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UMI
PART I:
THE SOURCE OF COLOUR IN THE BONNETERRE DOLOSTONE, VIBURNUM TREND, SOUTHEAST MISSOURI

PART II:
A FLUID INCLUSION STUDY OF THE DRUSY QUARTZ OF THE POTOSI DOLOSTONE, SOUTHEAST MISSOURI

by

Brenda A. MacMurray

A thesis submitted in conformity with the requirements for the degree of Master of Science, Graduate Department of Geology, in the University of Toronto

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Abstract

This thesis is divided into two parts. In the first part the source of the brown colour of the Bonneterre Dolostone in Southeast Missouri was investigated because of its possible connection to the ore forming processes in the Viburnum Trend. The results were firmly inconclusive.

In the second part, fluid inclusions in the drusy quartz of the Potosi Formation, which lies stratigraphically above the Viburnum Trend, were examined in order to investigate a possible connection between deposition of the quartz and mineralizing fluids from the Viburnum Trend.

The Mississippi Valley-Type (MVT) ore forming fluids of the Viburnum Trend and the mineralizing fluids of the Barite District are lower temperature and much more saline than the fluids from the quartz inclusions of this study. Therefore, if this area is an exit path for spent MVT fluids migrating north from the Viburnum Trend, they did not precipitate the drusy quartz in the Potosi Formation.
Acknowledgements

I would like to thank Dr. Greg Anderson, my thesis advisor, for his encouragement, helpful insight and support. I would also like to thank my other thesis committee members, Drs. Grant Henderson and Ed Spooner, for their frequent and generous support. Many thanks to Dr. George Rossman for his absorbance spectral analysis. Special thanks to Dr. Colin Bray, without whom fluid inclusion work would not have been possible.

I would like to express my deepest appreciation for the love and support of my family and friends. My mother, in particular, was always available to share my feelings of discouragement and enthusiasm.
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PART I:
THE SOURCE OF COLOUR IN THE BONNETTERRE DOLOSTONE,
VIBURNUM TREND, SOUTHEAST MISSOURI
Introduction

The purpose of this study is to investigate the origin of the colour of the brown dolostone of the Bonneterre Formation of the Viburnum Trend, Southeast Missouri. The brown-coloured dolostone encompasses the ore deposits of the area (Fig. 1). The brown colour was believed to be caused by higher concentrations of organic material than the surrounding rocks (Anderson, personal communication, 1994) or by iron content within the dolostone (Sverjensky, 1980). The organics and/or iron content may be related to the permeability of the Bonneterre dolostone and therefore, to the deposition of the Pb-Zn ore within the Viburnum Trend. These possibilities are the focus of this study.

Figure 1. Outline of the lead mineralization areas (black), digitate algal reef (cross-hatched) and brown rock facies (lined) of Southeast Missouri (from Anderson, 1991).
The Cambrian Bonneterre dolostone is known to host the large Mississippi Valley-Type Pb-Zn deposits of Southeast Missouri. The mineralized area of the Viburnum Trend "lies near the southern edge of the central stable region of the North American craton" (Thacker and Anderson, 1977).

Geology

The Paleozoic sedimentary rocks in this region are mostly dolomitized limestones together with a basal sandstone and interbedded shale units. The basal sedimentary unit above the St. Francois Precambrian basement is the Cambrian Lamotte Sandstone (Fig. 2). The Bonneterre Formation, primarily dolomitized limestone, was deposited on the Lamotte Sandstone and occasionally pinches out against the Precambrian basement. The carbonates of the reef complex of the lower Bonneterre are mostly digitate stromatolites and reef-associated tan-coloured calcarenites.

The Bonneterre Formation, ranging from 250-325 feet thick in the Viburnum Trend, is divided into offshore, reef and backreef facies (Fig. 3). The backreef facies, comprised of burrowed carbonate muds and planar stromatolites, surrounds the main area of Precambrian knobs of the St. Francois Mountains and extends southward for a considerable distance (Hagni, 1986, after Howe, 1968). The forereef facies is grey or brown lime mudstone. Carbonates of the succeeding middle and upper Bonneterre Formation are those of a normal offshore shelf facies. Most of the major lead and lead-zinc ore deposits of the Southeast Missouri Lead District occur in the Bonneterre Formation. Valuable stratigraphic and petrographic studies of Bonneterre Formation and the region include Lyle (1977), Larsen...
The Davis Formation, which conformably overlies the Bonnerterre, is comprised of interbedded shales and carbonates (Fig. 2). It is believed to have played an important role in controlling paths of ore fluids, by forming an impermeable barrier to their upward and lateral migration, and thus preventing mineralization of younger stratigraphic units.
Figure 3. WNW-ESE section through the Viburnum Trend and the St. Francois Mountains showing the offshore, reef and backreef facies of the Bonnetere Formation (from Gregg and Shelton, 1989).

Structure

The most prominent faults in the lead district are northwesterly trending, and include the Ellington, Black, Simms Mountain, and Ste. Genevieve faults. Horrall et al. (1983) have suggested that fluid flow along these faults may have leached copper, cobalt, and nickel from some of the older mafic and ultramafic intrusions in the Reelfoot rift to provide a source for those metals in the Southeast Missouri ores. However, within the Viburnum Trend, the role of faults is controversial as faulting is relatively minor in the area.
Location of Ore

Ore deposits in the Old Lead Belt, Fredericktown, and Indian Creek subdistricts were primarily in the lower third of the Bonneterre Formation; those in the Viburnum Trend are in the middle third of the formation (e.g., Magmont Mine, Fig. 4). The Bonneterre limestones are largely dolomitized in the vicinity of ore deposits and throughout most of the backreef facies. The effect of the less permeable reef facies on regional fluid movement causes an abrupt change in the transmissivity of fluids (Leach and Sangster, 1993). As a result, there were opportunities for fluid mixing and sulphide precipitation. Gregg (1985) has shown that the basal few feet of the Bonneterre has been dolomitized over wide regions in Missouri by the passage of early fluid through the underlying Lamotte Sandstone. After deposition, the Bonneterre Formation was locally dolomitized and, in and near the reef complexes, was subjected to dissolution, brecciation, and mineralization (Graf, 1983). The Bonneterre Dolostone host rock has experienced some recrystallization and crystalline calcite and dolomite were deposited in open spaces. Most of the ore is found within the more permeable carbonate facies and brecciated zones fringing the reef (Leach and Sangster, 1993). Ore is found exclusively within the "brown rock" of the Bonneterre Dolostone. It is deposited as a replacement or as open space filling.

Genesis

There are many theories as to the source of the metal-bearing fluids, method of transportation, source of sulphur and cause of precipitation of the Viburnum Trend Pb-Zn ores. One such theory suggests that organic matter reduces $\text{SO}_4^{2-}$ in the ore fluids, causing the
Figure 4. Stratigraphic section of Magmont Mine, Southeast Missouri, showing location of the ore horizon (from Bradley and Krolak, 1989).
precipitation of sulphides. It was thought to be possible that the brown colour of the Bonneterre Dolostone is related to the former presence of organic material, as coatings on minerals or incorporated into the minerals themselves. The presence of organics in any of these forms could also have had an effect on permeability trends. Discussions of the genesis of Mississippi Valley-Type deposits and studies of fluid flow in the region of the Viburnum Trend include Leach and Sangster (1993), Anderson (1991), Viets and Leach (1990), Rowan and Leach (1989), Anderson and MacQueen (1988), Anderson and Garven (1987), Sverjensky (1986), Giordano and Barnes (1981), and Jackson and Beales (1967).

**Procedures**

Core samples of Bonneterre dolostone were collected from the Brushy Creek Mine area, underground and around the Casteel Mine (#35), and underground at the Magmont Mine. Sample locations and descriptions are listed in Table 1. All samples are very fine grained (2-300μm, average approximately 50μm). Most are believed to be from the offshore shelf facies or the forereef of the middle Bonneterre Formation. For comparison purposes, sample T1-2 from the Tsumeb area of Namibia was also used.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O1306-9</td>
<td>Brushy Creek Mine area - 976-977 ft.</td>
<td>Mineralized brown rock</td>
</tr>
<tr>
<td>O1306-10</td>
<td>Brushy Creek Mine area - 1055-1056 ft.</td>
<td>* &quot;Finger&quot; texture</td>
</tr>
<tr>
<td>O1284-44</td>
<td>Brushy Creek Mine area - 1144 ft.</td>
<td>White rock (zone 3, backreef facies)</td>
</tr>
<tr>
<td>Sample Code</td>
<td>Location</td>
<td>Description</td>
</tr>
<tr>
<td>-------------</td>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>C1449-b</td>
<td>Casteel Mine area - ~600 ft.</td>
<td>Mineralized bleached white dolostone</td>
</tr>
<tr>
<td>C1449-nb</td>
<td>Casteel Mine area - ~600 ft.</td>
<td>Mineralized brown rock</td>
</tr>
<tr>
<td>G27</td>
<td>Casteel Mine underground</td>
<td>Dark brown grainstone with trace mineralization</td>
</tr>
<tr>
<td>M172-8</td>
<td>Magmont Mine u/g - 1274 ft. level; 880-882 ft.</td>
<td>Unmineralized grey rock from between Davis Shale and False Davis</td>
</tr>
<tr>
<td>M172-9</td>
<td>Magmont Mine u/g - 1274 ft. level; 956-976 ft.</td>
<td>Mineralized brown rock</td>
</tr>
<tr>
<td>M172-10</td>
<td>Magmont Mine u/g - 1274 ft. level; 1022-1024 ft.</td>
<td>Weakly mineralized brown rock</td>
</tr>
<tr>
<td>T1-2</td>
<td>Tsumeb area of Namibia</td>
<td>Very dark brown dolostone containing patchy coarse white calcite</td>
</tr>
</tbody>
</table>

**Table 1.** Sample locations and descriptions.
* * Describes a pattern of darker dolostone "fingers" within lighter dolostone.

Several techniques were employed in the examination of these dolostones:

1. X-ray diffraction patterns were used to confirm the identification and content of the samples.

2. A scanning electron microscope (SEM) equipped with an energy dispersive X-ray (EDX) analyser with a windowless detector was used in an attempt to characterize the location of the organics and/or iron within each specimen.

3. Microprobe analysis was used to assess whether levels of iron oxide within the dolostone could be the cause of the brown colour. Analyses of brown and non-brown samples were compared.

4. To evaluate whether the organic content of the Bonneterre dolostone was the origin of the
brown colour, total organic carbon analysis was performed. Analysis was performed by X-Ray Assay Laboratories (XRAL) using a technique called Coulom.

5. XRAL also conducted a geochemical analysis covering 32 elements using ICP. The results of this study were examined to determine if there were any anomalous concentrations of particular elements.

6. Samples were sent to Dr. George Rossman at California Institute of Technology for analysis of the absorbance spectra of individual dolomite crystals. This method was used to determine the degree of uniformity of the brown colour within the crystals and to evaluate a possible source for the colour.

Results

1. As stated earlier, X-ray diffraction patterns confirmed the identification and content of the samples.

2. Data collection by the EDX analyser on the SEM proved ineffective for the purpose of this study.

3. Mass spectrometer data collected on the microprobe revealed slight differences in the iron content of the brown and non-brown dolostones. Analyses were performed on light and dark spots within the brown and non-brown samples. The numbers were collected and averaged and the brown dolostones were shown to contain slightly more iron (higher FeO content) than the non-brown samples (Table 2).

4. Total organic carbon analysis indicated a slightly higher organic content in the non-brown dolostone than in the brown samples (Table 3). Statistical analysis using the F-test for both
the microprobe data and the total organic carbon analysis showed that the differences in the variances between the brown and non-brown sample groups was too great to be able to use the t-test to effectively compare the means.

<table>
<thead>
<tr>
<th>BROWN</th>
<th>NON-BROWN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample</td>
<td>FeO Content</td>
</tr>
<tr>
<td>C27</td>
<td>0.350</td>
</tr>
<tr>
<td>0.349</td>
<td>0.153</td>
</tr>
<tr>
<td>1.162</td>
<td>0.157</td>
</tr>
<tr>
<td>0.498</td>
<td>0.092</td>
</tr>
<tr>
<td>0.921</td>
<td>0.228</td>
</tr>
<tr>
<td>0.506</td>
<td>0.175</td>
</tr>
<tr>
<td>0.707</td>
<td>0.253</td>
</tr>
<tr>
<td>0.857</td>
<td>0.459</td>
</tr>
<tr>
<td>0.415</td>
<td>0.405</td>
</tr>
<tr>
<td>1.280</td>
<td>0.298</td>
</tr>
<tr>
<td>0.419</td>
<td>0.168</td>
</tr>
<tr>
<td>C1449-10</td>
<td>0.104</td>
</tr>
<tr>
<td>0.078</td>
<td>0.952</td>
</tr>
<tr>
<td>0.325</td>
<td>1.488</td>
</tr>
<tr>
<td>0.407</td>
<td>1.128</td>
</tr>
<tr>
<td>0.241</td>
<td>0.882</td>
</tr>
<tr>
<td>0.309</td>
<td>0.152</td>
</tr>
<tr>
<td>0.202</td>
<td>0.152</td>
</tr>
<tr>
<td>M172-910</td>
<td>1.254</td>
</tr>
<tr>
<td>0.565</td>
<td>0.533</td>
</tr>
<tr>
<td>1.712</td>
<td>1.459</td>
</tr>
<tr>
<td>2.019</td>
<td>2.363</td>
</tr>
<tr>
<td>0.718</td>
<td>1.741</td>
</tr>
<tr>
<td>O1306-3</td>
<td>2.299</td>
</tr>
<tr>
<td>2.574</td>
<td>2.282</td>
</tr>
<tr>
<td>2.107</td>
<td>2.771</td>
</tr>
<tr>
<td>0.929</td>
<td>0.118</td>
</tr>
<tr>
<td>0.028</td>
<td>0.024</td>
</tr>
<tr>
<td>0.453</td>
<td>0.080</td>
</tr>
<tr>
<td>0.172</td>
<td>0.008</td>
</tr>
<tr>
<td>0.008</td>
<td>0.006</td>
</tr>
<tr>
<td>Average</td>
<td>0.850</td>
</tr>
</tbody>
</table>

Table 2. Mass spectrometer data collected from the microprobe: FeO content of brown and non-brown dolostone samples. The F-test shows that the variances between the two groups was too great to be able to use the t-test to compare the means.

5. Geochemical analysis revealed some dissimilarities between brown and non-brown samples of the Bonneterre dolostone (Fig. 5). It was uncertain whether there was one
particular element that was the cause of the differences in colour.

6. Data collected on the absorbance spectra of the brown and non-brown Bonneterre dolostone was inconclusive. Spectra for each sample were particularly flat and unremarkable (eg. G27, Fig. 6). Analyses were run several times and the equipment was cleaned and tuned to ensure accuracy but the results remained anomalously flat (Rossman, 1996, personal communication) (Appendix 1). Spectra for brown minerals should show a high level of absorbance across the entire spectrum with significantly less absorbance in the red end of the spectrum (700 nm region) (Rossman, 1998, personal communication).

<table>
<thead>
<tr>
<th>NON-BROWN</th>
<th>BROWN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample</td>
<td>% Organic Carbon</td>
</tr>
<tr>
<td>M172-8</td>
<td>0.14</td>
</tr>
<tr>
<td>1284-44</td>
<td>0.17</td>
</tr>
<tr>
<td>O1306-10</td>
<td>0.12</td>
</tr>
<tr>
<td>C1449-b</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Table 3. Total organic carbon analysis results showing a slightly higher organic carbon content in the non-brown samples than the brown dolostone samples.

Conclusions

The data were inconclusive. It was difficult to determine the source of the brown colour of the ore-hosting Bonneterre dolostone. The brown rock showed slightly higher levels of FeO and lower organic content than the non-brown dolostone. Dissimilarities were also noted in the geochemical analysis of brown and non-brown dolostones but it is uncertain
which element or whether there was one particular element that may have caused the difference in colour.

Figure 5. Geochemical (ICP) analysis results showing differences between non-brown (O1284-44), brown (G27), and organic-rich (T1-2) dolostone samples. Results are indicated in ppm of the specified element except for Na, Mg, Al, Si, P, K, Ca, Ti, Mn, Fe which are expressed as a percentage.
Figure 6. Absorbance spectrum for brown rock sample G27.
References


Appendix I-1: Graphic results of Absorbance Spectra

M172-9
Mineralized Brown Rock

M172-8
Gray Rock
Wavelength, nm

O1306-9
Rock

Absorbance

Wavelength, nm

O1306-10
"Fingered"

Absorbance

Wavelength, nm
PART II:
A FLUID INCLUSION STUDY OF THE DRUSY QUARTZ OF THE POTOSI
DOLOSTONE, SOUTHEAST MISSOURI
Introduction

The purpose of this part of the thesis is to investigate a possible relationship between the Lead-Zinc ores of the Viburnum Trend and the drusy quartz of the Potosi Dolostone. The area of Potosi Dolostone where samples were taken is located north and northeast of the mines of the Viburnum Trend within the area of the Southeast Missouri Barite District. Geological and geochemical evidence suggests that metal-bearing brines were expelled northward from the Ouachita orogen in late Paleozoic time (Horrall, 1995; Leach et al., 1991; Kaiser et al., 1987, after Leach et al., 1984; Farr, 1986; Leach and Rowan, 1986). A widespread fluid inclusion study of inclusions in sulphides and late dolomite cement by Leach et al. (1991) reveals that a thermal gradient of decreasing temperatures may have existed from south to north across the Ozark region in late Paleozoic time. It is uncertain where the large volume of MVT fluids went following mineralization of the Viburnum Trend. The possibility that these fluids may have exited through the Southeast Missouri Barite District is the focus of this study. After depositing sulphides within the Viburnum Trend it is possible that the fluids moved up-section through either the white rock facies to the east or the major fault systems to the north. If the fluids moved up the fault systems, they may have precipitated the drusy quartz in vugs within the Upper Cambrian Potosi Dolostone. In this thesis, fluid inclusions within the drusy quartz of the Potosi Dolostone were examined to determine a possible relationship to the Mississippi Valley-Type ore fluids of the Viburnum Trend.
Geology

The study area is within the Southeast Missouri Barite District in Washington County. The area is located within a large structural block bounded on three sides by major fault systems (Kaiser et al., 1987). These include the Palmer, Shirley, Big River and Vineland Fault Systems (Figure 1).

Figure 1. Structural features of the area around the Washington County barite district (modified from Wagner, 1973).
The Potosi Dolostone is a brown, medium to fine grained dolostone of Upper Cambrian age (Figure 2). In his 1973 PhD thesis, Wagner describes three primary textural lithologies. These include the more abundant calcarenites and algal stromatolitic biostromes and less common carbonate muds. Dolomitization of these lithologies occurred before the introduction of the silica-bearing fluids which formed chalcedony and drusy quartz.
mainly in vugs or fractures. The drusy quartz is found most commonly in the digitate algal stromatolitic beds, particularly on the outer edge of the algal columns. This frequently results as a texture of hollow tubes of quartz crystals known as "honeycomb" or "pipe" druse (Wagner, 1973) (Plate 1). According to Dake (1930), a conglomerate with waterworn and rounded fragments of apparent Potosi drusy quartz exists at the base of the Lower Ordovician Gasconade Formation. If this rounded quartz really is from the Potosi Formation, the introduction of silica-bearing fluids into the Potosi Dolostone was earlier than the Lower Ordovician (pre-Gasconade). Despite this observation, it was considered worthwhile to investigate the fluids in the Potosi drusy quartz, with the possibility of further investigating the reported conglomerate fragments in the future.

The Mississippi Valley Type Lead-Zinc mineralization of Southeast Missouri has been dated by several different techniques. In 1995, Hay et al. concluded that the maximum age of the ore event was 297±7 Ma using K-Ar dating of K-feldspar from clay pods which were thought to be associated with mineralizing fluids. Paleomagnetic dating studies determined that the age of mineralization was 286±20 Ma (Symons, 1995, after Wisniowiecki et al., 1983). Regional geochemical, isotopic and paragenetic studies link the mineralization of Southeast Missouri to other districts where mineralization occurs in mid-Pennsylvanian (late Cretaceous) rocks (Symons et al., 1997, after Leach and Rowan, 1986, Leach, 1994 and Goldhaber et al., 1995). These studies all agree that the MVT mineralization of Southeast Missouri occurred around late Cretaceous to early Permian time.
Plate 1. Sample of Potosi Dolostone displaying the "honeycomb" or "pipe druse" texture.
Procedures

Samples of Potosi Dolostone were collected from across Washington County. Sample locations were chosen to obtain a representative cross section of the Southeast Missouri Barite District (Figure 3). Fluid inclusion sections (0.2 to 0.5 mm thick) of Potosi Dolostone containing drusy quartz were cut and polished on both sides (Plate 2). The sections were then examined under a transmitted light microscope to locate inclusions. A rough map of the inclusion locations was made. The sections were then soaked in methyl alcohol for approximately 1.5 to 2 days to remove the section from the glass slide. The sample was carefully broken into small chips, approximately 3-7 mm in size, and placed in the fluid inclusion stage. A sketch was drawn of the field of view containing the inclusions to be analysed (Figure 4). The temperature was reduced to between -95 and -100°C or until the fluid in the inclusions froze. The temperature was increased by 25°/minute until approximately 10° below the expected temperature of melting. The temperature was increased by 5°/minute until approximately 2° below the expected temperature of melting. Then the rate of temperature increase was reduced to 0.5°/minute until the fluid melted. The melting temperature was recorded and the procedure was repeated twice. If the melting temperatures did not vary by more than 0.5°C, the average of the three trials was recorded as the melting temperature \( T_m \) of the inclusion. Melting temperature results collected were used to calculate salinities expressed as equivalent weight % NaCl (MacFlinCor: Brown and Hagemann, 1994) (Figure 5).

The chips were then heated to determine the homogenization temperature \( T_h \). Homogenization temperature results indicate the temperature of fluids that passed through...
Figure 3. Map of the study area, Southeast Missouri, showing sample locations.
LEGEND

- Mine shaft
- Sample location

T[p] Homogenization temperature of a primary inclusion (°C)
Sal[p] Salinity of a primary inclusion (equivalent weight % NaCl)

T[s] Homogenization temperature of a secondary inclusion
Sal[s] Salinity of a secondary inclusion (equivalent weight % NaCl)
SAMPLE AND LOCATION MAP
SE Missouri Barite District
North of Viburnum Trend
Drawn: September, 1996 / February, 1998

LEGEND
- Mine shaft
- Sample location
T(p) = Homogenization temperature of a primary inclusion (degrees Celsius)
Sali(p) = Salinity of a primary inclusion (equivalent weight % NaCl)
T(s) = Homogenization temperature of a secondary inclusion (degrees Celsius)
Sali(s) = Salinity of a secondary inclusion (equivalent weight % NaCl)
**Plate 2.** Section of Potosi Dolostone (each marked interval = 1 mm).
Figure 4. A sketch of the field of view containing the fluid inclusions to be analysed (32X).

Figure 5. An example of the input screen for the MacFlinCor program (Brown and Hagemann, 1994).

the Potosi Dolostone and had contact with the drusy quartz during the time of crystallization or after their deposition. The temperature was increased by 25°/minute until the gas bubble
appeared to be much smaller. The temperature was increased by $5^\circ$/minute until the gas bubble was seen to bounce quickly around the inclusion. Then the rate of temperature increase was reduced to $0.5^\circ$/minute until the gas bubble disappeared. The temperature was reduced until the bubble reappeared and the procedure repeated twice. If the homogenization temperatures did not vary by more than $0.5^\circ$C, the average of the three trials was recorded as the homogenization temperature ($T_h$) of the inclusion.

Primary and secondary inclusion data were collected and used for this study because of the uncertainty of the relative timing of quartz mineralization and possible passage of ore fluids.

**Results**

The drusy quartz crystals of the Potosi Dolostone are remarkably clean and mostly free of inclusions (Plate 3). Fluid inclusions within the drusy quartz are very small. The average size of the inclusions analysed was $5\mu$m by $3\mu$m. The inclusions were subrounded to cigar-shaped with occasional subangular triangle-shaped inclusions (Figure 4 or Plate 3). The vapour bubble appeared to occupy up to 30% of the inclusion (average approximately 15%). There were, on average, only 4-5 inclusions found per sample that were large enough to obtain melting and homogenization temperatures. Of these 4-5 inclusions, only 2 or 3 provided useful data (i.e. did not leak).

Melting temperatures ($T_m$) ranged from $-0.5^\circ$C to $-7.7^\circ$C with an average of $-3.15^\circ$C. The salinity values calculated from the melting temperatures ranged from 0.827 to 11.343 equivalent weight % NaCl. Homogenization temperatures ($T_h$) ranged from 159 to 281°C.
Plate 3. Fluid inclusion in drusy quartz of Potosi Dolostone (40X).
The geographic distribution of temperature of homogenization and salinity of primary and secondary fluid inclusions was plotted in three-dimensions with projections on North-South and East-West planes. There did not appear to be any pattern to the geographic distribution for either the temperature of homogenization or salinity (Figures 6 and 7).

The fluids found in the quartz inclusions from the Potosi Dolostone are very different from fluids from the Viburnum Trend and the Southeast Missouri Barite District. The temperatures of homogenization for Viburnum Trend fluids range from approximately 80 to 150°C (Leach et al., 1991, after Leach and Rowan, 1986 and Rowan and Leach, 1990; Viets and Leach, 1990; Sverjensky, 1986; Hagni, 1983; Roedder, 1977). Leach et al. (1991) indicated that salinities of Viburnum Trend fluids are greater than 15 and frequently greater than 20 equivalent weight % NaCl (very saline). The MVT ore forming fluids of the Viburnum Trend are lower temperature and much more saline than the fluids from the Potosi quartz inclusions (Figure 8).

Fluid inclusion data of the barite district suggests that the mineralizing solutions were saline brines with temperatures ranging from approximately 70 to 110°C and with salinities of 20 to 25 equivalent weight % NaCl (Kaiser et al., 1987; Leach, 1979). These fluids are also much more saline and lower temperature than those of the Potosi Formation drusy quartz (Figure 8).

Henry (1988) used a stratigraphic reconstruction to estimate the maximum burial of the Bonneterre Dolostone from the Viburnum Trend. It was determined that the maximum possible burial of the Bonneterre Formation was approximately 1100m and that evidence of anomalous organic maturities, temperatures from fluid inclusions and fission track annealing
Figure 6. Geographic distribution of the temperature of homogenization of primary and secondary fluid inclusions in 3-dimensions with projection on the N-S and E-W planes.
Figure 7. Geographic distribution of the salinity of primary and secondary fluid inclusions in 3-dimensions with projection on the N-S and E-W planes.
studies suggest a period of higher geothermal gradient in the Ozark region (approximately 100°C/km) (Henry, 1988). Even with this higher geothermal gradient in the region, the temperature of the Bonneterre Formation would not have exceeded 125°C at maximum burial. The maximum temperature of the Potosi Dolostone would not have exceeded that of the Bonneterre and would be less than 125°C. The fluid inclusion data from this study demonstrate that the silica-bearing fluids that deposited the drusy quartz were higher temperature (159 to 281°C) than the Potosi Dolostone host rock ever reached by burial.
Conclusions

The fluids found in quartz inclusions within the Potosi Dolostone are very different from the ore fluids of the Viburnum Trend and the fluids of the Southeast Missouri Barite District. The Mississippi Valley-Type ore forming fluids of the Viburnum Trend and the mineralizing fluids of the Barite District are lower temperature and much more saline than the fluids from the quartz inclusions of this study. Therefore, the fluids from the Potosi Formation drusy quartz are not similar to the Mississippi Valley-Type fluids from the Viburnum Trend. If this area was an exit path for spent MVT ore fluids migrating north from the Viburnum Trend, they did not precipitate the drusy quartz in the Potosi Formation.

This study raises several questions requiring further investigation. Some research into the nature of the (possible) Potosi pebbles within the conglomerate at the base of the Gasconade Formation is required. Does this conglomerate determine that the age of the drusy quartz is Upper Cambrian to Lower Ordovician? The fluid inclusions from the drusy quartz have a temperature range of 160 to 280°C, with relatively low salinities. If these fluids really are Upper Cambrian to Lower Ordovician in age, it raises the question of the origin of such hot fluids so early in the stratigraphic history of the area.
References


Horrell, K.B., 1995, Evidence for focusing of Mississippi Valley-type ore fluids along the Bloomfield Lineament Zone, southeast Missouri: Extended Abstracts, International


Symons, D.T.A., 1995, Summary of the paleomagnetic dating studies of Mississippi Valley-type deposits: Extended Abstracts, International Field Conference on Carbonate-


Appendix II-1: Table of Fluid Inclusion Data - Homogenization and Melting Temperatures

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<th>Inclusion Number</th>
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<th>Secondary - $T_h$</th>
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