[PS]Diagenetic Complexities of the Middle Ordovician Antelope Valley Limestone, Lone Mountain, Eureka County, Nevada*

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Abstract

The Antelope Valley Limestone (AVL, upper Pogonip Group) consists of laminated mudstones and skeletal wackestones and packstones deposited on the western Laurentian passive margin carbonate shelf during Middle Ordovician time. The AVL is exposed on the west side of Lone Mountain and is unconformably overlain by the Ordovician Eureka Quartzite and a sequence of Upper Ordovician through Devonian carbonates. For this study, the diagenetic history of the AVL was interpreted using thin-section petrography.

The AVL has undergone a long and complex diagenetic history. Following deposition, initial marine diagenesis is represented by the presence of micritic envelopes surrounding skeletal allochems. Evidence for the first stage of meteoric diagenesis (both vadose and phreatic zones) is the dissolution of skeletal allochem cores and peloids, and the formation of early calcite isopachous, blocky and meniscus cements. Fine-grained euhedral dolomite locally replaced micrite during meteoric or early burial diagenesis. Burial diagenetic silica (chalcedony and chert) cements locally occluded secondary porosity formed during meteoric diagenesis. The void-filling textures of the silica cements are consistent with pore filling and not replacement. Further evidence of burial diagenesis is the presence of sutured (locally stylolitic) contacts and fractured grains. Several generations of spar-occluded cross-cutting fractures are present. Sparry calcite crystals containing inclusions of the silica burial cement formed either during late-stage burial or post-burial meteoric diagenesis. Tertiary porosity was formed by dissolution of earlier calcite cements during a second stage of meteoric diagenesis, possibly during exhumation as calcite grains show strain, an indication of tectonism. A final stage of fine-grained splotchy dolomitization partially replaces depositional, early meteoric, burial, and post-burial calcite. This diagenetic history is consistent with the multiple phases of Late Paleozoic and Mesozoic compressional tectonism and Miocene to recent basin-and-range extension documented in the Lone Mountain area.

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The Antelope Valley Limestone is part of the Ordovician Pogonip Group. At Lone Mountain, the upper part of the Antelope Valley Limestone and the entire Copenhagen Formation are missing (Ross, 1970) so that the Eureka Quartzite is unconformably overlying the middle Antelope Valley Limestone.

Location

Lone Mountain is located approximately 30 km east of the town of Eureka, Nevada and north of US Highway 50.

Project Background

This project originated as a field trip taken in association with a carbonate petrology graduate course in the fall of 2008. The objective of this field trip was to construct a diagenetic history of the Paleozoic carbonates in the region, including the Ordovician Antelope Valley Limestone, the upper Ordovician through Silurian Hanson Creek Formation, and the Devonian Devil's Gate Limestone. Sections of all units were measured and hand-specimens were collected at an average of every 5 meters, except where lithologic differences warranted a closer sample spacing. A total of 12 samples were taken of the Antelope Valley Limestone.

Of all the units, the AVL showed the most diagenetic complexity in petrographic studies and was selected for further investigation.

Stratigraphic Column

Tectonic History

During Middle Paleozoic time, the Eureka area sat on a passive margin carbonate shelf near the equator (Cook and Corboy, 2004). Beginning in latest Devonian time, the western margin of North America was subjected to a series of contractional tectonic events, including the latest Devonian-Early Mississippian Antler Orogeny (Speed and Sleep, 1982), a series of tectonic events in Mississippian through Permian time (i.e., Trexler et al., 2004), the latest Permian through early Triassic Sonoma orogeny, mid-Jurassic Nevadan orogeny, Jurassic-Cretaceous central Nevada thrust belt (Taylor et al., 1993), and late Mesozoic through early Tertiary Laramide and Sevier orogenies (Dickinson, 2006). By early Tertiary time, the numerous contractional events resulted in overthickened and gravitationally unstable crust in central and eastern Nevada, resulting in a series of localized Tertiary metamorphic core complexes (Coney, 1980; Wernicke, 1981, 1992; Davis and Lister, 1988). Beginning with establishment of the San Andreas fault ~18 Ma, the compressional force holding up the thick Nevada crust was relaxed and the crust failed by a series of ~north-south normal faults, forming the Basin and Range province (Atwater, 1970; Dickinson, 1997; Atwater and Stock, 1998).

In the field, the Antelope Valley Formation generally crops out as low-relief benches on the southwestern flank of Lone Mountain. The section measured for this project was a total of 192 meters thick, dipping at an average of 22°S. Laminated and bedded wackestones and packstones dominate the formation, though mudstones and grainstones are present. Chert nodules are fairly common and chert beds are present near the middle of the formation. Common allochems include pisoids, peloids, and skeletal fragments (mostly brachiopods). Distinctive receptaculites (problematica)-, maclurites, (gastropod)- girvanella (oncolite)- rich beds crop out near the top of the Antelope Valley Formation.

The AVL can be divided into three broad units, a lower micritic unit with sparse fossils, a middle unit of wackestone with chert horizons and numerous fossils, and an upper unit of wackestone/packstone representing four or five shallowing-up cycles that are topped by brachiopod grainstones.

Antelope Valley Limestone capped by Eureka Quartzite

Thin section mineralogy is dominated by calcite, with lesser dolomite (planar-e and planar-s), quartz (detrital and replacement chert and chalcedony), detrital plagioclase, and iron-oxides. The samples are dominantly packstones and wackestones (deposited in a lagoon or shallow to intermediate subtidal environment), with one bindstone observed, and a few peloidal-skeletal grainstones (deposited in a carbonate shoal or shallow subtidal environment). Common allochems include: skeletal grains (nuia sibirica, trilobite fragments, brachiopods (including stems), crinoid stem and arm plates, sponge spicules, gastropods (girvanella), receptaculites, ostracods, bryozoans, foraminifera, corals, and thartharella sp.), pisoids, peloids, and intraclasts. Primary porosity is generally interparticle, intraparticle, and/or shelter, and is occluded by sparry calcite and/or dolomite. Secondary porosity, where present, is generally moldic (including inversion) or fracture, occluded by sparry calcite, dolomite, and/or silica.

Receptaculities in Antelope Valley Limestone

Deposition

The Antelope Valley Limestone at Lone Mountain is comprised mainly of wackestones and packstones. The carbonate sediment was deposited in a range of marine, shallow-water environments, including lower slope, upper slope and shelf. Depositional facies include restricted platform and lagoon. Biological grains include Girvanella, a green algae Nuia sibirica (?) and Recepitculites (both Problematica, but grouped with algae), the Gastropod *Maclurites*, and crinoid, trilobite and echinoderm (unknown species) fragments. Non-biologic depositional grains include quartz silt, peloids, and oncoids. Several horizons of nodular chert occur, particularly in the upper part of the sampled section. The rhythmic nature of these horizons could be the result of sea level changes, either local or global. The upper AVL consists of four oto five shallowing-up cycles capped by brachiopod grainstones (see photo below).

Marine Diagenesis

After initial deposition, marine fluids that were pH neutral to slightly basic, but high in CO_2 infiltrated the sediment column, leading to the formation of micritic rims around grains. Oxidizing conditions during this period of early diagenesis consumed any organic material present
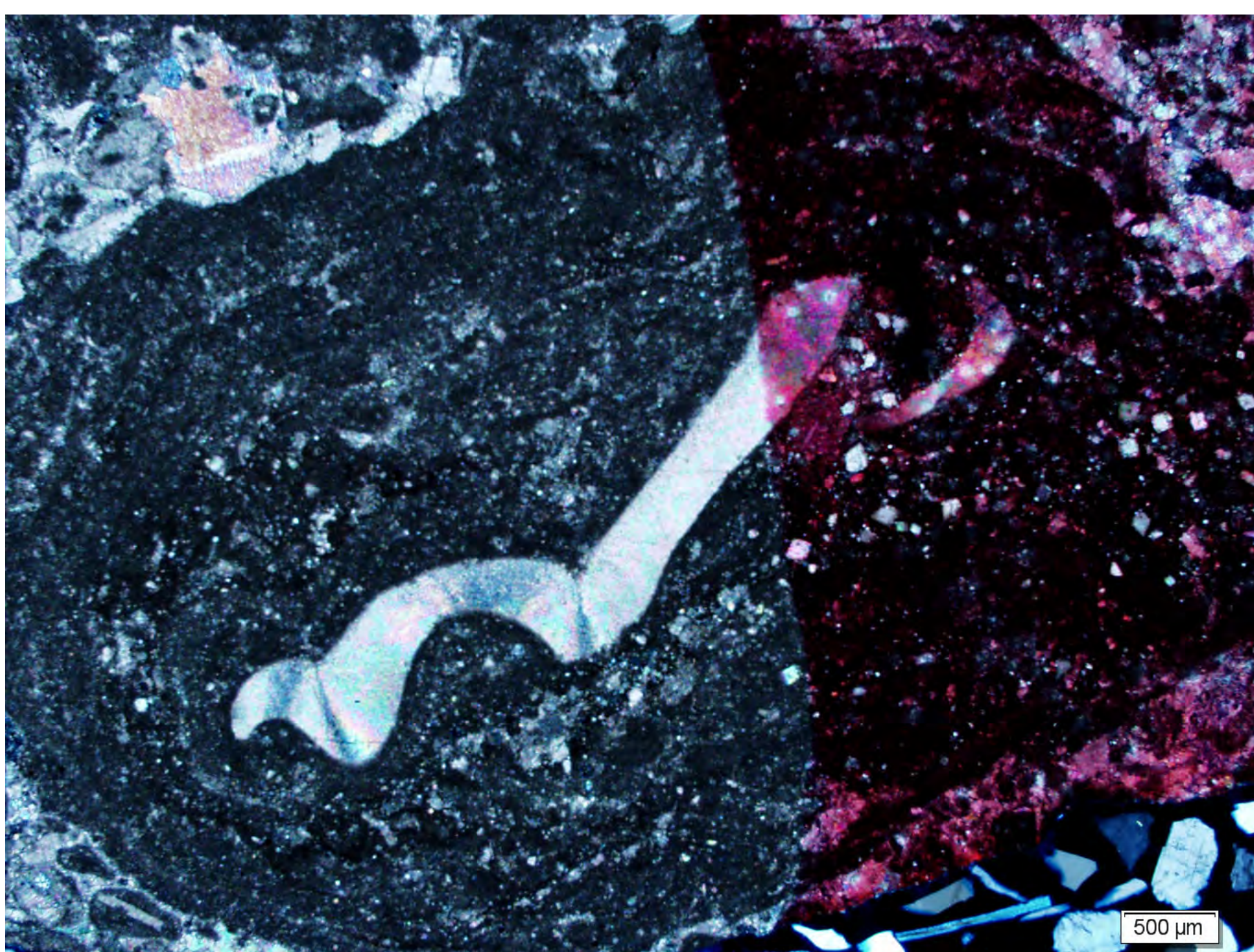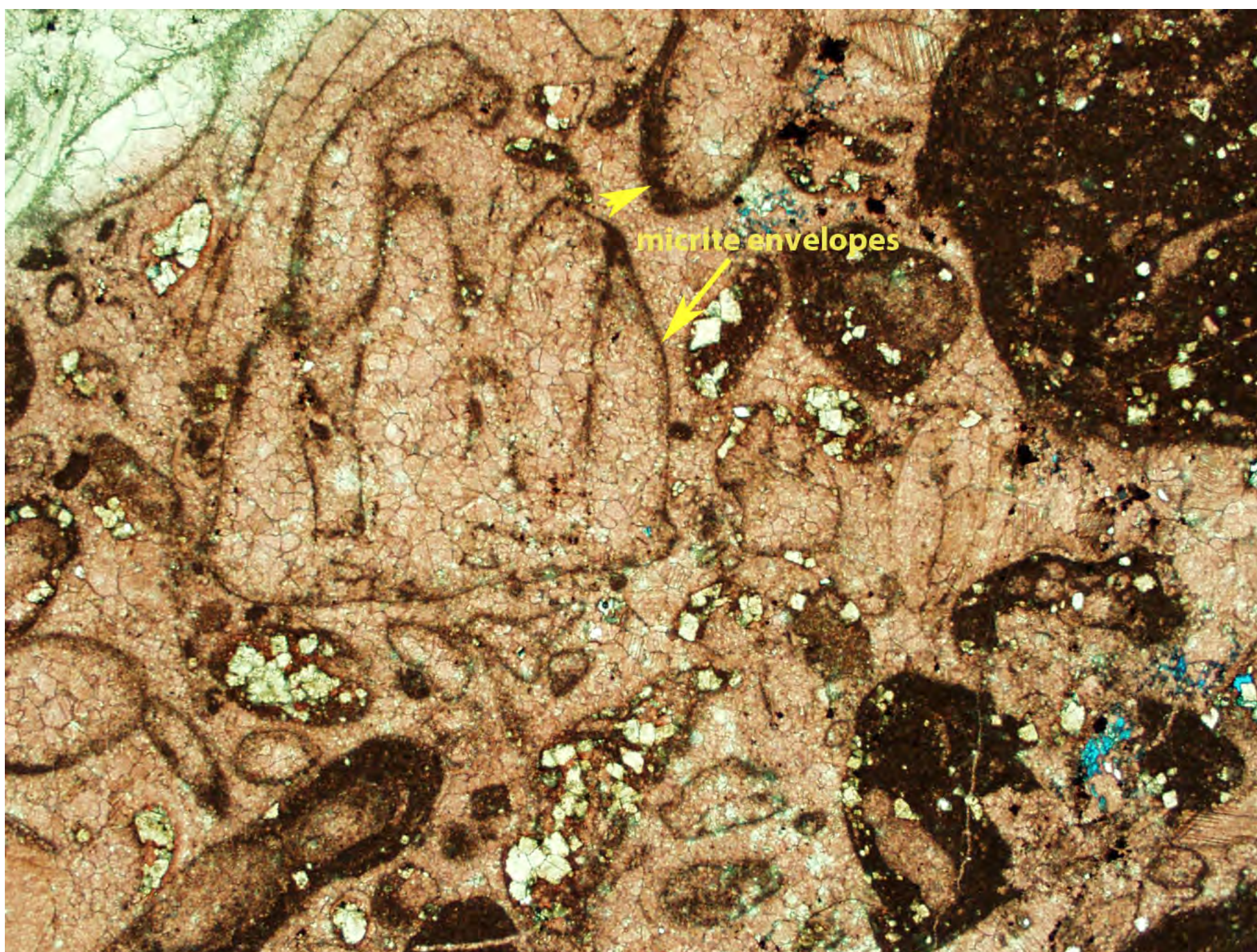
Allochems and intraclasts are preserved by the formation of micritic rims that limit the amount of fluids percolating through the grains.
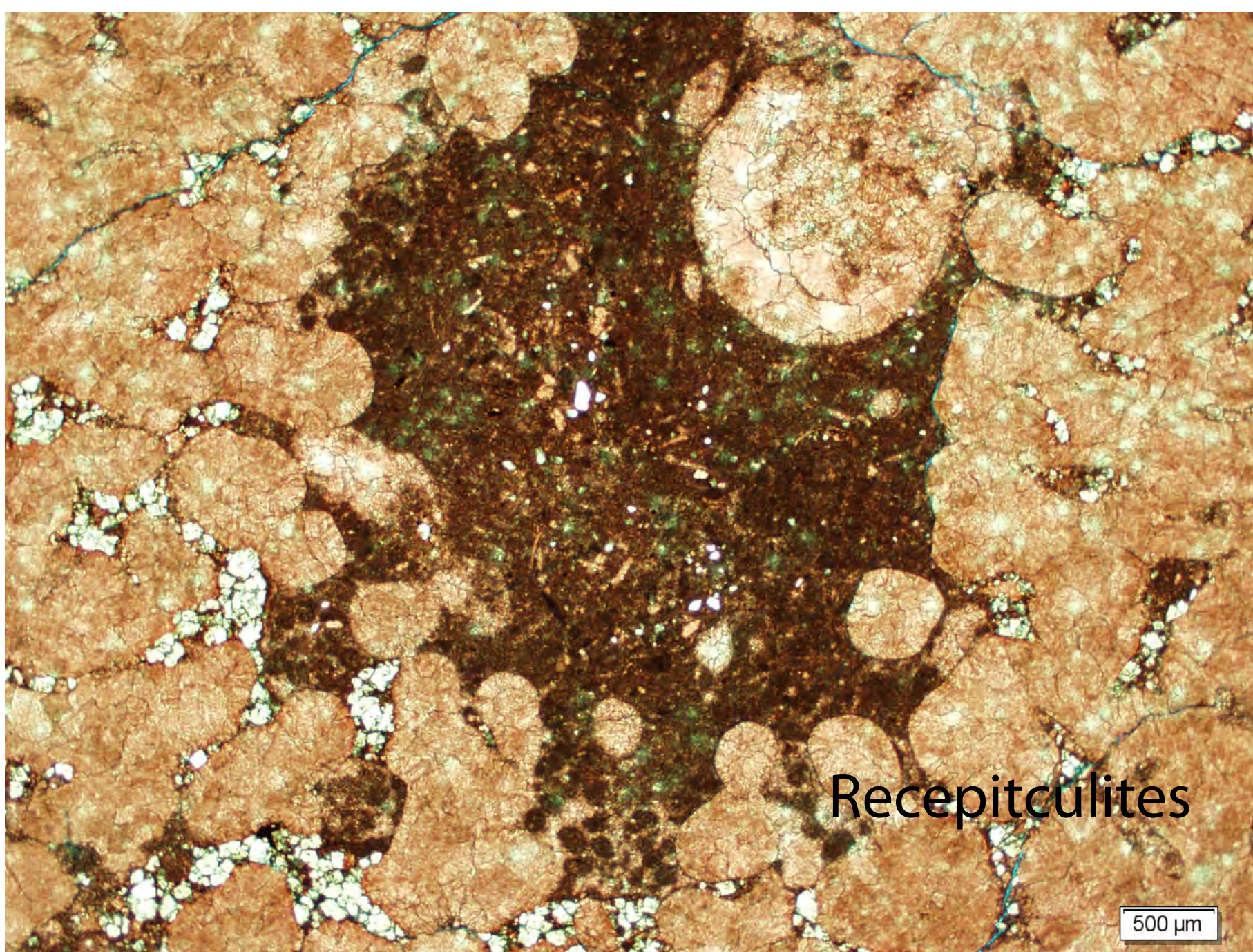
Meteoric Diagenesis

Meteoric diagenesis occurs when ground waters interact with pore fluids. The result can be the formation of meniscus cements, syntaxial overgrowths, and isopachous cements. Dissolution of aragonite and high-Mg calcite leads to the formation of secondary porosity.
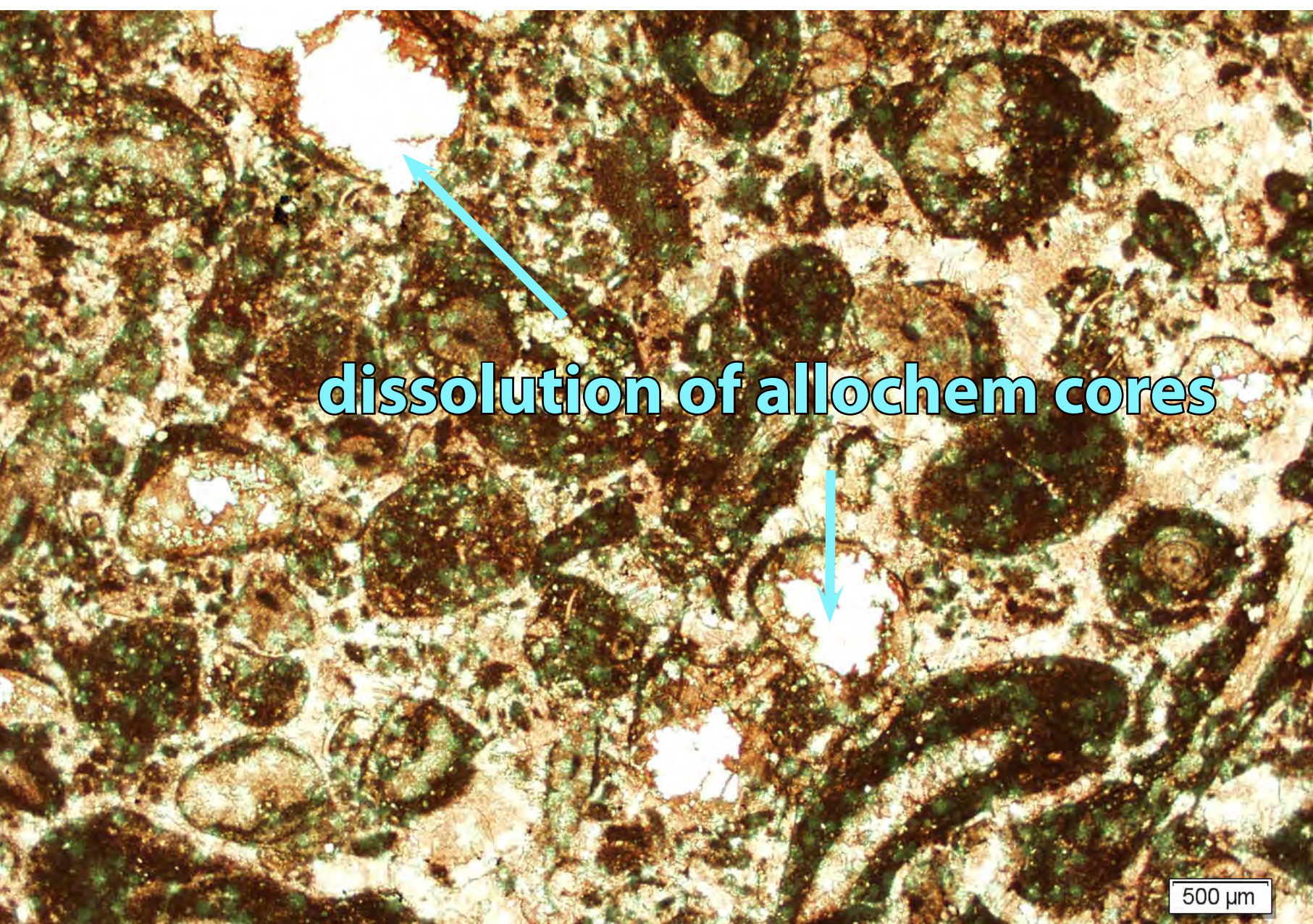
In the AVL samples, meteoric fluids may have also been neutral to slightly basic, but were (at least locally) undersaturated with respect to calcite (or possibly aragonite), resulting in allochem core dissolution.
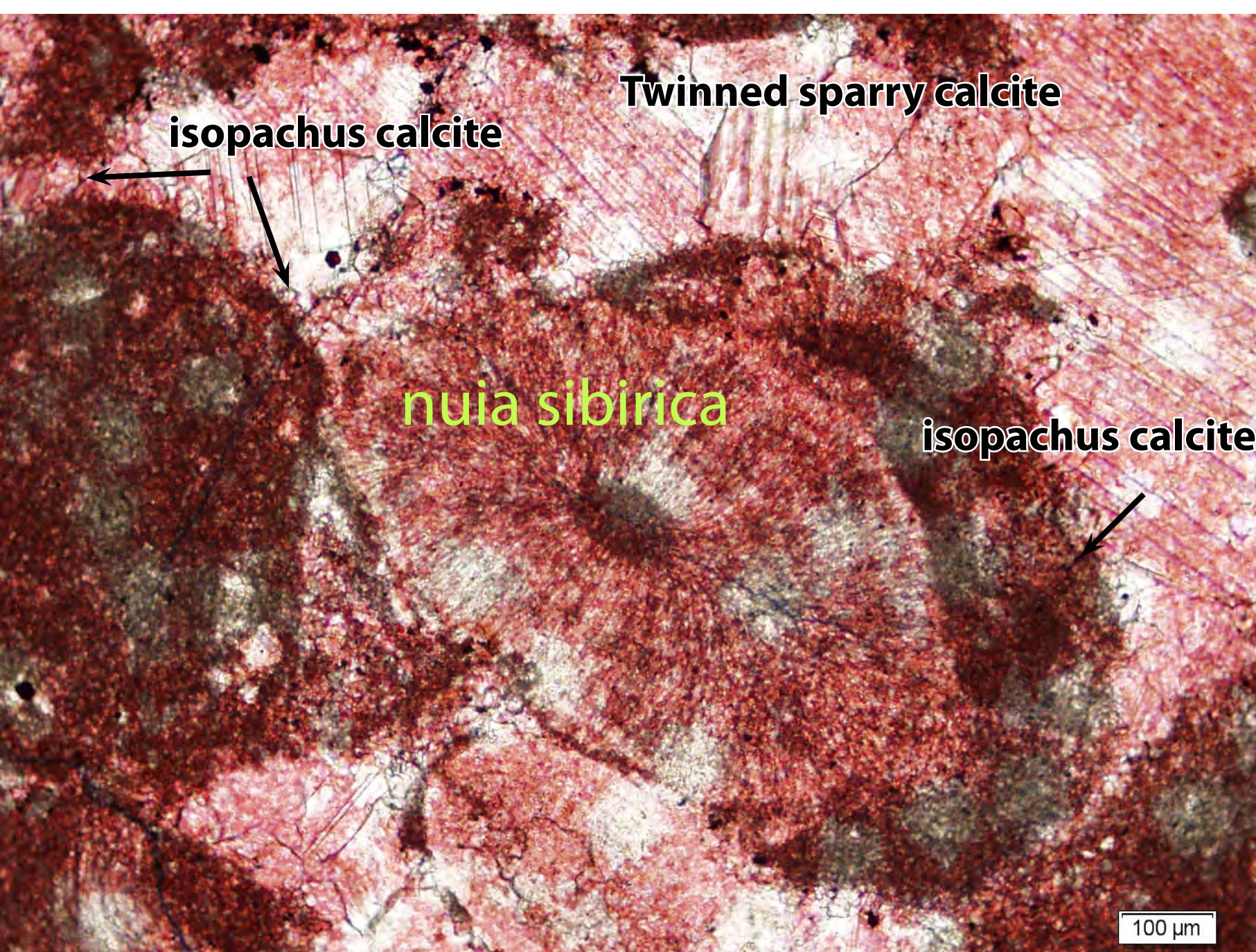
Isopachus cements formed along the outer rims of some grains and calcite cements reduced primary interparticle porosity. Sometime post-grain dissolution, silica cements (primarily chert) infilled these void spaces during late meteoric diagenesis or early burial diagenesis
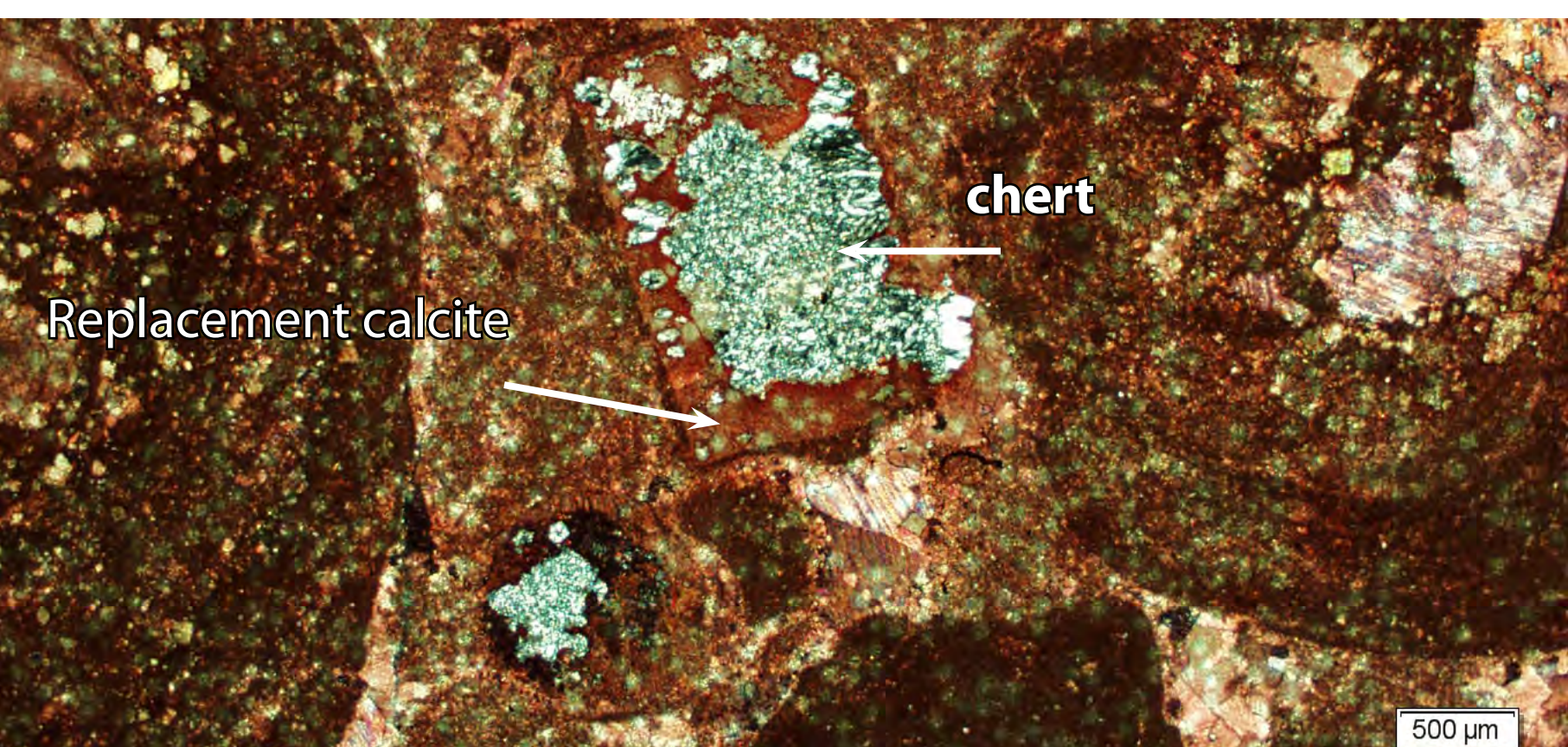
Burial Diagenesis

Burial diagenesis is recognized by both physical (e.g. mechanical compaction) and chemical (e.g. cementation) processes.

In our AVL samples, the silica appears to only fill void space created during dissolution in the meteoric realm, suggesting that interparticular porosity was already filled by the time the silica enriched fluids entered the system, perhaps pointing to a burial, rather than meteoric, origin. Dolomite replaced calcite during burial diagenesis; the origin of Mg is most likely seawater and/or formation fluids high in Mg. Dolomitization occurs as small (>0.05 mm), euhedral rhombs replacing calcite, most noticeably in the cements
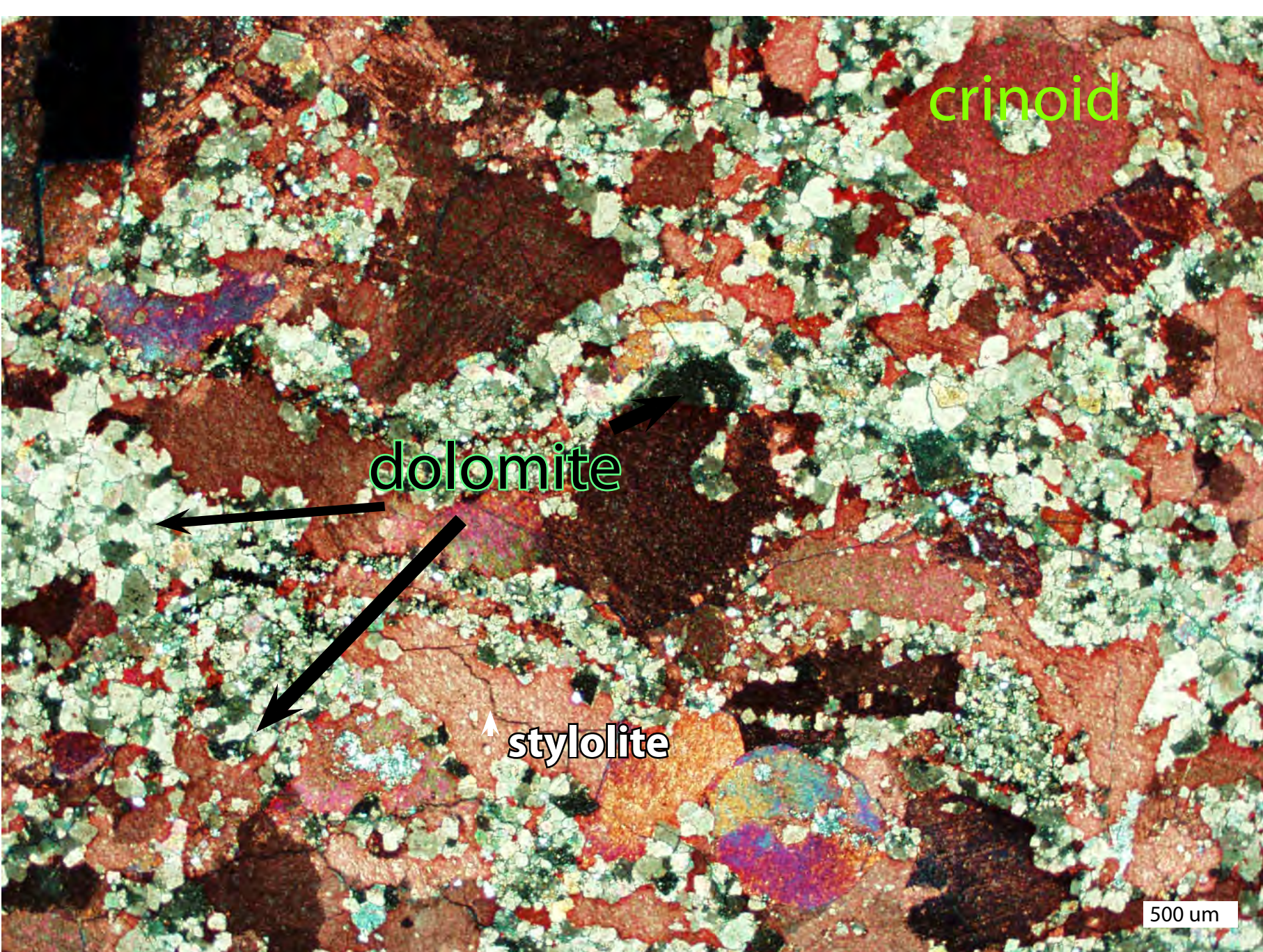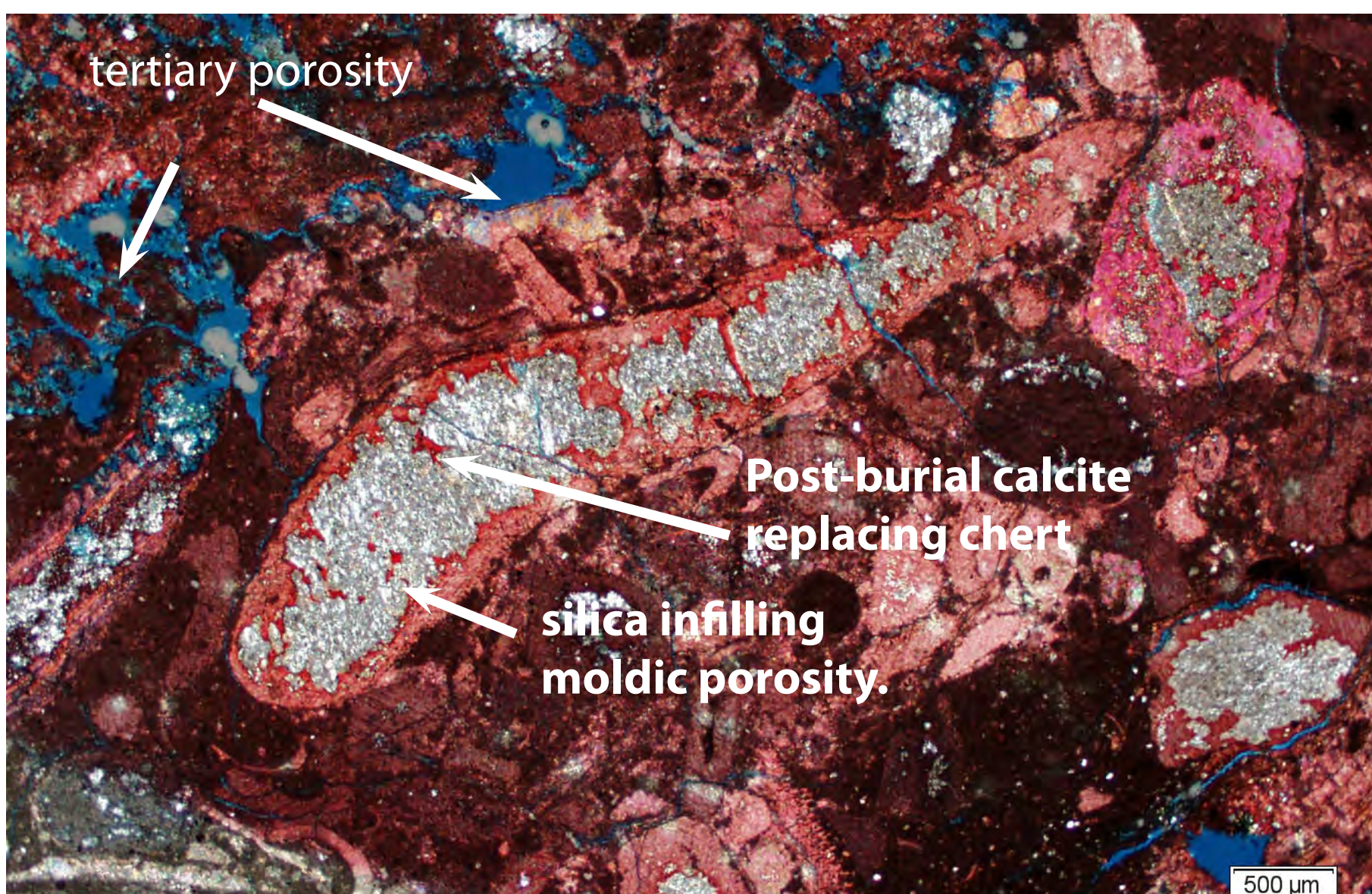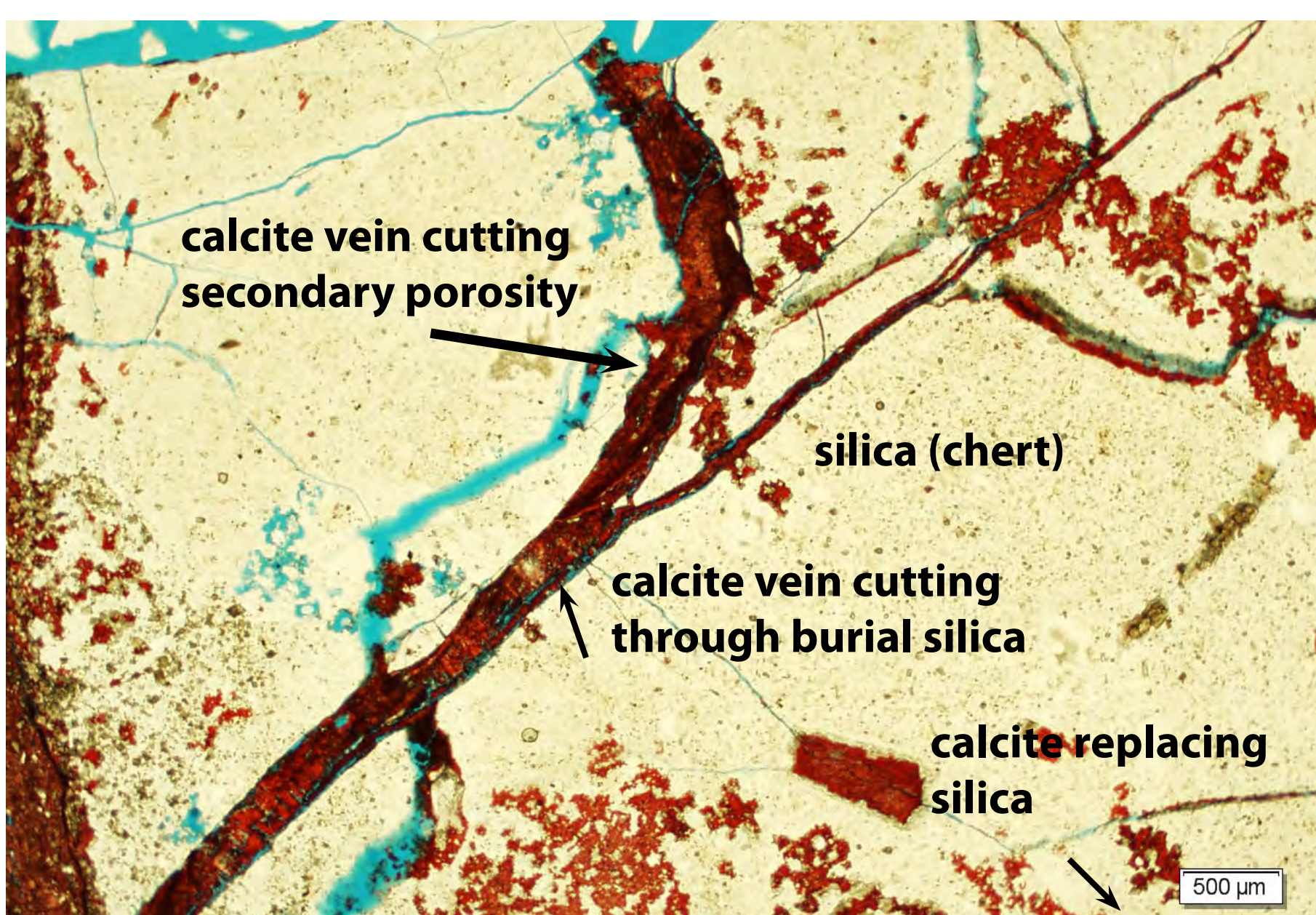

Burial fluids were probably compactional fluids that were high in TDS, neutral to slightly acidic, and locally supersaturated with respect to calcite or dolomite. Fluids that resulted in silicification may have either been supersaturated with respect to amorphous silica and/or more acidic than other fluids, allowing for precipitation of silica instead or in place of calcite
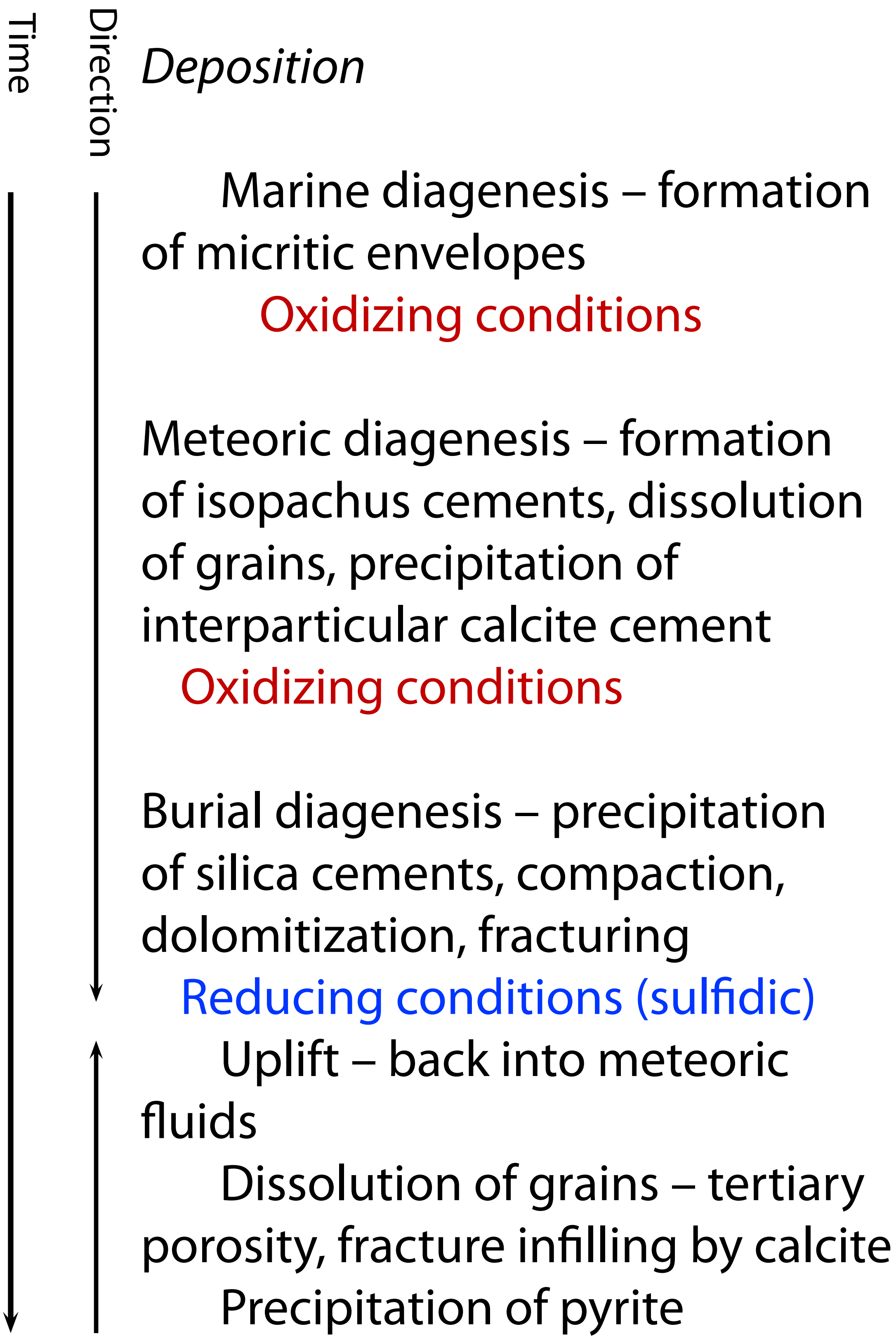
Post-Burial Diagenesis

The presence of sulfides (pyrite) in some samples indicates that reducing conditions existed at some time during diagenesis. On the basis of petrographic evidence these sulfides appear to have been precipitated in pore space that was created during a second round of meteoric diagenesis, most likely during uplift. The fluids for these sulfides were most likely formation fluids that were expelled during compaction.
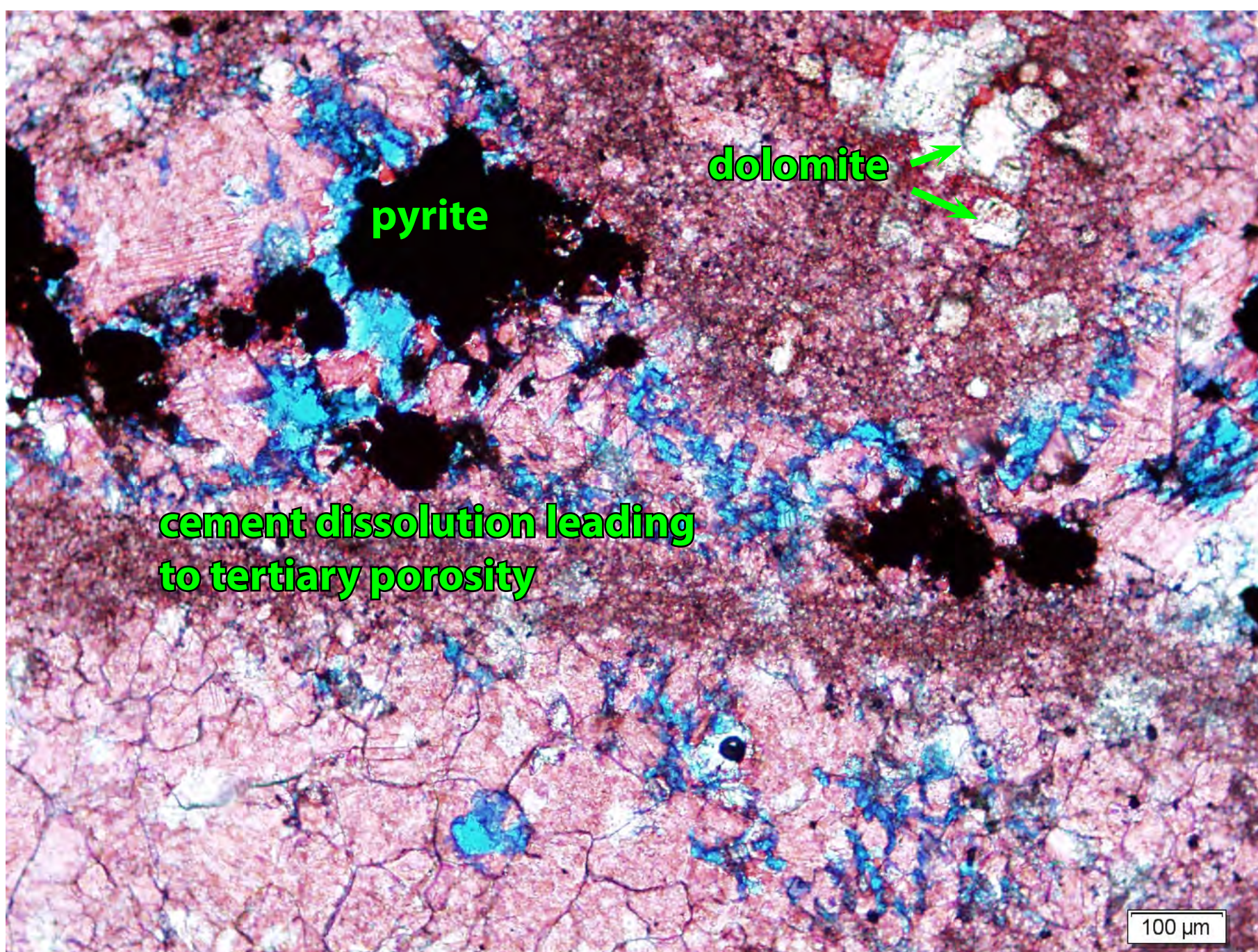
Late-stage calcite cement fills fractures that were most likely formed as a result of compaction during burial diagenesis. This calcite postdates the silica cement, and could have formed during uplift in the meteoric zone.

Diagenetic Sequence

Time
Direction

Deposition

Marine diagenesis – formation of micritic envelopes
Oxidizing conditions

Meteoric diagenesis – formation of isopachus cements, dissolution of grains, precipitation of interparticular calcite cement
Oxidizing conditions

Burial diagenesis – precipitation of silica cements, compaction, dolomitization, fracturing
Reducing conditions (sulfidic)

Uplift – back into meteoric fluids
Dissolution of grains – tertiary porosity, fracture infilling by calcite
Precipitation of pyrite

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