[PS]Origin of Chert in Mississippian Monte Cristo Formation, Southern Nevada, and Its Relationship to the Antler Orogeny*

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Abstract

Lower Mississippian carbonate rocks in southern Nevada were deposited along the proto-North American continental shelf in environments ranging from evaporative supratidal to subtidal. Within the Lower Mississippian succession, abundant stratabound nodular chert deposits first appear within the Kinderhookian to Osagean Monte Cristo Formation. Field and petrographic evidence at Sloan, located ten miles south of Las Vegas, indicates an early formation of the chert in a marine environment, possibly occurring penecontemporaneously with dolomitization. Silicification was controlled by the distribution of porosity, permeability, faunal and evaporite content of the pre-existing sediment. Replacement of algal structures by chert is particularly common in the Anchor member of the Monte Cristo Formation. The origin of silica and the mechanisms that lead to the formation of chert are poorly understood in this area, as are many other Paleozoic shelf carbonate-chert successions in the western Cordillera.

In the Monte Cristo Formation, geochemical analyses strongly suggest a non-biologic origin of the chert, ruling out sponge spicules or radiolarian as the primary silica source. We hypothesize that the principal source of the silica is related to a combination of processes associated with the ongoing Antler orogeny to the west; including direct input of volcanic ash, shedding of siliceous arc sediment, and localized sea level changes due to tectonic loading allowing influx of meteoric fluids. Understanding the relative influence of orogenic events on the origin and properties of chert in this area will provide a model that can be applied to nodular chert - carbonate associations in other regions.

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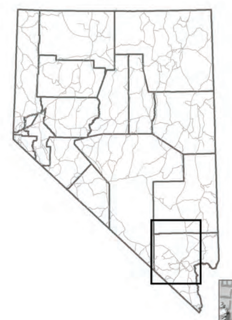
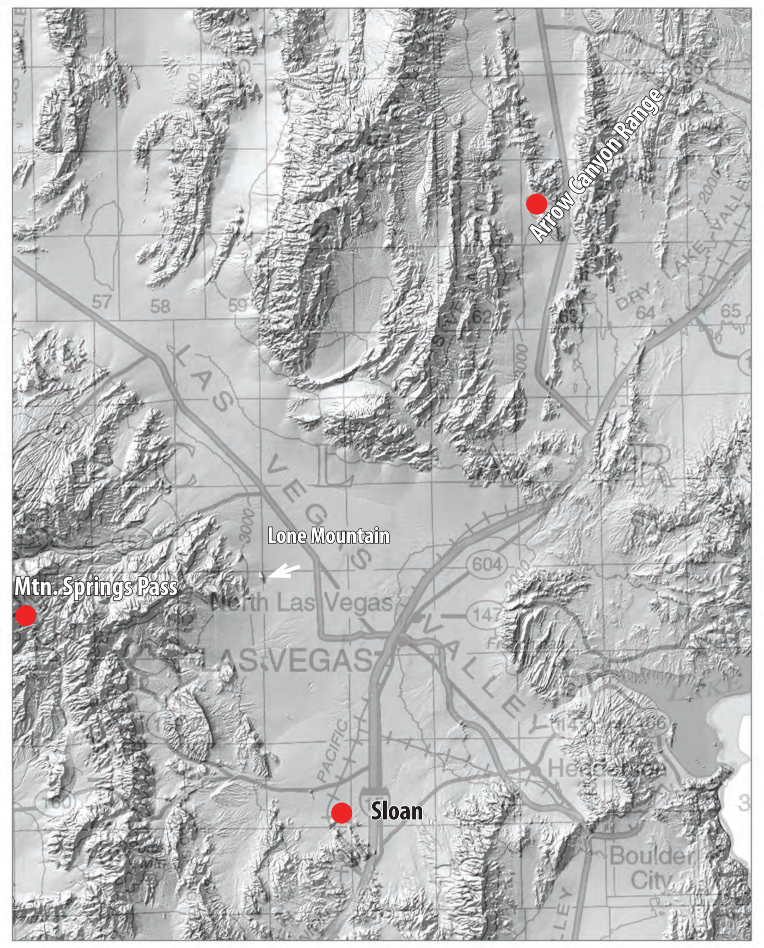
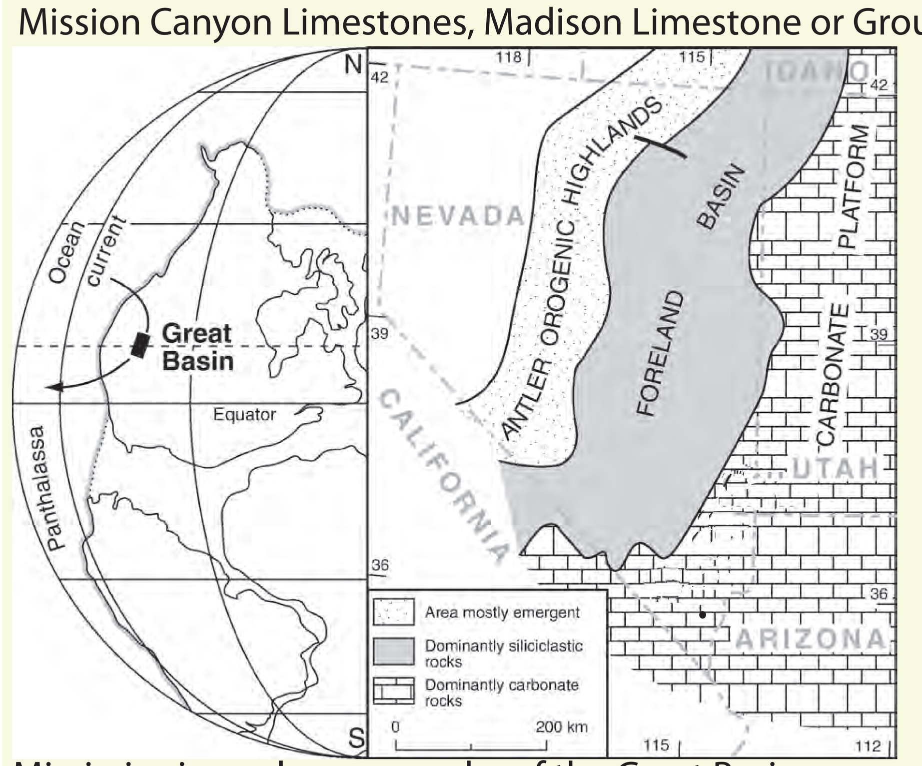
Location Map



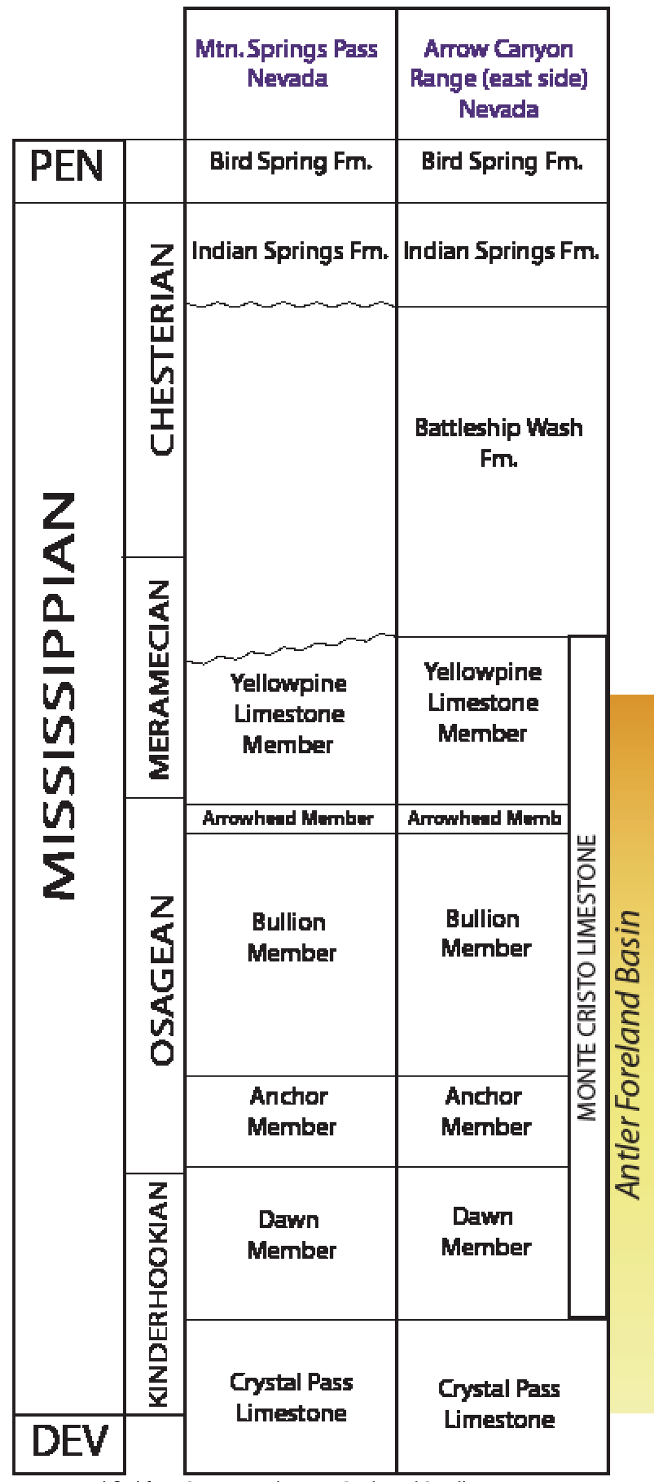


MISSISSIPPIAN CARBONATE PLATFORM

In the Western United States, a widespread sheet of shallow-water limestone and dolomite in the lower part of the Mississippian (Kinderhookian to Meramecian) is present through much of the Rocky Mountain province and extends westward into the Cordilleran miogeosyncline (Rose, 1976). In southern Nevada, these rocks are represented by the Monte Cristo Limestone (and to a lesser extent the earlier Crystal Pass Limestone), which is equivalent to other rock-stratigraphic units, including the Allan Mountain Limestone and Castle Reef Dolomite, Lodgepole and Mission Canyon Limestones, Madison Limestone or Group, Gardison and Deseret Limestones, and Leadville and Redwall Limestones (Rose, 1976). Mississippian and earlier Paleozoic paleogeography was described succinctly by Poole and Sandberg, (1991) as being compatible with the hypothesis that an offshore island-arc complex above an east-dipping subduction zone was separated from the continental slope and shelf by an oceanic or marginal sea. The carbonate rocks in southern Nevada were deposited in that shallow oceanic or marginal sea.



Mississippian paleogeography of the Great Basin. From Brand *et al.*, 2007

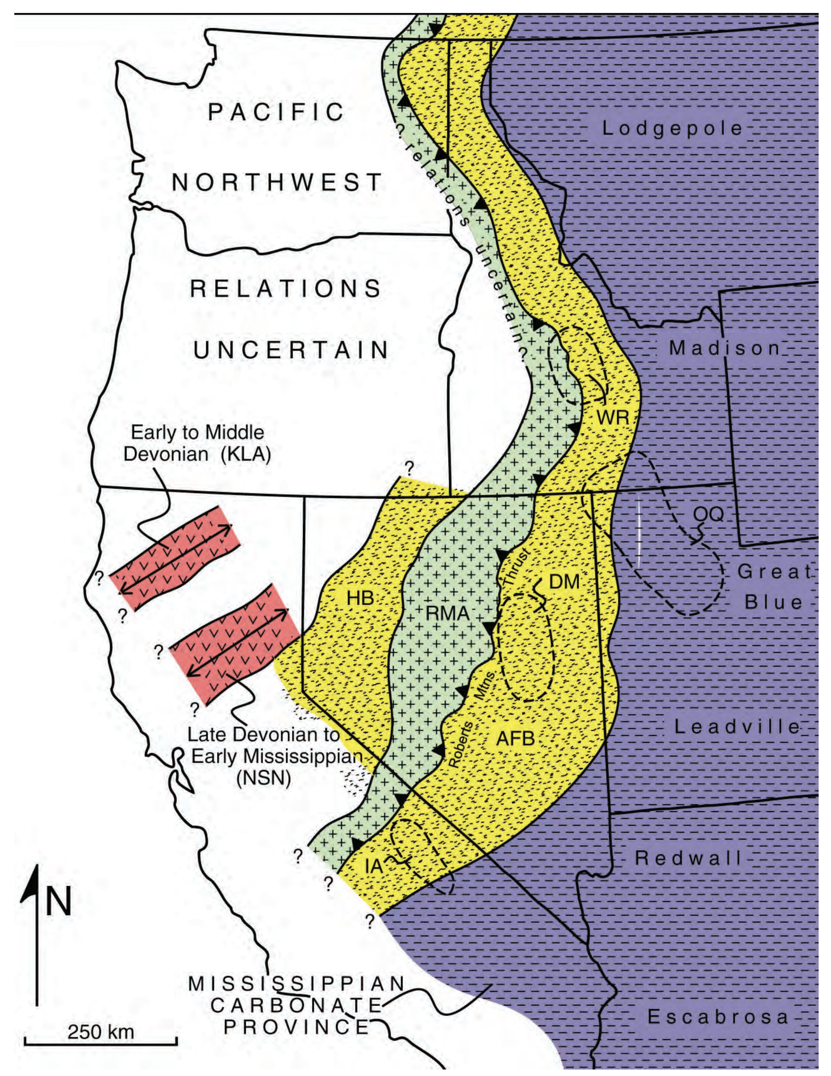


modified from Stevens et al., 1996; Poole and Sandberg, 1977, 1991

Does the appearance of layered, almost rhythmic, chert horizons signal the onset of Antler deformation?

THE ANTLER OROGENY

The Antler Orogeny refers to the folding and faulting of pre-Pennsylvanian rocks that is observed throughout northern Nevada and is generally considered to be Late Devonian and Mississippian in age. Although southern Nevada must have also been impacted by these orogenic events, research about how the orogeny effected the carbonate shelf are limited. It is likely that tectonic loading, changes to regional flow regimes, and increased siliceous sedimentation all occurred during the Antler orogeny. These changes must have impacted the structure of the shelf, influencing the rate and nature of deposition. Local and regional sea level changes due to the orogeny must have also impacted shelf sedimentation.



Graphic from Dickinson, 2006

DESCRIPTION OF ROCK UNITS

Monte Cristo Limestone

Five members comprise the Monte Cristo Limestone, from oldest to youngest:

Dawn Member:

Named by Hewett (1931) after exposures near the Dawn Mine in the Goodsprings Quadrangle, the Dawn member is the youngest rock unit of the Monte Cristo Limestone and represents the start of the carbonate platform (Poole and Sandberg, 1991). Evidence for this is the fact that the basal part of the Dawn commonly contains beds of cross-laminated arencaeous limestone (Bray, 1983). The Dawn ranges in thickness from about 15 m at Crystal Pass south of Goodsprings to over 50 m thick at Sloan. The Dawn is considered to be equivalent to the Whitmore Wash Member of the Redwall Limestone in the Grand Canyon area of Arizona and the Tin Mountain Limestone of Death Valley (Poole and Sandberg, 1991).

The Dawn is composed chiefly of medium dark-gray to medium light-gray limestone that is thin to very thickly bedded (Cehrs, 1975). The Dawn contains common corals but sparse conodonts, suggesting a shallow-water environment (Poole and Sandberg, 1976) .The Dawn Formation has been extensively dolomitized in the east. In the Sloan area, Deiss (1952) describes the Dawn unit as "approximately 175 feet thick (53 m) and consists of two lithologic units. The lower unit…consists of a medium to coarsely crystalline, thick-bedded dolomite that contains irregular solution cavities 1 to 10 mm and occasionally as much as 35 mm in diameter. The cavities are lined with white amorphous calcite. The upper unit consists of thinner-bedded (2 to 18 inches) medium crystalline dolomite, which in many places forms a small bench above the cliffs of the lower unit. The upper unit is so similar in composition to the dolomite in the overlying Anchor member that the contact of the Dawn and Anchor was arbitrarily drawn at the base of the lowest bed containing chert."

Anchor Member

The Anchor was named by Hewett (1931) after exposures at the Anchor Mine of the Goodsprings Quadrangle. The Anchor consists mainly of thinly bedded micrite with a large and diverse conodont fauna, suggesting deposition in a deepening environment (Poole and Sandberg, 1976). The outstanding feature of the Anchor Formation is the conspicuous chert nodule appearance throughout its thickness. The Dawn-Anchor contact appears gradational in all cases, with the first appearance of the cherts used to define this contact (Deiss, 1952). The Anchor varies in thickness from 30 m to over 120 m, averaging about 40 meters (Bray, 1983). The Anchor is considered to be equivalent to the Thunder Springs Member of the Redwall Limestone in the Grand Canyon area of Arizona.

Bullion Member

The Bullion Dolomite was named by Hewett (1931) for the cliff forming dolomite outcrops near the Bullion Mine of the Goodsprings Quadrangle. The Bullion is the most consistent lithologic unit within the area and is formed by one predominant rock type: a coarse-grained recrystallized obliterative dolomite (Cehrs, 1975). In the lower Bullion, numerous corals occur, which is interpreted to represent an upper-slope facies; thus the start of Bullion deposition represents a reversal of the deepening trend that occurred during Anchor deposition (Poole and Sandberg, 1976). Stevens et al. (1996) suggest that by middle Osagean, carbonate production exceeded any increase in accommodation space, initiating northwestward progradation of shallow-water carbonates.

At Sloan, the Bullion member is approximately 450 feet thick, and according to Deiss (1952) is "coarsely crystalline, thick-bedded, massive dolomite that contains many irregular solution cavities 1 to 5 millimeters in diameter. The dolomite is much jointed and weathers to angular tan-buff blocks. Chert is rare or absent expect in the basal 3 to 10 feet of the formation, where irregular nodules and masses of tan and gray chert are present."

Arrowhead Member

The Arrowhead was named by Hewett (1931) for a prospect in the Goodsprings Quadrangle. Although the Arrowhead in only 4 to 8 meters thick, it contains the most diverse biota of the Monte Cristo Limestone (Cehrs, 1975). In some locations, the Arrowhead is indistinguishable from the overlying Yellowpine Limestone and is grouped in with that unit. The Arrowhead has been interpreted as representing a slight deepening event that briefly interrupted the general late Osagean to late Chesterian shallowing of the southern part of the carbonate platform (Poole and Sandberg, 1991).

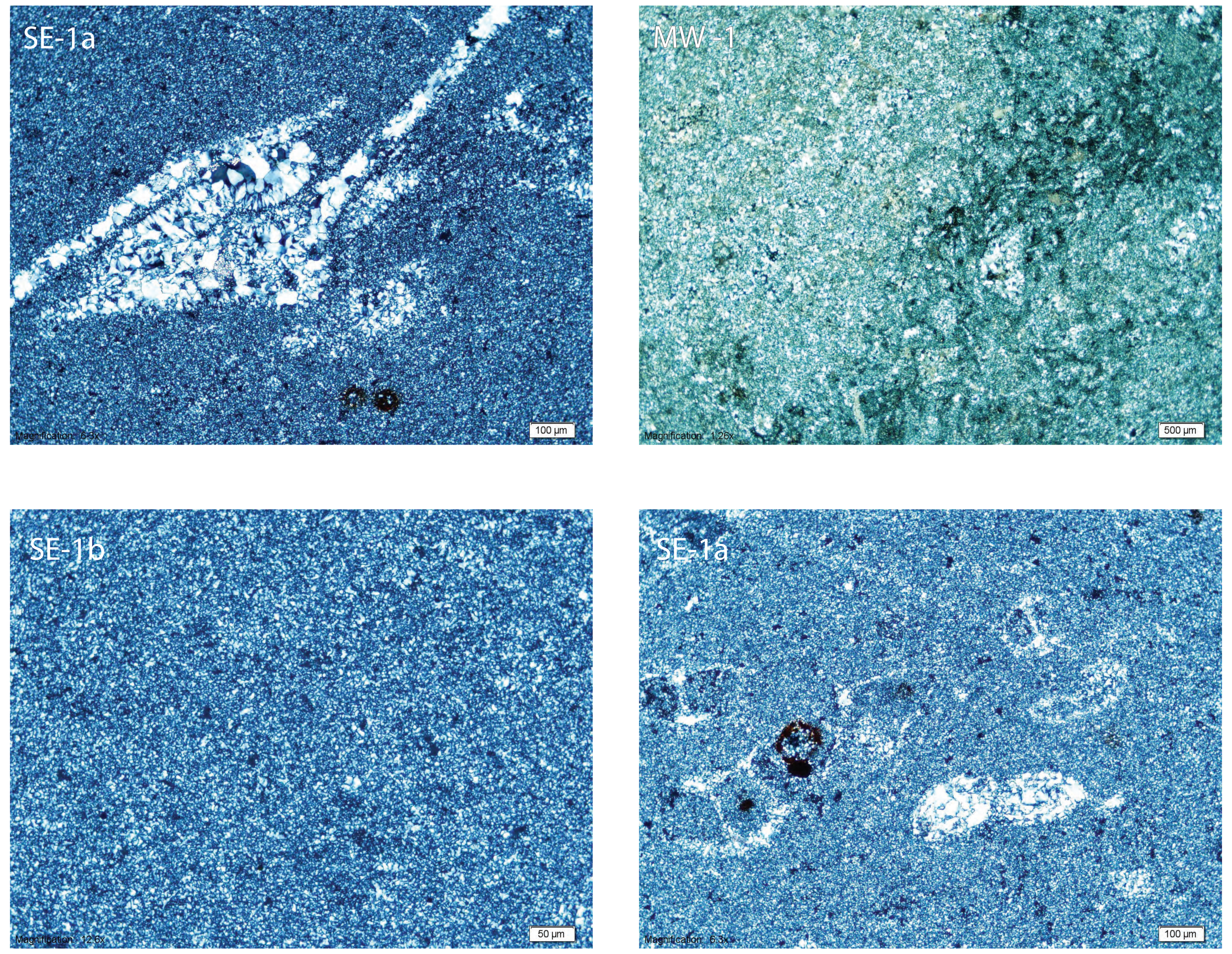
The Yellowpine Member

The Yellowpine limestone ranges in thickness from 20 to 35 meters. In the Sloan area, extensive dolomitization blurs to contact between the Bullion, the Arrowhead, and the Yellowpine units and they are usually mapped as a single unit, the Bullion (Deiss, 1952).

CHERT

Chert is a general term for a siliceous sedimentary rock of chemical, biochemical, or biogenic origin. It is an extremely dense or compact, semivitreous, cryptocrystalline, hard sedimentary rock with a splintery to conchoidal fracture. Although chert has been found throughout the geologic record, the nature of its formation and source of silica is still not well understood.
There are four silica minerals associated with chert: opal or opaline silica (amorphous $SiO_2\ nH_2O$); cristobalite (isotropic $SiO_2 + SiO_4$); chalcedony (microcrystalline SiO_2); and microquartz. "Impurities" in chert can include iron, magnesium, and aluminum among other elements, minerals and biologic debris. Seven different recurring silica fabrics have been recognized in cherts, including equigranular (microcrystalline quartz or microquartz and megaquartz) and fibrous types (chalcedony, quartzine or length-slow chalcedony, lutecite, zebraic chalcedony and microflamboyant quartz).

In the samples studied from the Monte Cristo Limestone, the majority of the cherts appear to be microqartz with minor megaquartz.



Thin section microscopy detailing chert textures. Clockwise from top left: brachiopod replaced by megaquartz in a chert (microquartz) matrix, Anchor member of Monte Cristo Limestone (MCL), Sloan, xpl; Chert showing both micro- and megaquartz habit, Anchor member MCL Mackay Wash, Arrow Canyon Range, xpl; Gastropod and brachiopod fragments in a microquartz matrix, Anchor member MCL, Sloan, xpl; Microcrystalline quartz (chert), Bullion member MCL, Sloan, xpl

Maliva and Siever (1989) suggest that circumstantial and direct evidence indicates that the silica in most Middle Paleozoic to Mesozoic platform and shelf nodular cherts originated as sponge spicules. Evidence from the Monte Cristo Limestone indicate that although sponge spicules have been identified, they are but a minor component of the biota. The dominate fauna are crinoids, gastropods, brachiopods and corals. The question is if sponges are not the source of silica for chert formation in the Monte Cristo Limestone, what is?

The presence of large volumes of chert, as beds, nodules, or lenses, within carbonate strata (particularly Mississippian carbonates) has been noted throughout the western, central, and southeastern portion of the United States (e.g., Osagian series). The source of this silicia is poorly understood, some possible sources include chemical weathering of silicates generated during orogenesis, sponge spicules, inputs of volcanic ash.

Chert occurrences in the Monte Cristo Limestone. Lenses (above) at Lone Mountain, Las Vegas; and nodules (below) from Mountain Spring Pass.

GEOCHEMISTRY - whole rock chemistry, averages

Sample	SiO_2(%)	TiO_2(%)	Al_2O_3(%)	Fe_2O_3T(%)	MnO(%)	MgO(%)	CaO(%)	Na_2O(%)	K_2O(%)	P_2O_5(%)	LOI(%)	Total(%)
Sloan Dolomite	3.98	0.004	0.118	0.123	0.027	15.7	29.0	0.102	0.023	0.051	46.2	95.3
Sloan Chert	90.6	0.004	0.179	1.32	0.011	0.652	1.10	0.132	0.021	0.006	1.45	95.4
Mtn. Pass Chert	92.5	0.009	0.246	0.295	0.004	1.19	3.08	0.078	0.044	0.067	3.41	101
Arrow Canyon Chert	94.6	0.006	0.284	1.64	0.017	0.163	0.307	0.227	0.038	0.023	0.296	97.6

DOLOMITIZATION AND CHERT

An interesting aspect of the Monte Cristo Limestone is the nature and extent of dolomitization in some areas. At Sloan, south of Las Vegas, the Monte Cristo Limestone has been completely dolomitized, obliterating many of the original depositional fabrics and textures. In other localities dolomitization has occurred, but appears to be hydrothermal in origin ("zebra" dolomite) and not nearly as pervasive. At Sloan, preservation of fossils occurs within the chert nodules of the Anchor Member. Currently, Barton Minerals is operating a quarry at Sloan, mining high grade dolomite for aggregate.

Recrystallization of dolomite has destroyed many of the sedimentary features within the Monte Cristo Limestone. In many of the studied sections, the only remaining features associated with original depositional environment are the fragments of lithified algal mats. In many instances, such fragments are recrystallized and their structures fully integrated into the uniform crystalline fabric of the rock, except for pink hematite staining and groups of voids which have been partially infilled with secondary euhedral dolomite, and in the Dawn member, by later blocky calcite.

It appears that at Sloan, an original dolomitization event occurred early, perhaps even as a penecontemporaneous replacement mineral in cryptocrystalline form, and a hydrothermal event, which was much more regional in nature, occurred much later.

Is there some connection between the early dolomitization of carbonate sediments and the formation of chert nodules? What water/climatic/tectonic conditions existed that led to the conversion of aragonite and calcite to dolomite and could those conditions favor early replacement by silica?

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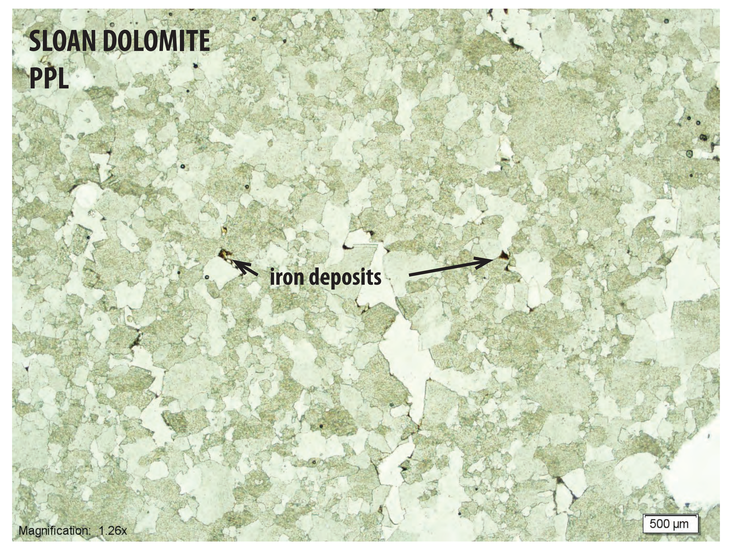

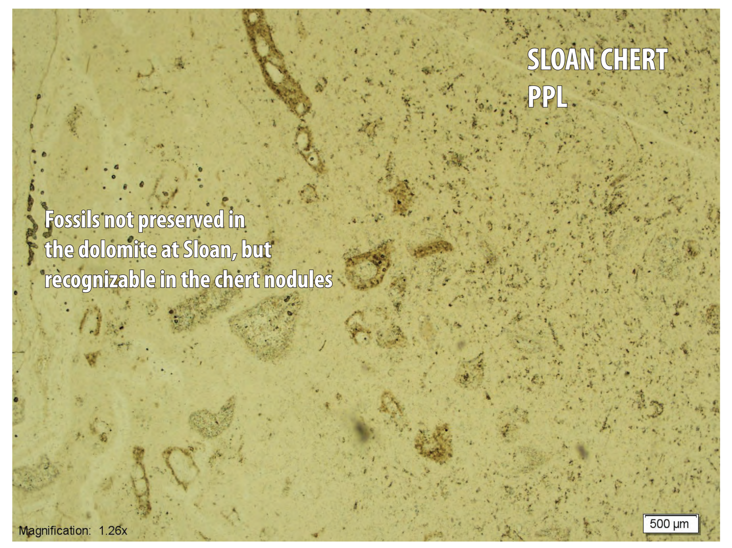

DISCUSSION

During the Mississippian, an extensive carbonate bank covered the western margin of the North American craton. In southern Nevada, deposition on the carbonate platform is represented by the Monte Cristo Limestone. Abundant biota has been preserved, including corals, bryozoan, crinoids, and conodonts, indicating deposition in shallow to moderately deep water. The shelf margin was located proximally just to the west of the Monte Cristo deposition. Correlations with other Mississippian units along the platform have been made by several workers (e.g., Langenheim et al., 1962, Rose, 1976;Poole and Sandberg, 1977; Stevens et al., 1995, 1996). During the Mississippian, the Antler arc collided with the western edge of the North American craton, leading to the development of a foreland basin to the north and west of the carbonate shelf. This collision has been well studied in central and northern Nevada, but the effects on the carbonate shelf are not well understood.

The appearance of large volumes of chert in carbonate sequences of Mississippian have been noted throughout the western Cordillera, but the source(s) of silica required for formation of chert has not been identified. Sources of silica include the dissolution and mobilization of sponge spicules, dewatering of basin sediments, input from terrigenous sources, eolian dust, and/or volcanogenic sediment. Mobilization of silica could result from regional fluid flow changes due to the encroaching Antler arc and stresses placed on the carbonate shelf.

Further geological analyses may be able to shed light on the possible sources of silica leading to the formation of cherts in the Mississippian Monte Cristo Formation and help to better understand the effects of orogenies on adjacent carbonate margins.

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