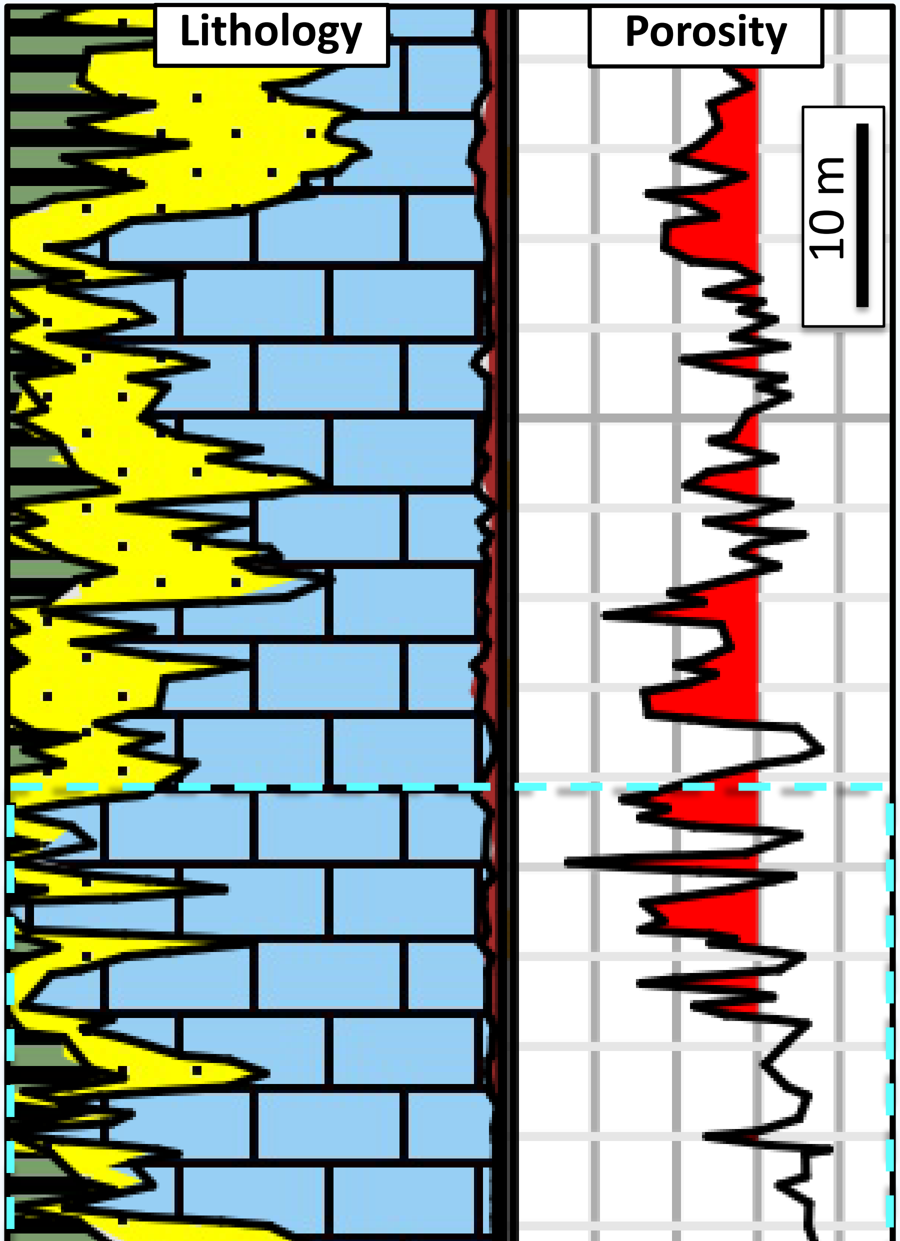
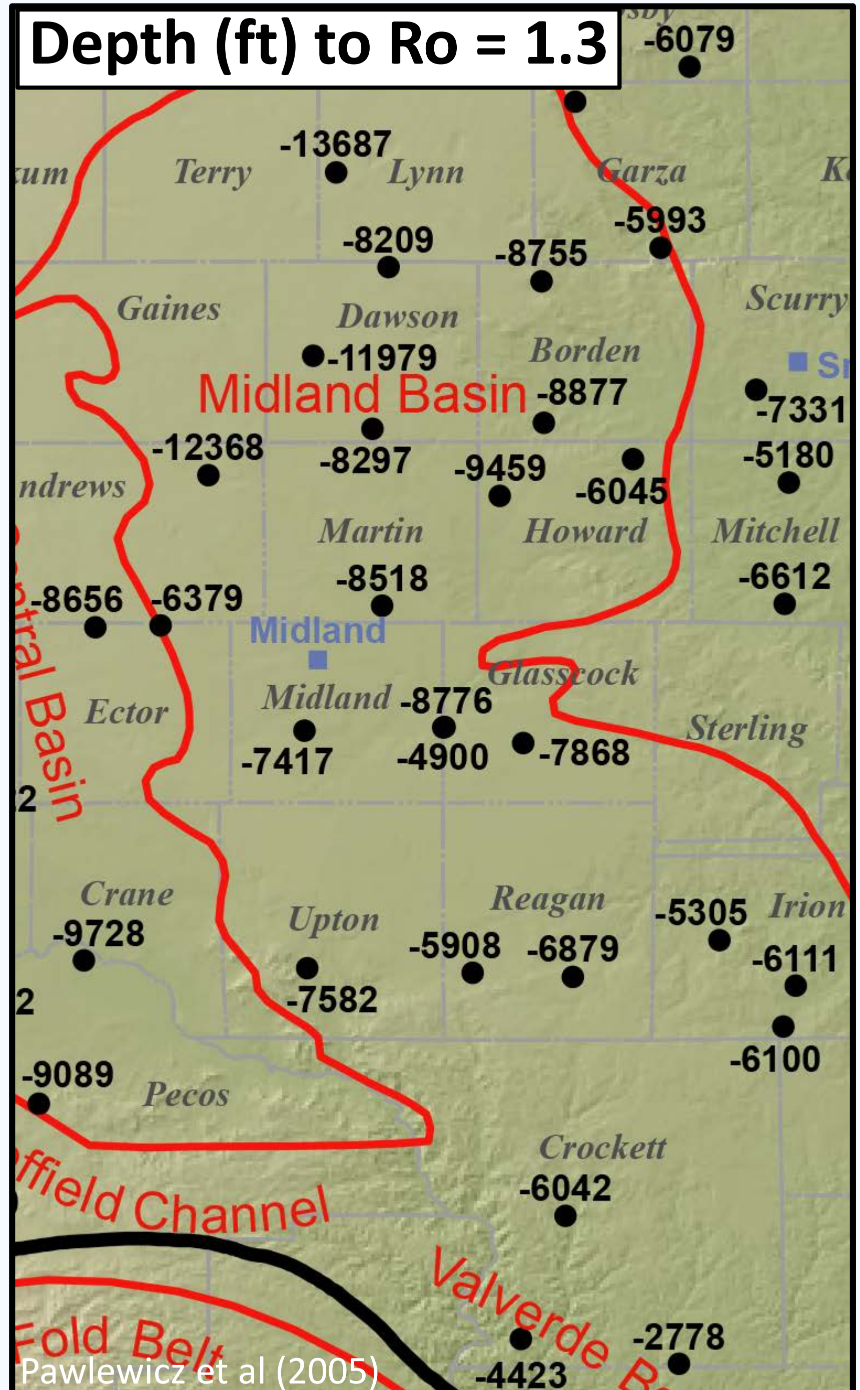
Wolfcamp A


Lithology
Porosity
10 m


Depth (ft) to Ro = 1.3
Midland Basin
Terry
Lynn
Garza
Gaines
Dawson
Borden
Scurry
Martin
Howard
Mitchell
Midland
Glasscock
Ector
Sterling
Crane
Upton
Reagan
Irion
Pecos
Crockett
-6079
-13687
-8209
-8755
-5993
-11979
-8877
-7331
-12368
-8297
-9459
-6045
-5180
-8518
-6612
-8656
-6379
-8776
-7417
-4900
-7868
-9728
-5908
-6879
-5305
-6111
-7582
-6100
-9089
-6042
-2778
-4423
Pawlewicz et al (2005)

Key Findings

- Tectonic fracturing opened the diagenetic system and triggered injection of exceptionally hot fluids into the Wolfcamp A

- These hot fluids may have enhanced source rock maturation & may be a key reason for the success of this play

- Extant macroporosity includes primary fusulinid intraparticle and fracture, as well as late moldic that developed contemporaneously with oil migration

- Other late dissolution, however, may have resulted in net porosity loss by enhancing chemical compaction

Setting

Ouachita Orogeny
E. Penn – E. Perm

↓

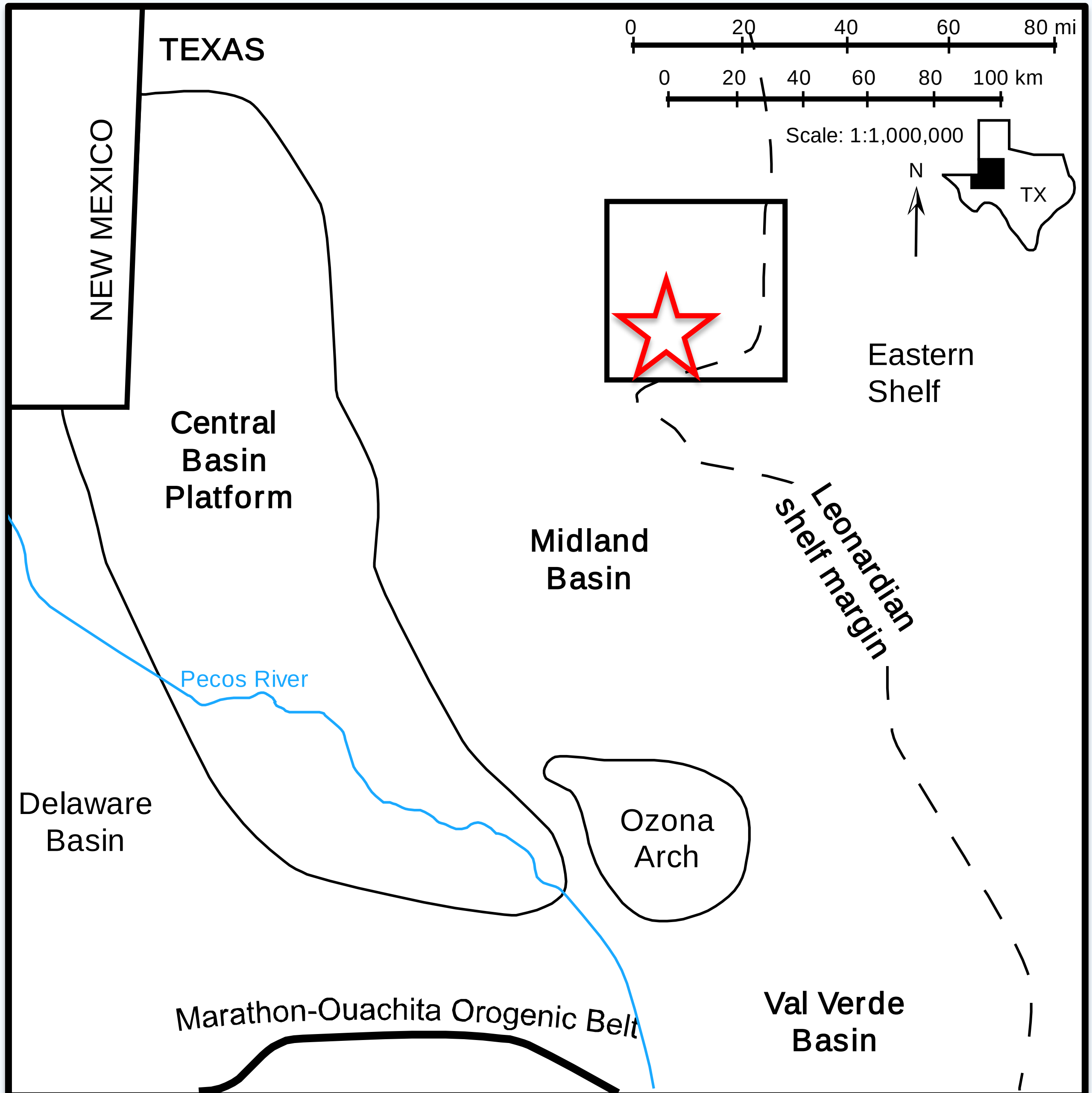
Laramide Orogeny
L. Cret – E. Tertiary

↓

Igneous Intrusions
Eocene – Oligocene

↓

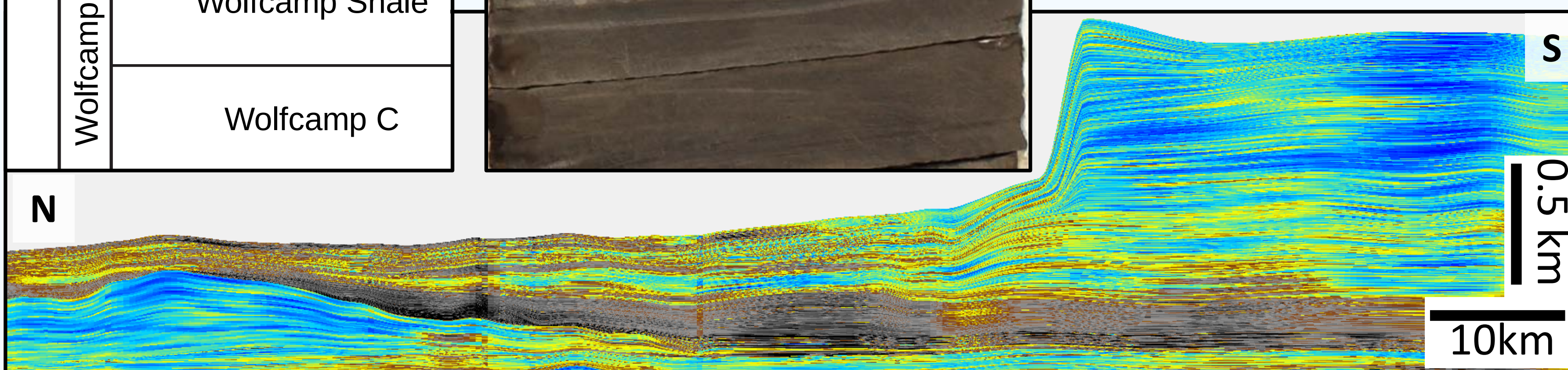
Basin & Range Extension
L. Oligocene - Miocene



Stratigraphy

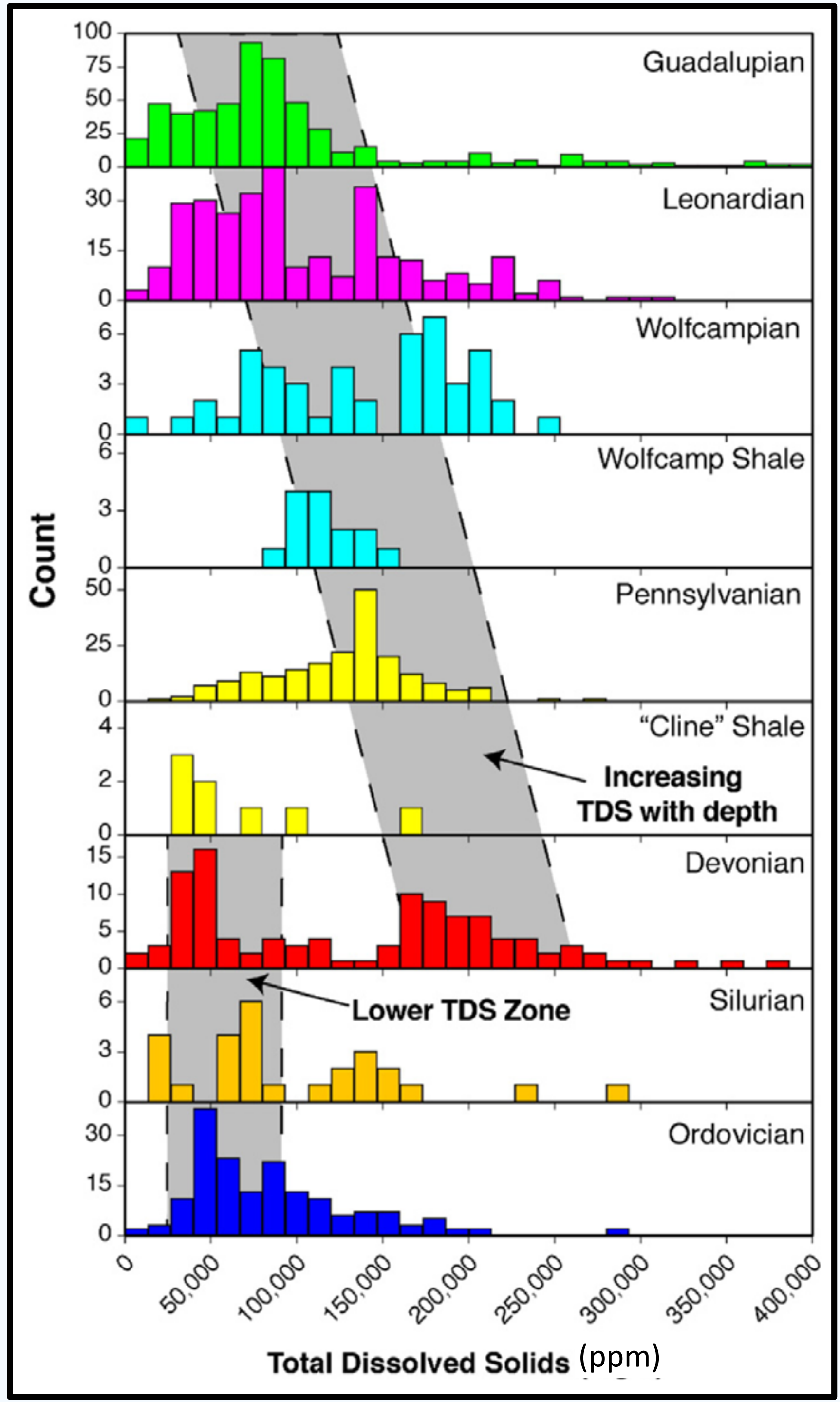
Permian	Leonardian	U. Leonardian	Spraberry
		L. Leonardian	Dean Sandstone
			Wolfcamp A
			Wolfcamp B
	Wolfcampian		Wolfcamp Shale
			Wolfcamp C

- Carbonate sediment gravity flows
- Fine-grained siliciclastics



Modern-day Hydrology

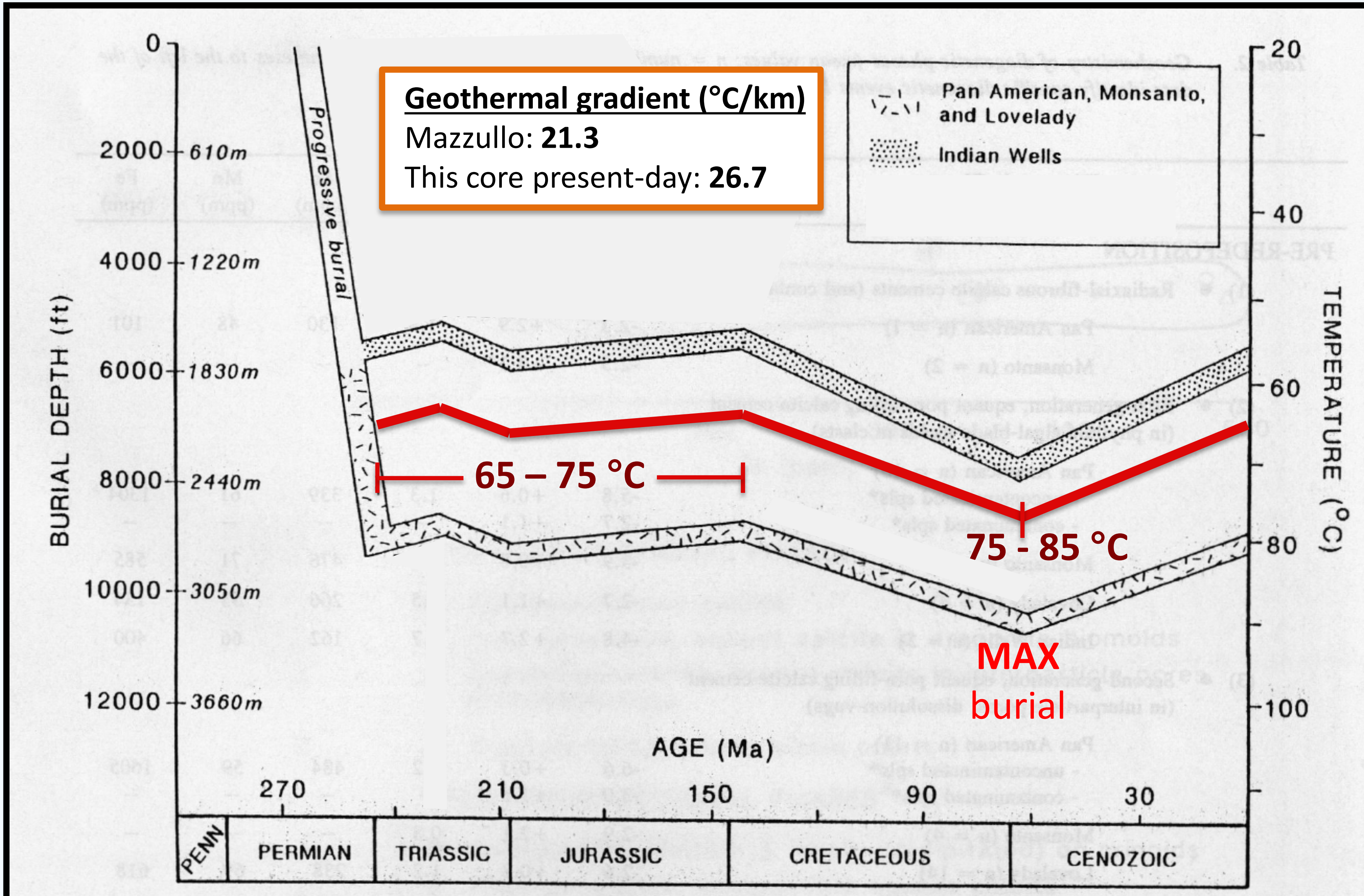
- Fluids in Wolfcamp A-aged reservoirs are interpreted as brines derived from reflux of Late Permian evaporated seawater



Engle et al (2016)

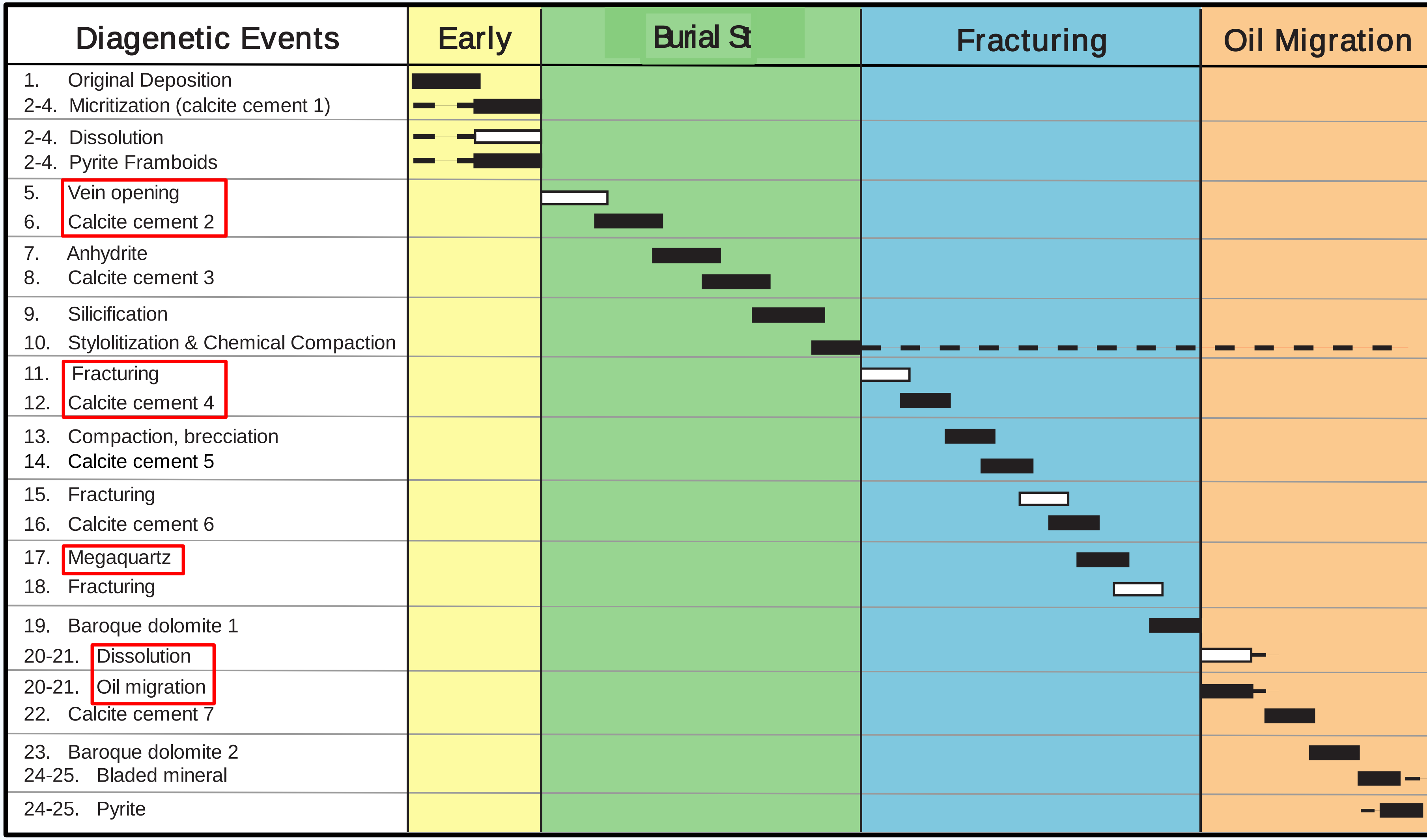
Burial History

Mazzullo (1994)



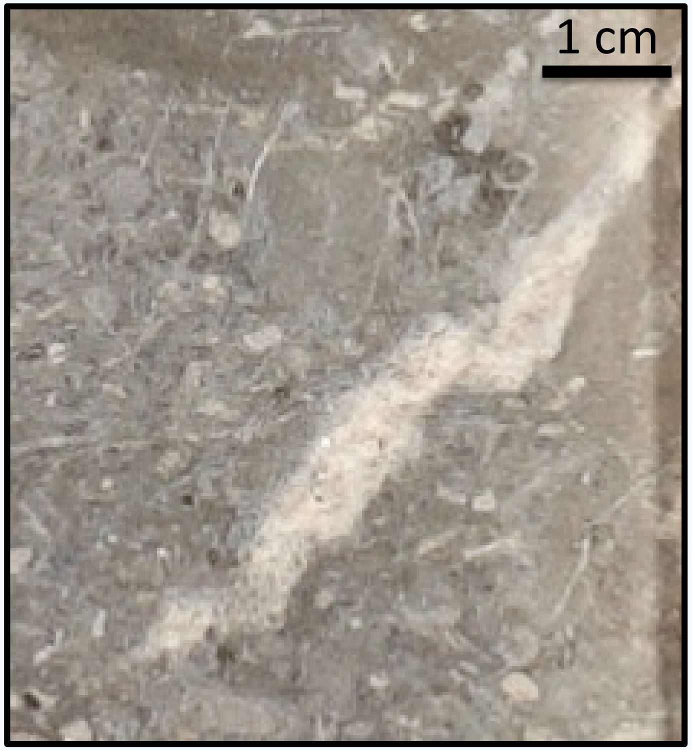
←Ouachita→ ←Laramide→Basin & Range

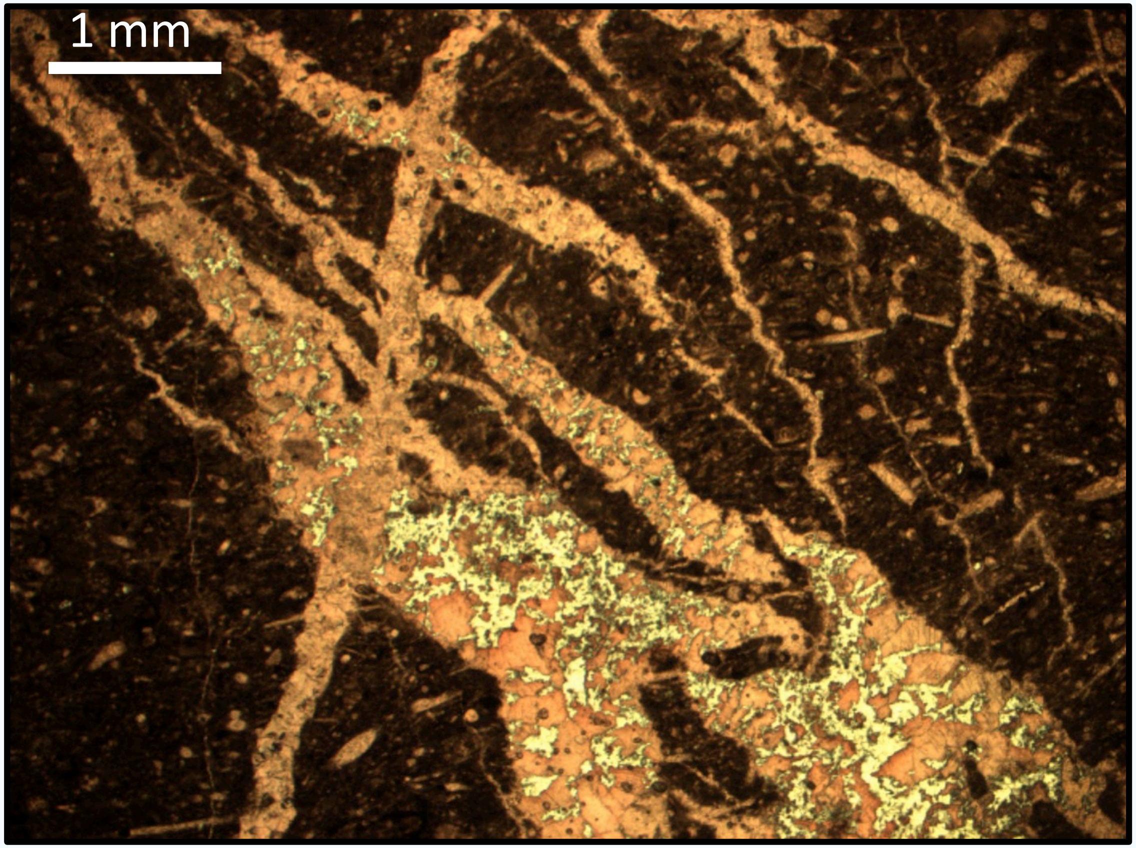
Paragenesis

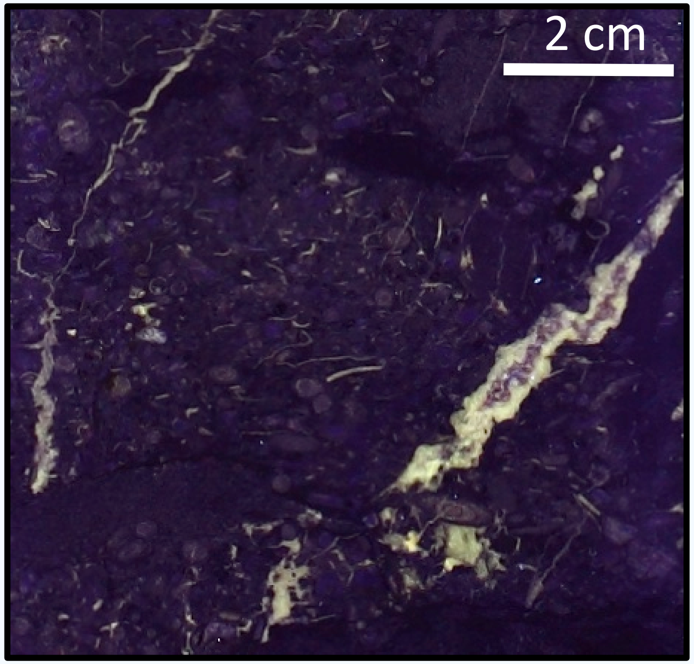


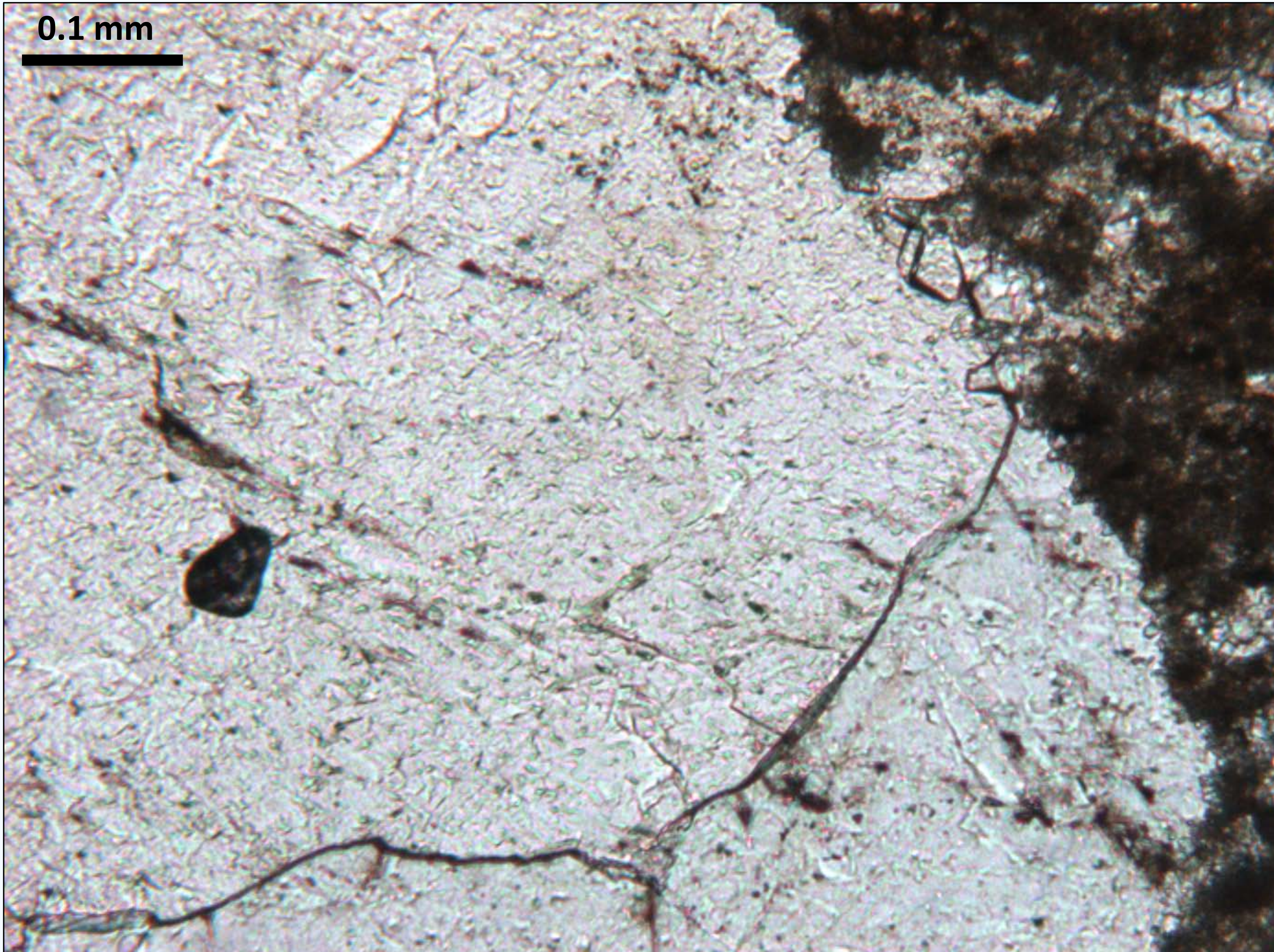
Burial Stage

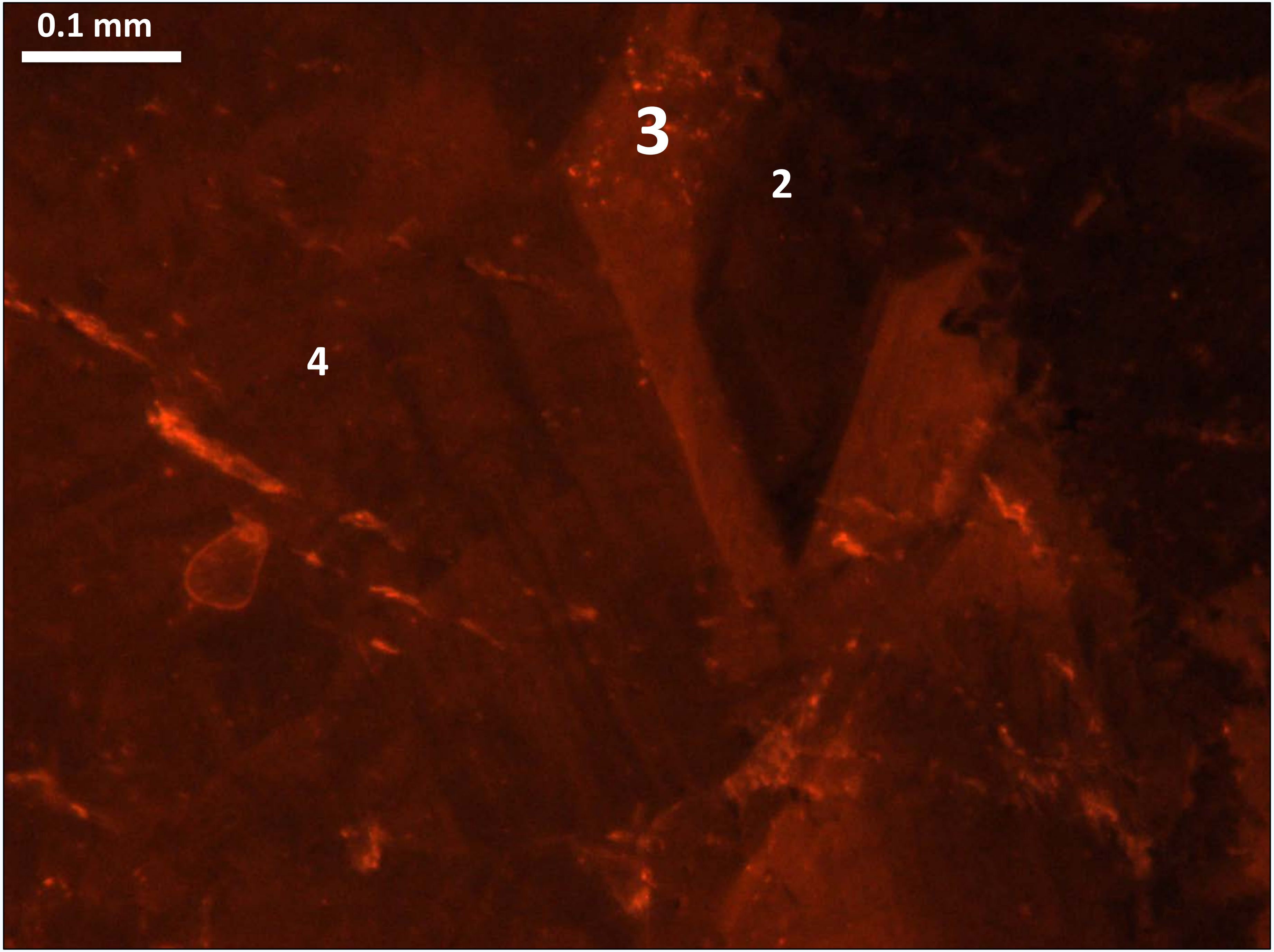
- Compactional vein opening & reduction by calcite

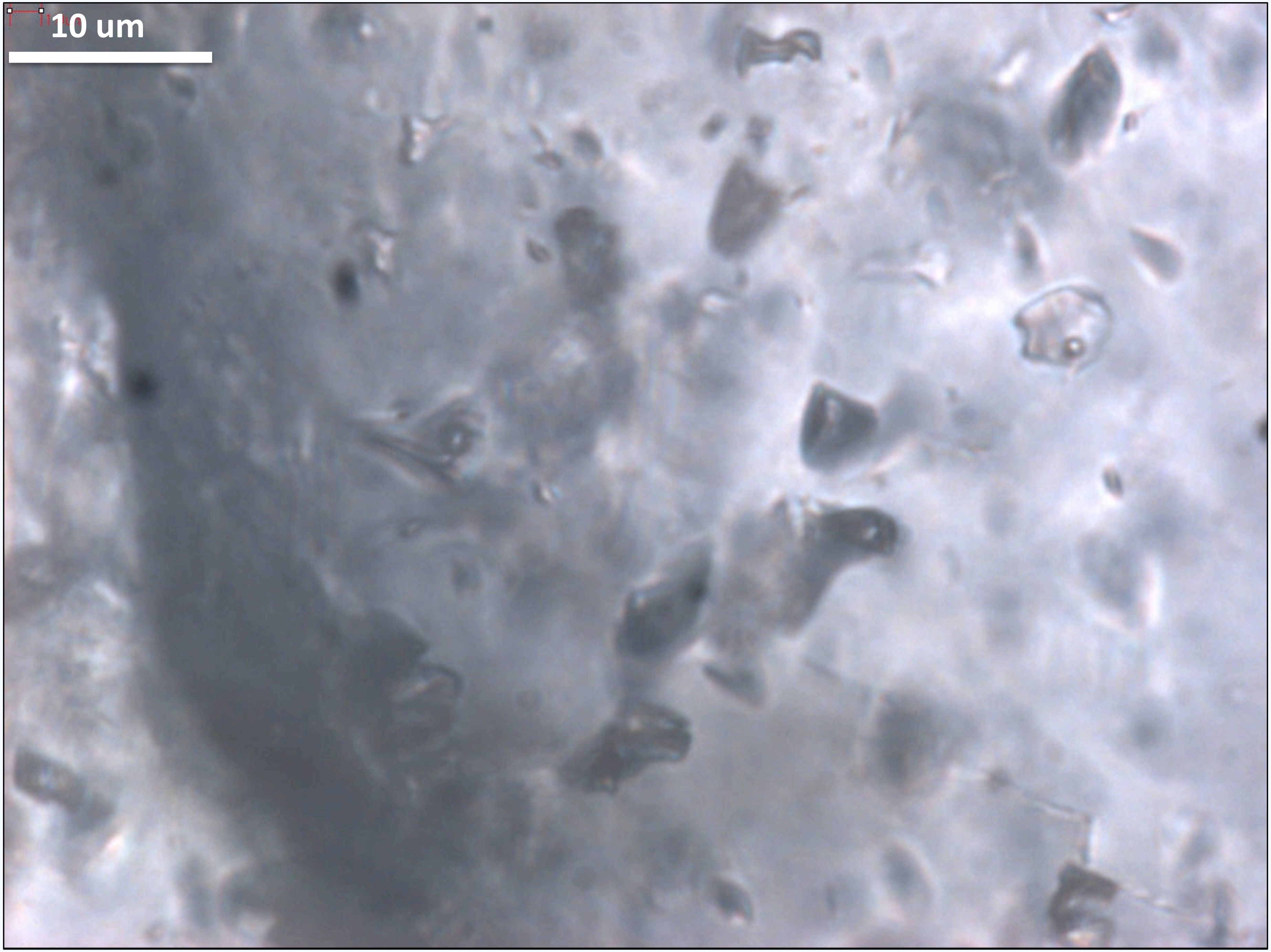




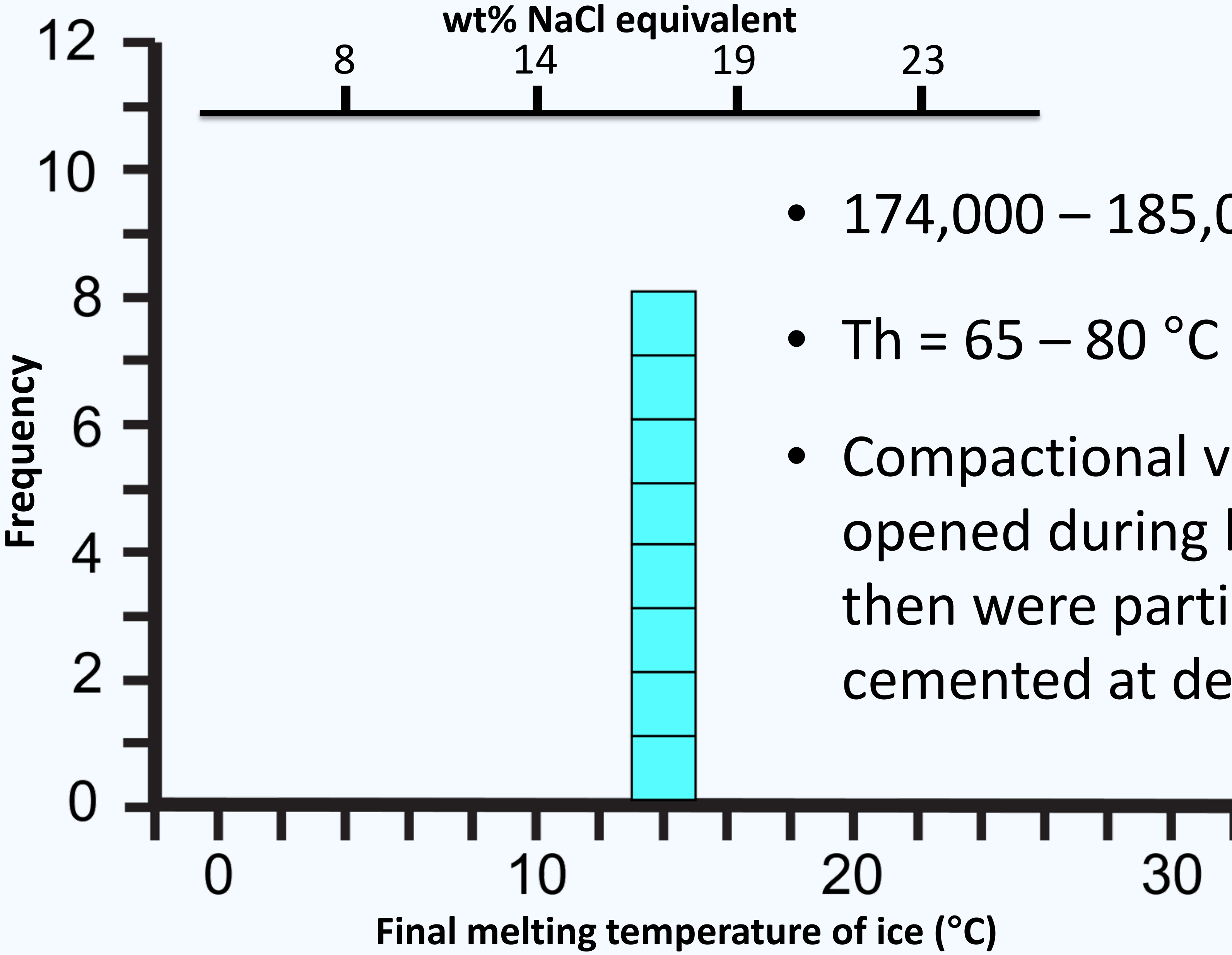



0.1 mm

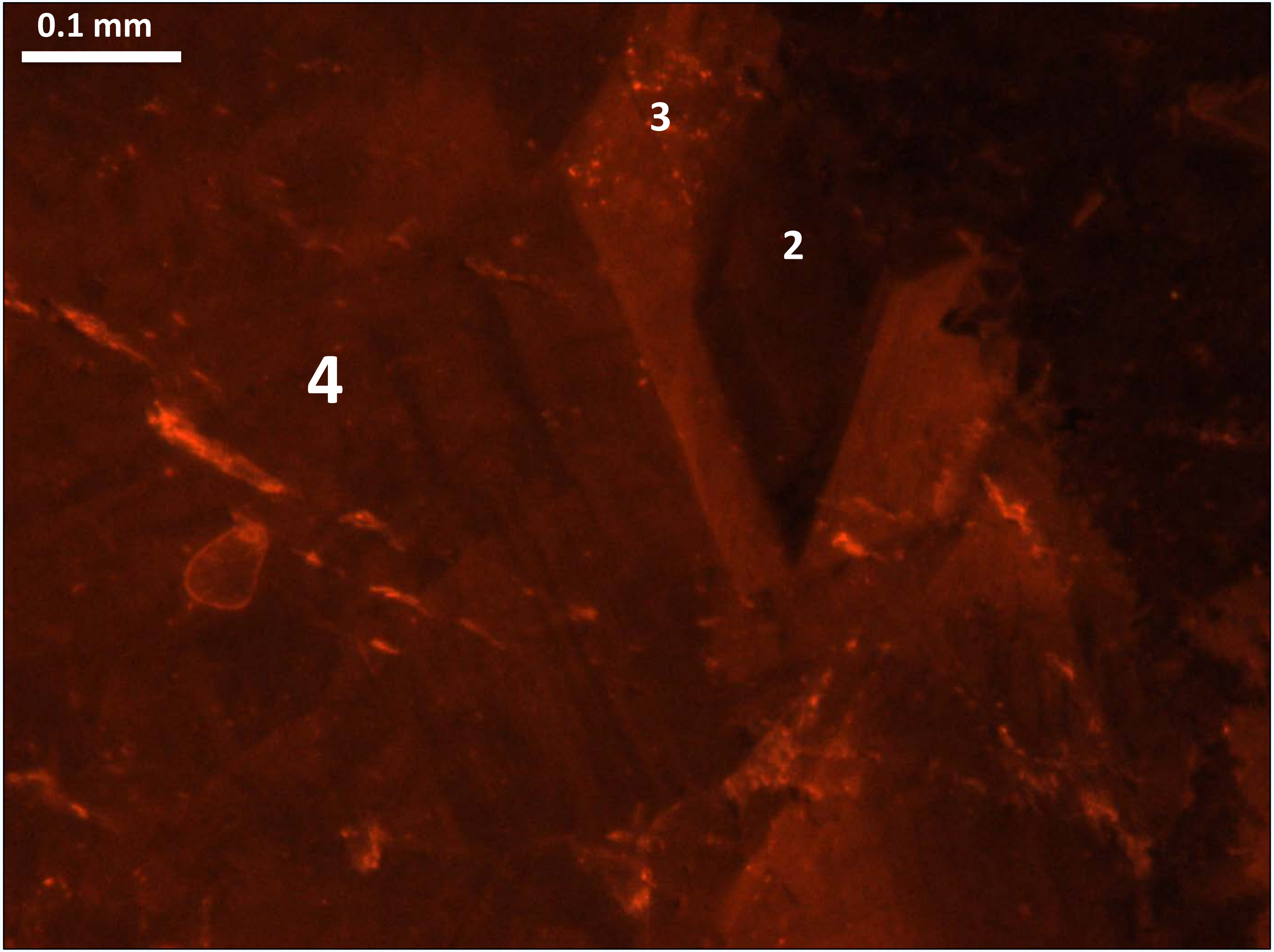

0.1 mm
3
2
4


10 um

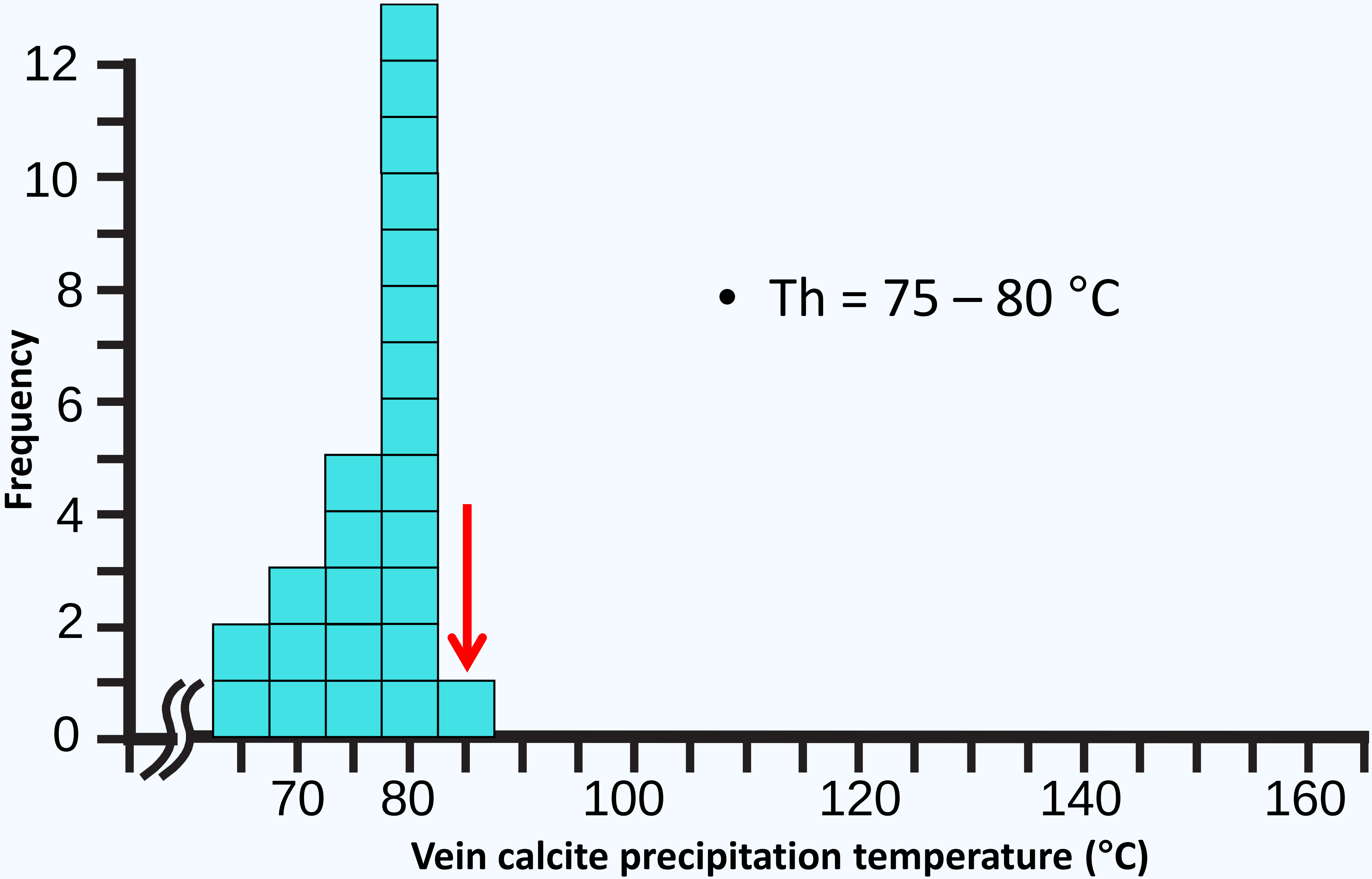
Vein-reducing Calcite #3



- 174,000 – 185,000 ppm
- Th = 65 – 80 °C
- Compactional veins opened during burial & then were partially cemented at depth

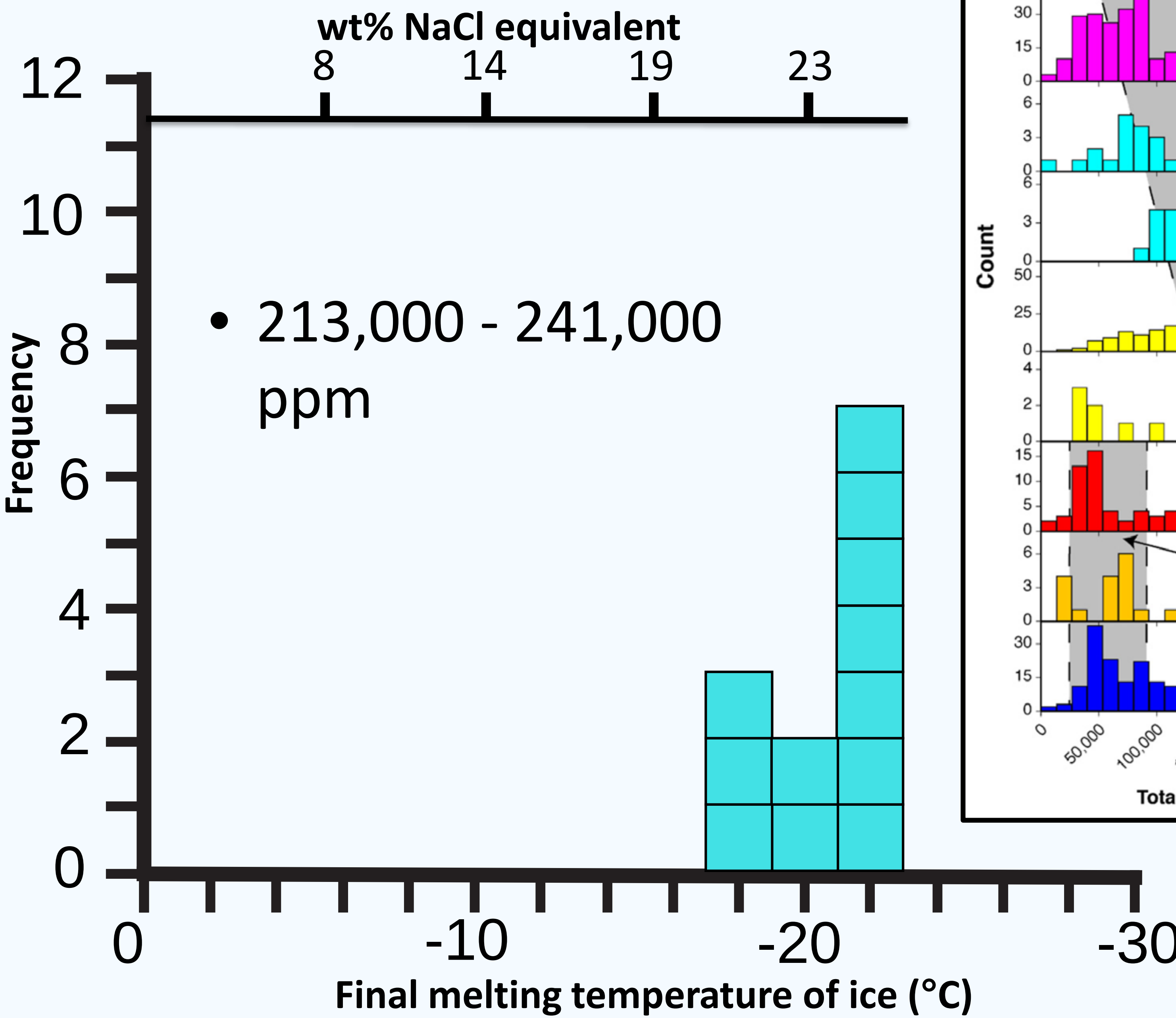

0.1 mm
3
2
4

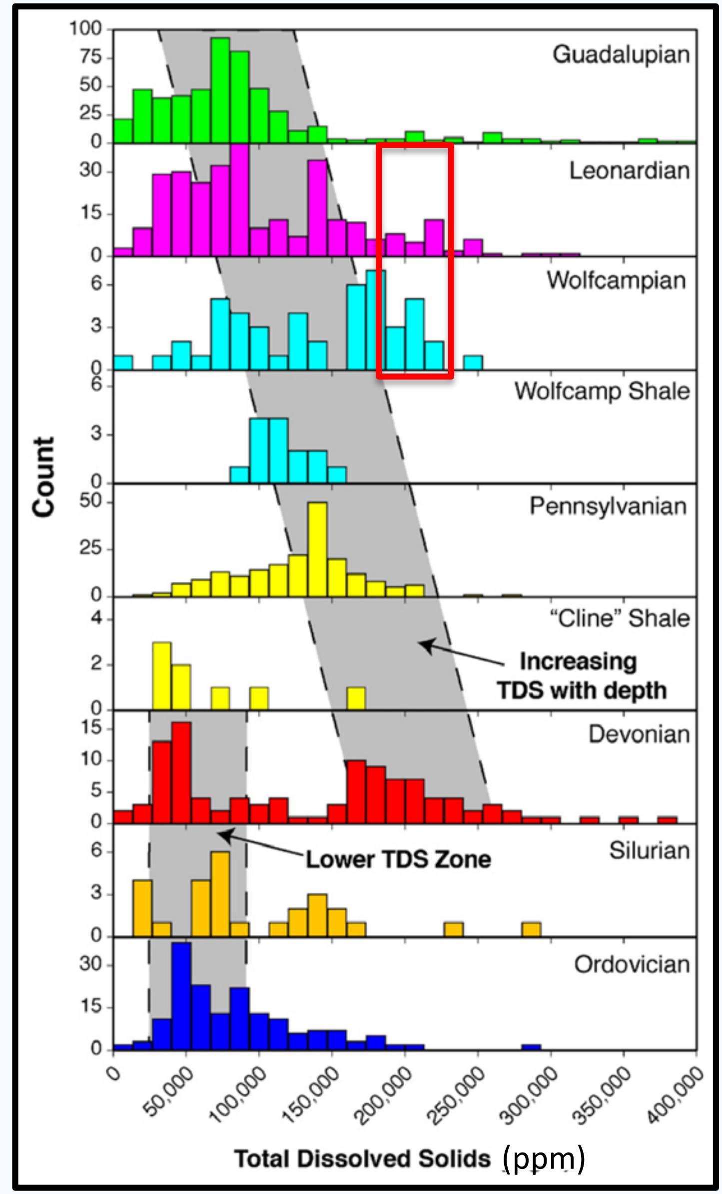
Vein-reducing Calcite #4



Vein-reducing Calcite #4

- 213,000 - 241,000 ppm

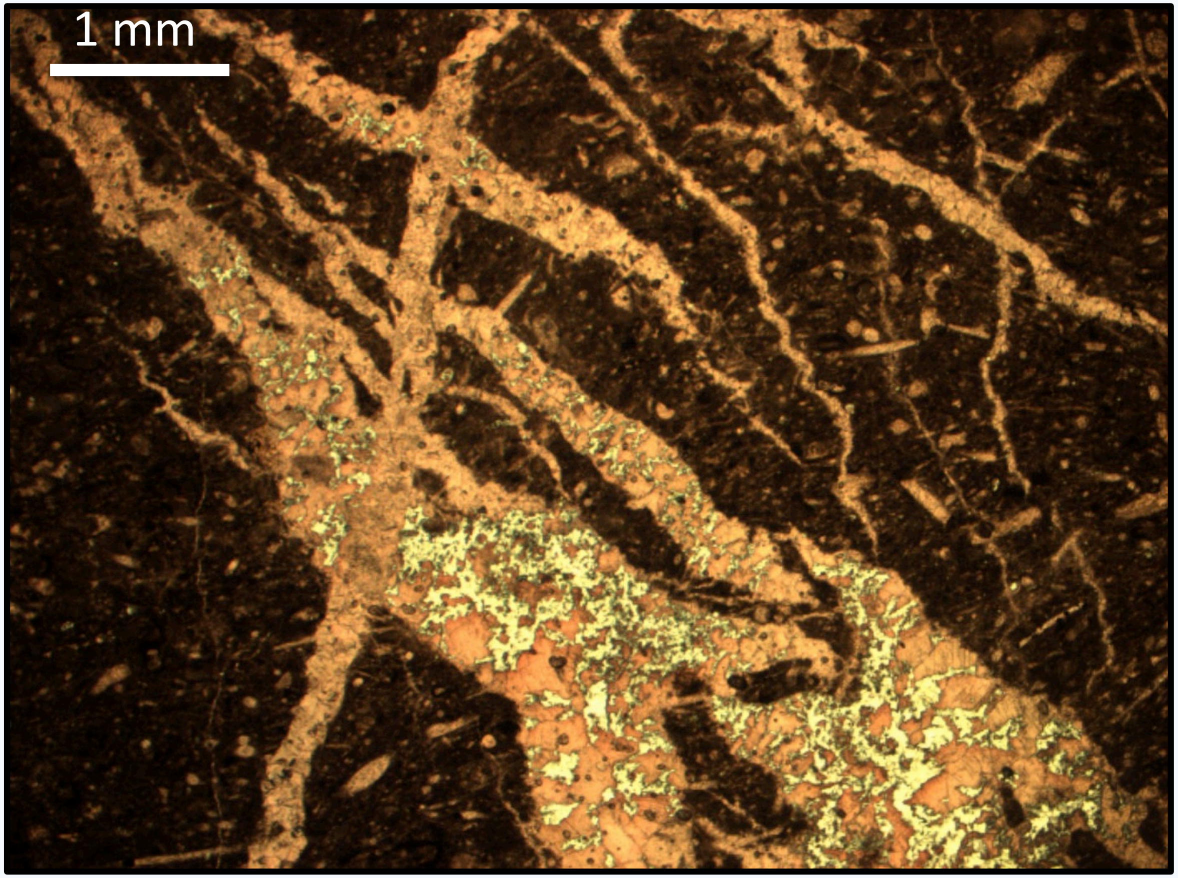




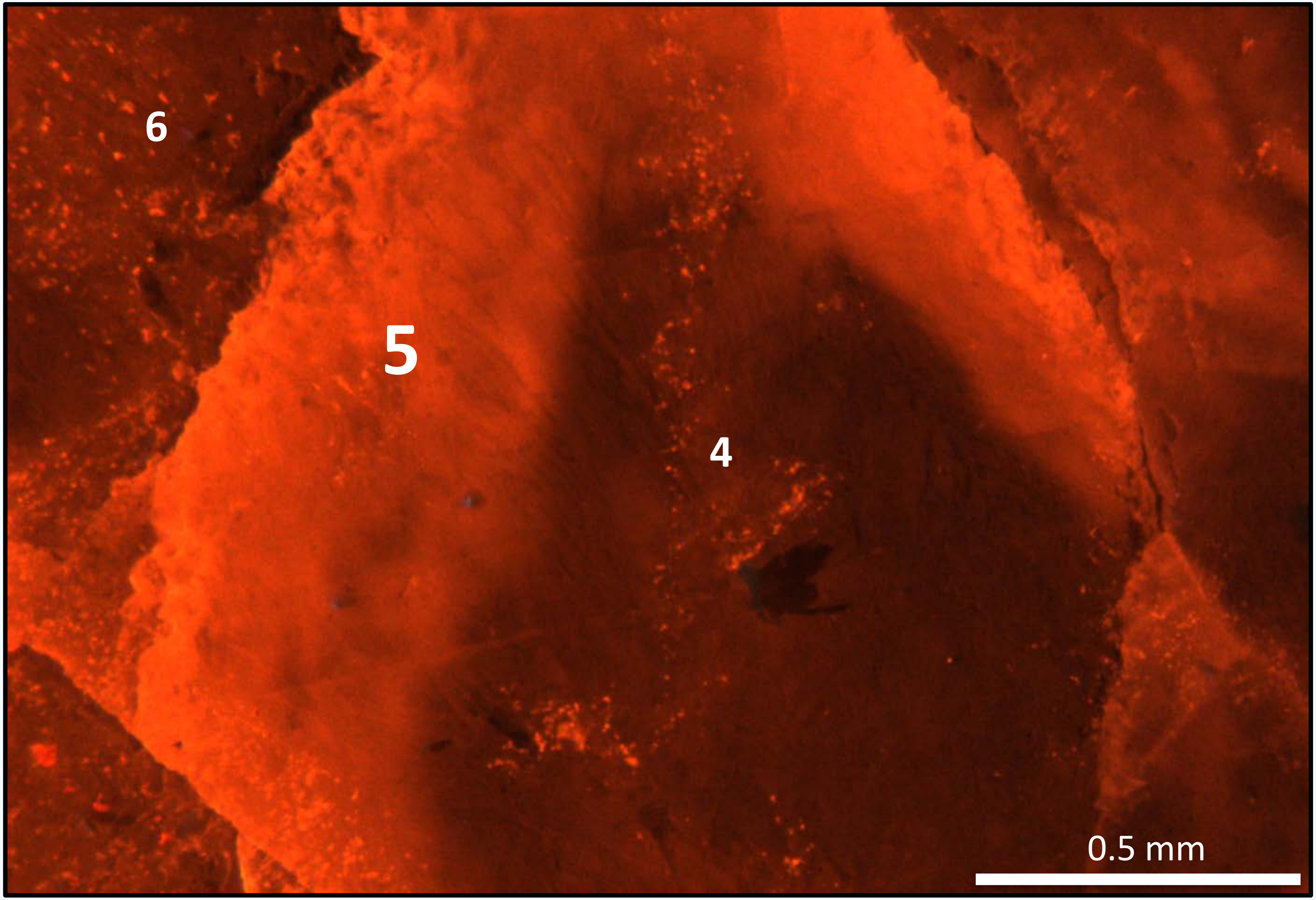
Engle et al (2016)

Tectonic Fracturing Stage

- After onset of chemical compaction

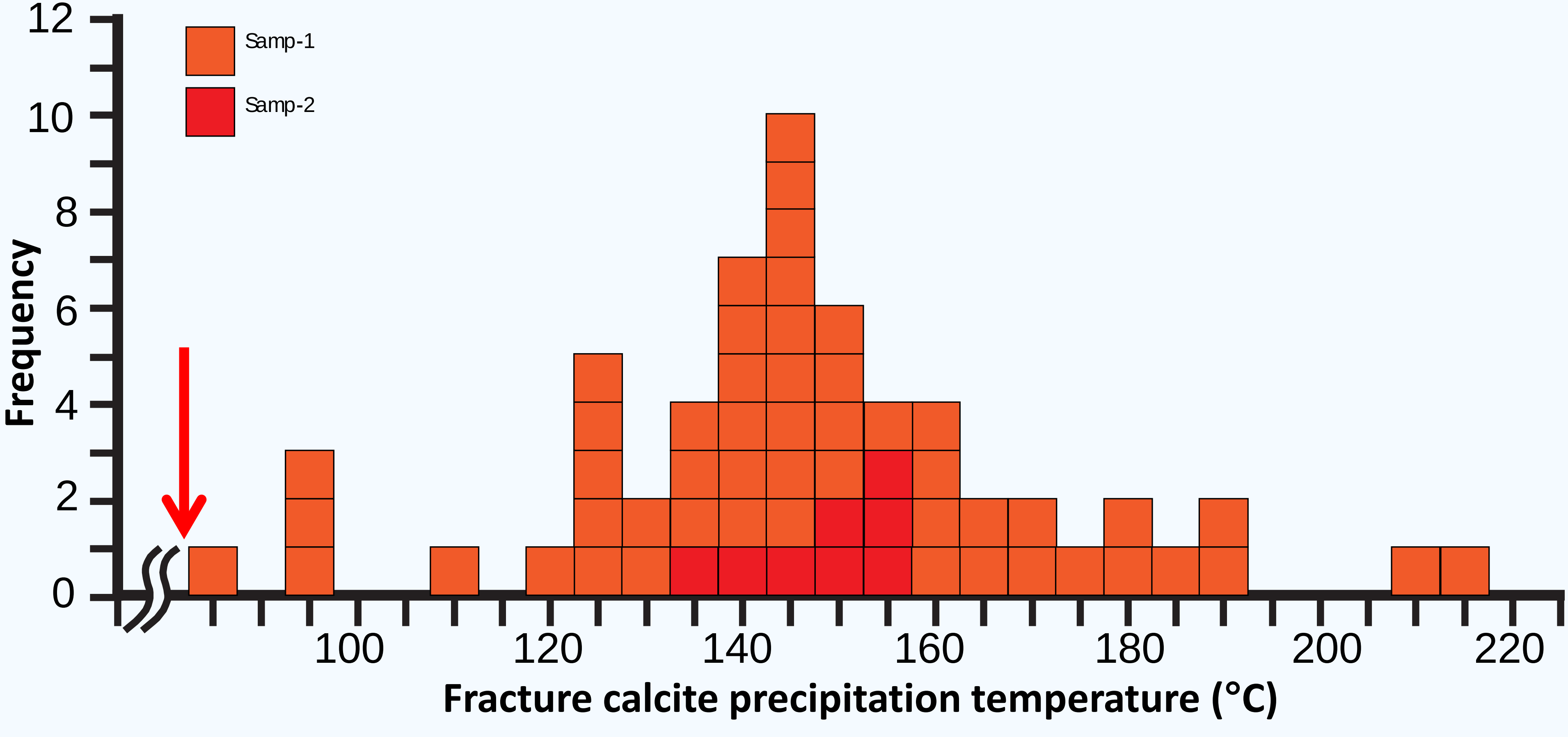


Fracture-filling Calcite

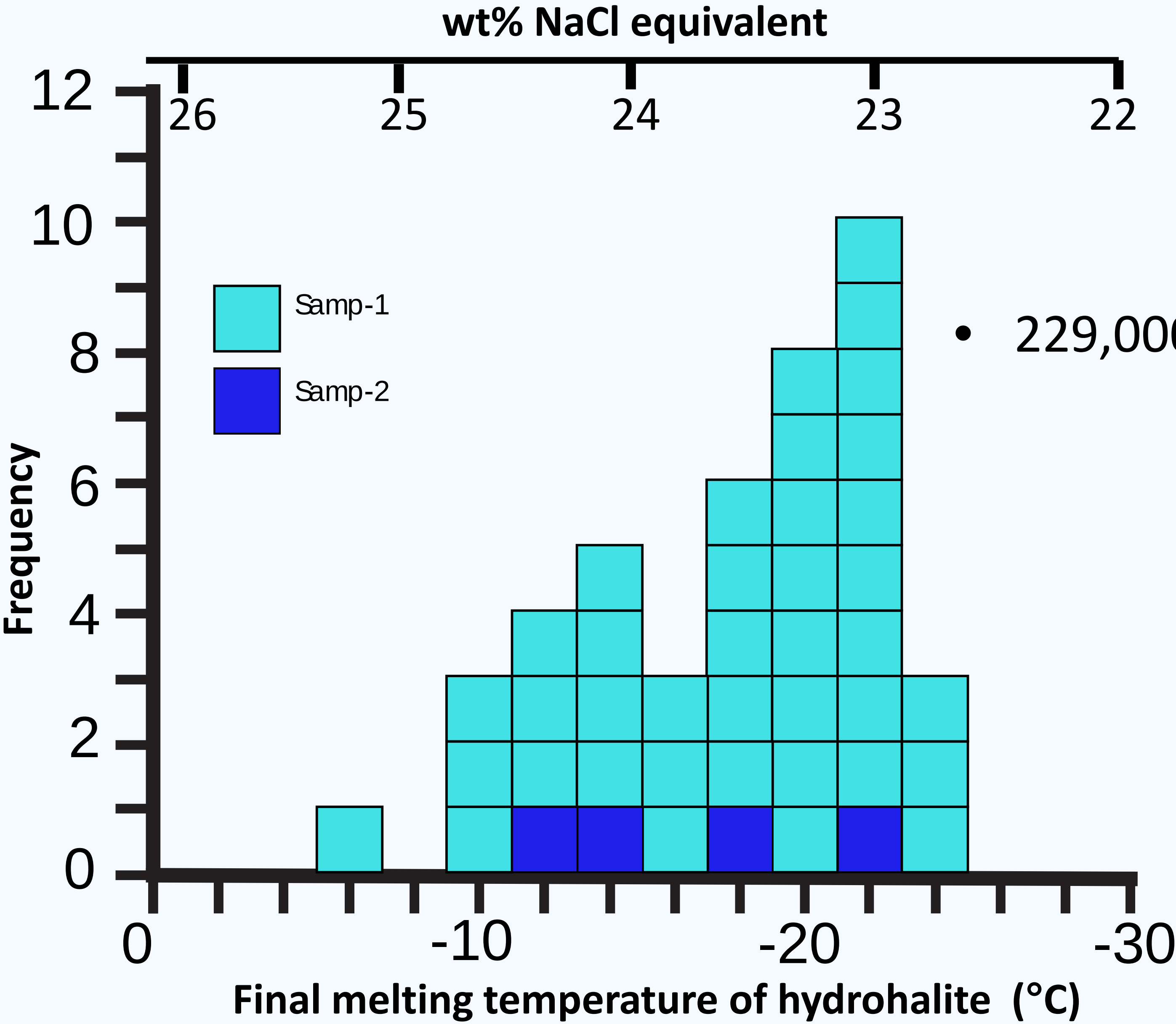


Fracture-filling Calcite

- These are anomalously  fluids!



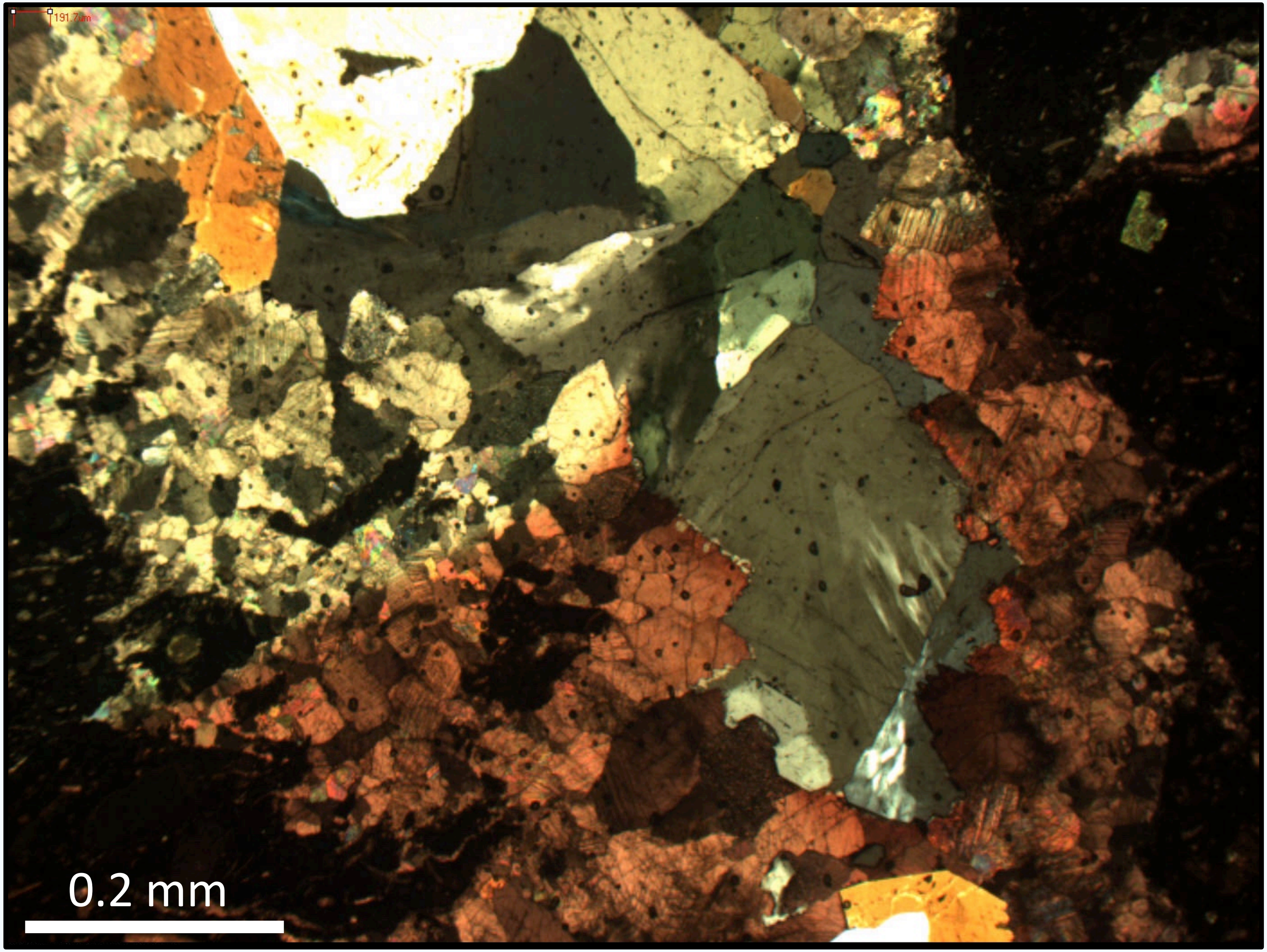
Fracture-filling Calcite



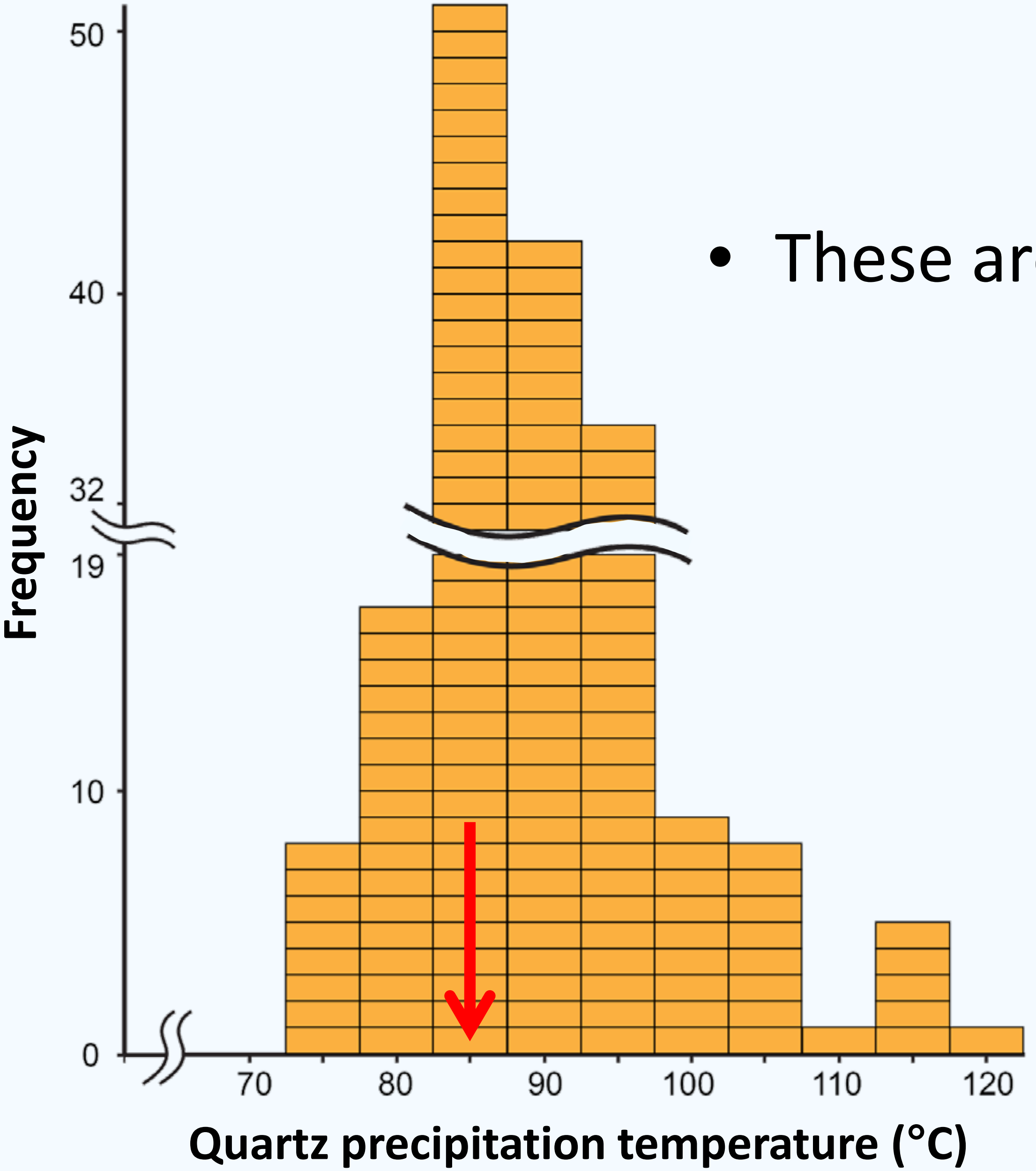
- 229,000 – 254,000 ppm

Late Quartz

- Later in tectonic fracturing stage

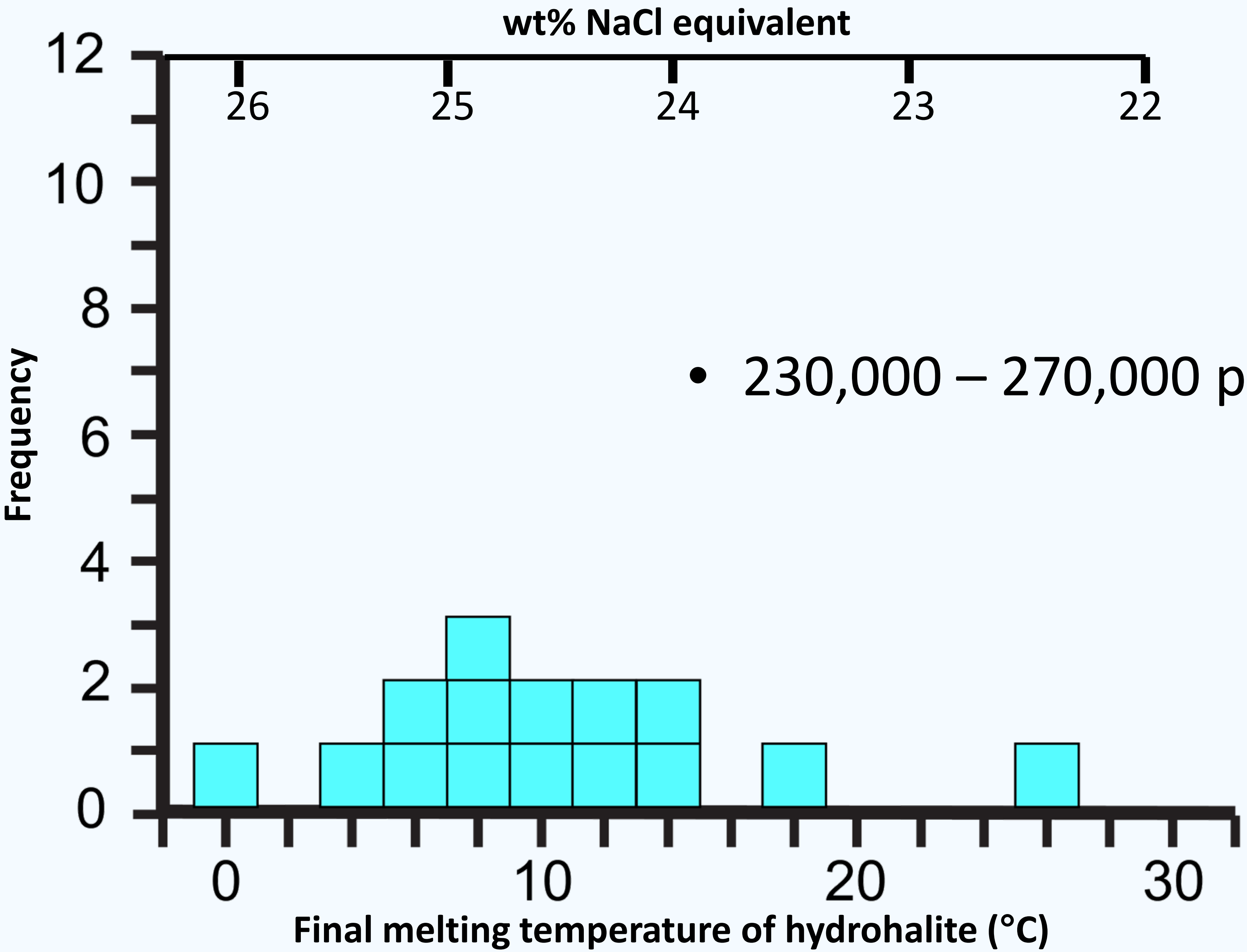


Late Quartz



- These are especially hot fluids

Late Quartz



- 230,000 – 270,000 ppm

High Temperature Fluid Source?

Heat from igneous intrusions and convection?

Tectonically valved deep basement fluids?

Top basement (max burial): **125 °C**

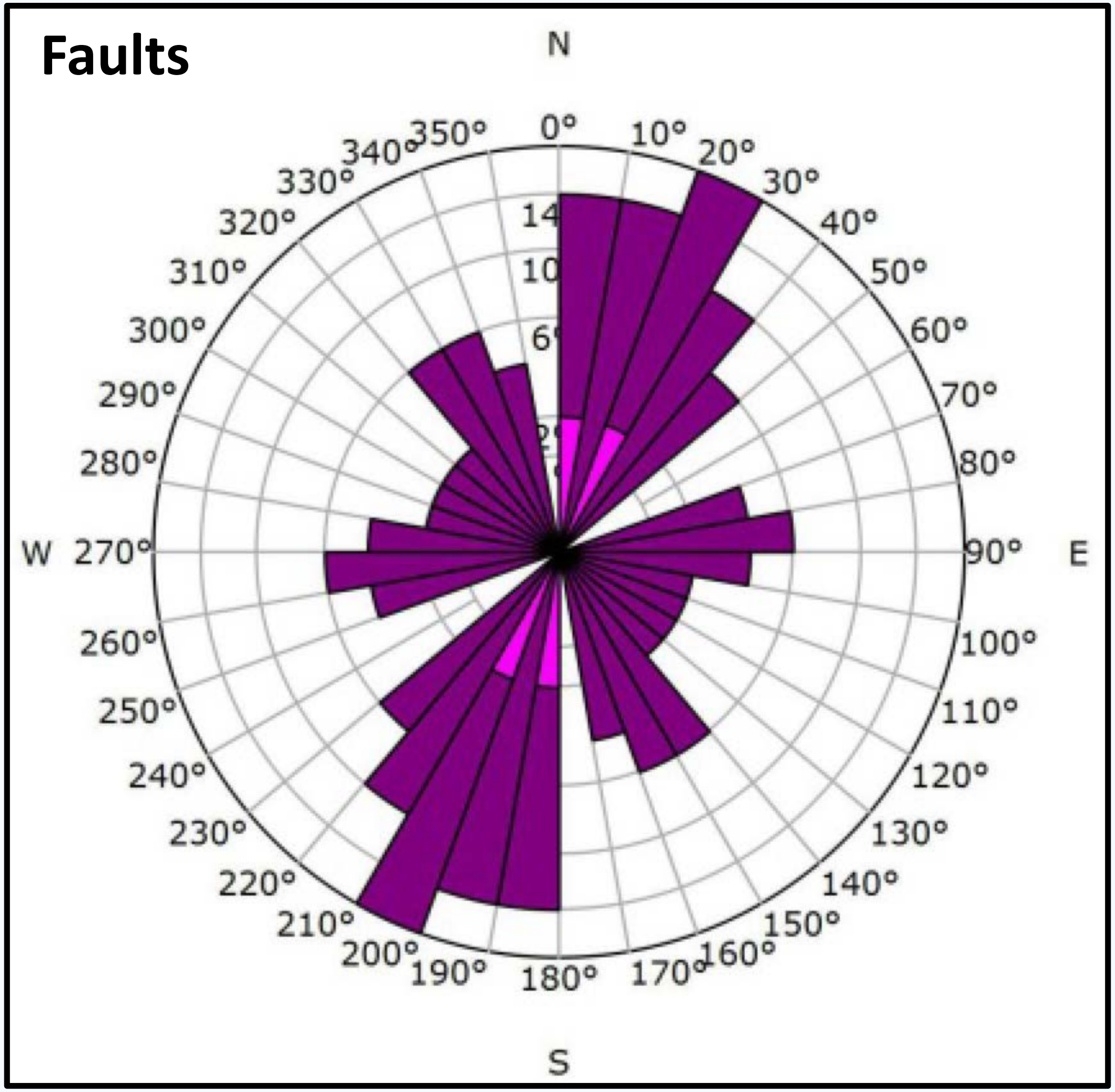
Long distance advective migration from Val Verde Basin?

Modern deepest top basement is 8km deep: **250 °C**

Thermal Maturation

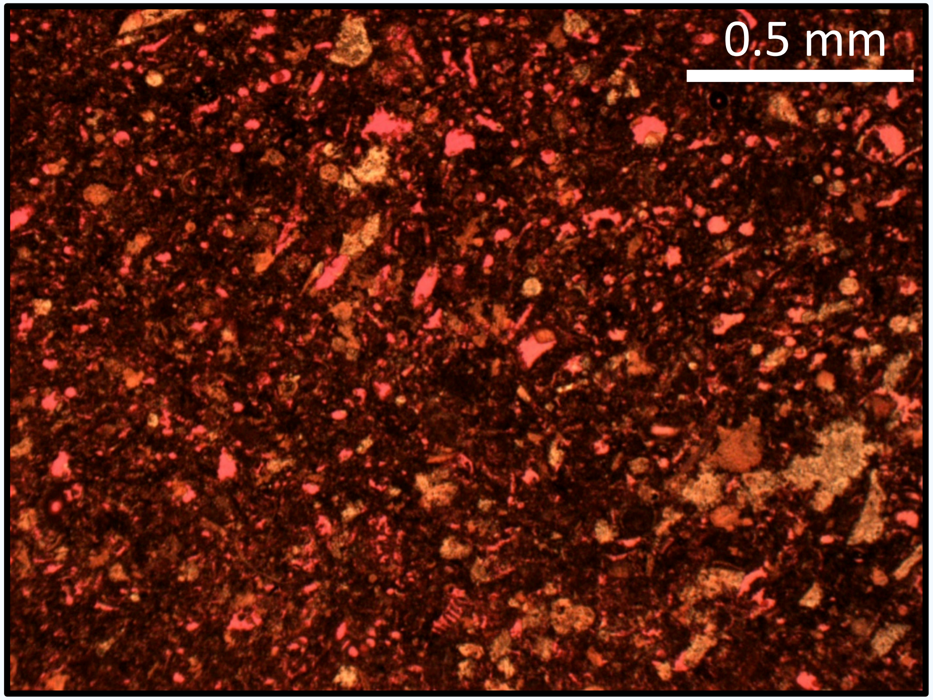
- Hydrothermal fluids likely enhanced thermal maturation
- Likely deep fluid source suggest fractures were pathway for upward migration
- Fracture width, type, or timing are likely controls on localized thermal maturity
- Therefore, knowledge of basin fracture systems should improve predictability of source rock maturity

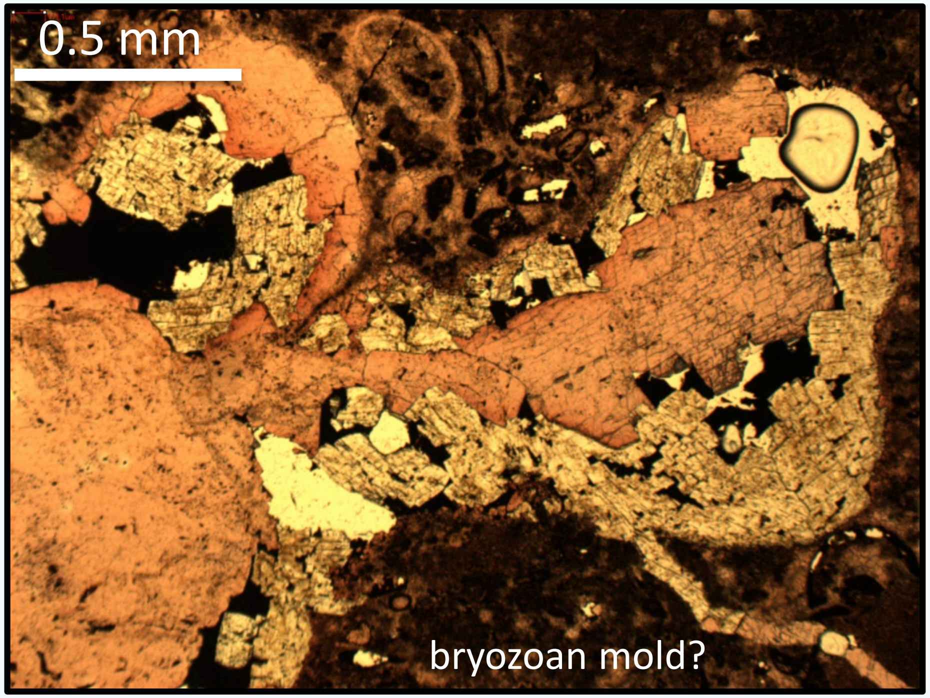
Fracture control?

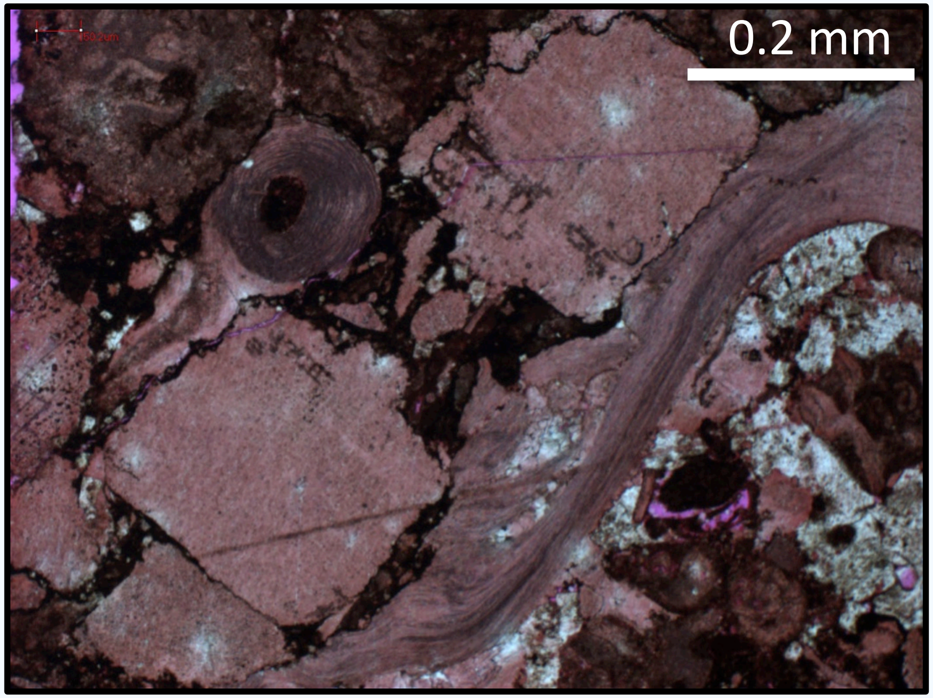


Late Dissolution & Oil Migration

- Yields porosity **enhancement** AND **reduction**
- **Bitumen** present in extant porosity







Where is success?

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References

Engle, M.A., Reyes, F.R., Varonka, M.S., Orem, W.H., Ma, L., Ianno, A.J., Schell, T.M., Xu, P., and Carroll, K.C., 2016, Geochemistry of Formation waters from the Wolfcamp and "Cline" shales: Insights into brine origin, reservoir connectivity, and fluid flow in the Permian Basin, USA

Mazzullo, S.J., 1994, Lithification and porosity evolution in Permian periplatform limestones, Midland Basin, Texas

Pawlewicz, M., Barker, C.E., and McDonald, S., 2005, Vitrinite reflectance data for the Permian Basin, west Texas and southeast New Mexico. US Department of the Interior, US Geological Survey