HYDROTHERMAL TRIPOLI DEPOSITS IN SOUTHERNMOST ILLINOIS

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ABSTRACT

Commercial tripoli (microcrystalline silica) deposits occur in southernmost Illinois in silicified Paleozoic sedimentary rocks. Two distinct districts, Elco and Wolf Lake, are surrounded by unaltered rock - mostly fine-grained, siliceous and cherty limestone that contains both detrital and biogenic silica.

Geologists previously interpreted southern Illinois tripoli as the product of prolonged weathering beneath a Tertiary peneplain. We propose instead that these deposits are of hydrothermal origin. Evidence includes localization of the deposits in two discrete districts, with jasperoid formed and carbonates removed. Fluid inclusions from the district are two-phase and have elevated (200°C) homogenization temperatures. Quartz veinlets and quartz-cemented breccia occur in both districts, particularly along faults. Silicified rocks are crisscrossed by three intersecting sets of closely-spaced faults that have been recurrently active. The presence of anomalously high metal content in cuttings from a deep well near the Elco district further suggests hydrothermal activity.

The Elco and Wolf Lake districts both overlie coincident gravity and magnetic highs inferred to represent plutons that provided heat for convective flow of groundwater. The districts are in line with several Late Cretaceous-Early Paleocene mafic

plutons along the northwest margin of the Reelfoot rift/Mississippi embayment. Evidently groundwater, perhaps mixed with magmatic fluids, was heated and circulated through fractures in the rocks, removing carbonate minerals and remobilizing silica.

INTRODUCTION

Paleozoic bedrock is extensively silicified in parts of Union and Alexander Counties, southernmost Illinois (fig. 1). Tripoli (white, friable microcrystalline silica) from this district is mined for use as fillers and extenders in products such as paint, plastic, rubber, adhesives, and sealants; and in buffing and polishing compounds. Other siliceous rocks, called novaculite, chert gravel, ganister, and calico rock, also have been mined for various purposes.

Geologists previously interpreted southern Illinois silica as the product of deep weathering during the Tertiary Period (Weller and Ekblaw 1940, Weller 1944, Lamar 1953). New geologic mapping (Berg and Masters 1994, Nelson and others in preparation) indicates this theory is untenable, although weathering may have residually enriched the silica deposits.

Geologic Setting

The southern Illinois tripoli district lies along the east margin of the Ozark dome, between the Illinois basin on the northeast and the Mississippi embayment on the southeast (fig. 1). Ordovician through Mississippian limestone with lesser shale, siltstone, and sandstone comprise the bedrock (fig. 2). Cretaceous and early Tertiary sediments, largely unlithified, occur in the Mississippi embayment and as erosional and downfaulted outliers on Paleozoic uplands.

Silicified rocks occur in two districts (fig. 1). The Elco district is by far the larger and is the scene of all current silica mining. Mining formerly took place also in the small Wolf Lake district (Berg and Masters 1994). Outcropping rocks that are silicified range from the Bailey Limestone (Silurian-Devonian) through the Ullin Limestone (Mississippian) and, locally, Upper Cretaceous gravel. Whether rocks below the Bailey are silicified is not known because no wells in the Elco or Wolf Lake districts penetrate that deeply.

Varieties of Silica

Tripoli is the name used for white, porous, highly friable microcrystalline silica from southern Illinois. More than 200 tripoli mines have operated in southern Illinois since the early 1900s. In the past most mines were single-entry, drift or slope, room-and-pillar underground operations; many of which were worked only briefly and with small production (Berg and Masters 1994).

Presently Unimin Specialty Minerals, Inc. operates one open-pit mine and one underground room-and-pillar mine in the Elco district and maintains processing plants at Elco and Tamms.

Minable bodies of tripoli are generally 2.5 to 12 m thick, conformable to bedding, and discontinuous. Tripoli is interbedded with and grades laterally to bedded chert. Most tripoli mines are in the Clear Creek Formation (Lower Devonian); a few formerly operated in the older Grassy Knob Chert and Bailey Limestone (Table 1).

Bedded chert comprises the bulk of the Clear Creek, Grassy Knob and Bailey Formations within the Elco and Wolf Lake districts (Table 1). The chert is mostly white to gray, but near the surface it is commonly stained red or orange by iron oxides. Dense, massive bedded chert in southern Illinois is sometimes called novaculite. Some chert is hard and vitreous, and some is soft and friable, grading to tripoli. Interbedded chert and tripoli from the Clear Creek Formation is being quarried for use in manufacturing Portland cement.

Other varieties of silica in southern Illinois include ganister and calico rock. Ganister has coarsely granular texture and is derived from the Mississippian Fort Payne Formation (Table 1); it formerly was mined for making refractory bricks. Calico rock is hard, slabby, dense silica rock of varied hue, derived from the Springville Shale (Mississippian) and locally used as a construction material.

Parent Materials

Most silicified rocks in southernmost Illinois originally were siliceous, cherty limestones (Fig. 2 and Table 1). These rocks can be seen in their unaltered state in outcrops and well samples outside the Elco and Wolf Lake districts.

Tripoli was derived from highly siliceous, cherty carbonate rocks and bedded chert of the Bailey, Grassy Knob and Clear Creek Formations (Silurian and Lower Devonian). Unaltered Bailey Limestone is dolomitic lime mudstone that contain abundant biogenic silica in the form of sponge spicules and radiolaria, along with abundant silt-sized detrital quartz. The overlying Grassy Knob Chert is composed of primary bedded chert intercalated with siliceous limestone and dolomite. The Backbone Limestone (fig. 2) is a pure crinoidal grainstone outside the tripoli district. It is absent in the tripoli district as a result of either nondeposition or dissolution. The Clear Creek Formation is similar in lithology to the Bailey.

Moving up-section, the Grand Tower Limestone (Middle Devonian) is a relatively pure limestone having a basal calcareous sandstone, the Dutch Creek Member. In the tripoli district the Dutch Creek is leached and brecciated, and the remainder of the Grand Tower disolved away, leaving a residual deposit of clay, silt, sand, and chert nodules. The St. Laurent Formation where unaltered consists of argillaceous to silty, cherty limestone and dolomite interbedded with calcareous shale and siltstone. These rocks are altered in the tripoli district to dark, porous, tripolitic, slabby siliceous rock interlayered with chert.

The Springville Shale (Mississippian) is slightly calcareous silty mudstone and siltstone that alters to calico rock. The Fort Payne Formation is siliceous, cherty micritic to fine-grained carbonate rock that alters to ganister. The overlying Ullin Limestone, a fairly pure bryozoan-crinoid limestone, is dissolved away in the same fashion as the Grand Tower.

Erosional remnants of Upper Cretaceous conglomerate that cap hills in the Elco district are locally cemented with silica.

The boundaries of the Wolf Lake and Elco tripoli districts are gradational. Along the margins of the districts, certain layers of the Clear Creek Formation were selectively silicified. Calcareous tripoli and siliceous limestone are intricately intergrown. Commonly, fossils and burrow-fillings are still calcite, whereas the groundmass is altered to tripoli.

In brief, carbonate minerals were dissolved from bedrock in the Elco and Wolf Lake districts, accompanied by deposition of silica that was remobilized from detrital and biogenic quartz in thwese rocks.

Structure

Mapping reveals pervasive small-scale faulting throughout the Elco and Wolf Lake silica districts, in contrast to surrounding areas of unaltered rock, which contain few faults and fractures. Evidently faulting was an important control on silicification.

Previous geologists observed faults in the districts, but had difficulty mapping them for several reasons. Loess cover, dense vegetation, thick residual chert, rugged topography, scarcity of marker beds, lithologic similarity of altered formations, and complex structure all hamper mapping in the area. Thus, Savage (1920), J. Weller and Ekblaw (1940), and Nelson and Lumm (1985) mapped only a few large structures such as the Ste. Genevieve fault zone, Delta and Atwood faults, and Harrison Creek anticline (fig. 1). J. Weller (1944) and Lamar (1953) described but did not map widespread small-scale faulting in the silica districts. They attributed the small faults to settling and collapse during silicification rather than to tectonic activity.

Even our new maps (Devera 1993, Devera and Nelson in preparation, Nelson and others in preparation) show only a small fraction of the faults we saw in the tripoli districts. Many fault undoubtedly are concealed by surficial materials. The large majority of exposed faults have displacements of a few meters and cannot be traced along strike. Such faults are too small to show on fig. 1 or on 1:24,000-scale maps. Virtually every bedrock exposure longer than 10 m shows faults. All large exposures in the tripoli district, such as quarries and mines, reveal two or three intersecting sets of faults. No other area of comparable extent in southern Illinois has such a density of faults.

Faults in the Elco and Wolf Lake districts are not randomly oriented, as would be expected for solution-collapse structures: they occur in several distinct systems. One system consists of high-angle normal faults that strike NNW. The Atwood and Delta faults are the largest examples (fig. 1). The NNW- trending faults have planar surfaces that dip 60° to 80° and bear vertical striations and mullion. Attitudes of drag folds and fault slices also indicate dip-slip movement. Some of these faults have narrow breccia zones mineralized with silica and iron and manganese oxides. The youngest rocks known to be offset are Middle Devonian.

Another system consists of faults that strike due north. This system includes the Iron Mountain fault, the Cape Road fault, and many smaller faults in the northern part of the Elco district. These faults splay off the southern end of the Ste. Genevieve Fault Zone at the southeast corner of the Wolf Lake district. North-trending faults are planar to gently sinuous and dip at 60° to 90°. They commonly outline horsts and grabens and displace strata as young as Eocene. Horsts are bounded by high-angle reverse faults that diverge upward; they appear to be positive flower structures caused by wrench faulting. Grabens contain megabreccias composed of sharply angular clasts and blocks up to several meters across of younger, downdropped rocks. A megabreccia zone along the Cape Road fault is nearly 1/2 km wide. Similar breccia-filled grabens in the Thebes Gap area are interpreted as pull-apart structures produced by divergent strike-slip faulting (Harrison and Schultz 1994). An en echelon fracture pattern along the Cape Road fault suggests left-lateral wrenching.

Faults that strike N30-45°E are common in the southern part of the Elco district. They are linear and dip vertically or nearly so. Vertical offsets are small and change direction along strike, indicating strike-slip movement. Some northeast-striking zones are marked by intensely silicified breccia zones. In the Thebes Gap area immediately southwest of the Elco district, Harrison and Schultz (1994) mapped many northeast-striking right-lateral faults that displace units as young as the Mounds Gravel (Pliocene to early Pleistocene). Northeast-striking faults in the Elco district appear to be part of the same system.

Several small faults that strike N40-60°W were observed in the Elco district. Slickensides, mullion, pinnate fracture sets, and positive flower structures indicate left-lateral strike-slip or oblique-slip on these structures. Many faults in the Wolf Lake district strike northwest; slip directions cannot be determined for most.

Small east-west faults are scattered throughout the Elco district. Most are high-angle reverse faults that are accompanied by kink folds and small monoclinal drape folds.

Joints are abundant throughout both tripoli districts; many outcrops exhibit two to four sets. The preferred trends of jointing are N-S (abundant), NNE (locally common), E-W (widely spaced throughout district) and WNW (scattered examples).

Linear fault planes, consistent trends, and particularly the abundant evidence for strike-slip displacement indicate that these faults are tectonic structures. Multiple episodes of tectonism have taken place in southern Illinois since Devonian time (S. Weller and St. Clair 1928, Nelson and Lumm 1985, Clendenin et al. 1989, Schultz and Harrison 1992, Harrison and Schultz 1994). Each episode further fractured the rocks, creating pathways for hydrothermal fluids.

Solution-collapse structures do exist in the tripoli district. They include small random folds, minor zigzag offsets, and fissures and cavities filled with laminated clay and silt. Small size, random trend and lack of continuity distinguish solution-collapse structures from tectonic ones. Removal of carbonate thinned the section, as shown by near-total dissolution of the Grand Tower Limestone in the Elco district. No data are available on the degree of thinning by solution for other formations.

Intensive fracturing was a necessary, but not sufficient condition for silicication. Rocks throughout the tripoli district are highly faulted, whereas bordering unsilicified rocks contain far fewer faults. However, rocks are not silicified in some highly-fractured areas near the tripoli district. Most notably, rocks are not altered along the complex fault zones in the Thebes Gap area, only a few km southwest of the Elco tripoli district ((Harrison and Schultz 1994).

Origin of silica

J. Weller and Ekblaw (1940) and J. Weller (1944) proposed that tripoli, ganister and calico rock in southern Illinois were formed by deep weathering of siliceous limestones, dissolving carbonate minerals and concentrating residual quartz. Weller proposed that weathering extended as deep as 120 m below a south-sloping peneplain that probably developed during the Miocene and Pliocene Epochs. Lamar (1953), Levine (1973) and Pickering and others (1986) agreed with the deep-weathering hypothesis.

The deep-weathering model fails to explain why altered rocks are confined to the Elco and Wolf Lake districts. Elsewhere in southern Illinois, the Pliocene-early Pleistocene (?) Mounds Gravel directly overlies unaltered Paleozoic bedrock, including limestone that is karst-prone (Pryor and Ross 1962, Ross 1964). Unaltered Bailey Limestone in the Thebes Quadrangle is variably overlain by Mounds Gravel, Wilcox Formation (Eocene), or McNairy Formation (Cretaceous). Unaltered Clear Creek Formation is at the surface between the Elco and Wolf Lake districts. Cuttings from a borehole near the Delta fault in the Elco district show that silicified rock extends at least 180 m below the upland surface, which is capped with remnants of Tuscaloosa Gravel (Cretaceous). New mapping (Berg and Masters 1994, Nelson and others in preparation) indicates that depth of silicification bears no relation to depth below Cretaceous or Tertiary outliers.

Several lines of evidence support a hydrothermal origin for southern Illinois silica deposits. First, silica is not merely insoluble residue of limestone. Scanning electron microscopy shows that tripoli is composed of aggregates of euhedral quartz crystals 0.5 to 6 micrometers long (fig. 3), whereas chert is composed of interlocking, microscopic subhedral quartz crystals. Faint outlines of relict detrital quartz grains can be recognized in the cores of some euhedral quartz grains in tripoli. Outside of the tripoli districts silica in the Clear Creek Formation occurs as abraded detrital silt grains and as sponge spicules and radiolaria.

Euhedral quartz crystals from the Clear Creek Formation in the Elco district contain two-phase (liquid-vapor) fluid inclusions. Preliminary thermomicrometric determinations on these inclusions indicate trapping at about 200°C of a fluid with low salinity (Berg and Masters 1994). No pressure correction was made because silicified Cretaceous and Tertiary strata in the area imply a shallow depth of silicification. Both the elevated temperature and the low salinity are consistent with a hydrothermal origin. The closest previously recognized area of hydrothermal activity is the Illinois-Kentucky fluorspar district about 90 km to the east. Fluid inclusions from the fluorspar district are more saline and generally homogenized at lower temperatures than inclusions from the tripoli district (Richardson and Pinckney 1984, Richardson and others 1988).

Hydrothermal activity also is suggested by abundant quartz veinlets, drusy quartz, and quartz-cemented breccia. Massive erosion-resistant siliceous beds (previously described as chert) occur at the top of the Clear Creek Formation in the Elco and Wolf Lake districts. The abundance of vugs, laminae, and breccia is more typical of jasperoid than of chert. Jasperoid such as this commonly forms by silicification of carbonates (Lovering 1972). The best development of jasperoid is in the heart of the Elco district, about 2 to 3 km west of the village of Elco. Here, ledges of vuggy and brecciated siliceous rock are concentrated along NE-striking faults. Mammillary deposits of limonite, goethite, and hydrated manganese oxides also occur in the Elco district, particularly in the St. Laurent Formation (Middle Devonian) along major faults.

Cuttings from the Humble No. 1 Pickel borehole (fig. 1) just west of the Elco district contain anomalously high concentrations of metals. These samples had the highest total metal content among 29 wells drilled around the margins of the Illinois basin - including several in the Illinois-Kentucky fluorspar district and several in the upper Mississippi Valley zinc-lead district. The Pickel borehole had the highest values of silver, arsenic, and lead, the second-highest molybdenum value, and the third-highest copper value. The mineralized section was primarily in dolomite of the Knox Group (Cambrian-Ordovician) (Erickson and others 1987).

Discussion

We propose that southern Illinois tripoli was produced by hydrothermal alteration of siliceous parent rocks. Mafic plutons near the top of Precambrian basement are the postulated heat source. The Elco and Wolf Lake silica districts both overlie large, roughly circular, coincident magnetic and gravity highs (fig. 4). The magnetic highs are shown on maps by Heigold (1976) and Hildenbrand and others (1993), while the simple Bouger gravity highs appear on the maps of McGinnis and others (1976) and Heigold and others (1993).

The inferred Wolf Lake and Elco plutons are in line with a series of known and inferred plutons that lie along the northwest margin of the Mississippi embayment in southeast Missouri and Arkansas (fig. 5). The edge of the embayment in turn follows the northwest margin of the Reelfoot rift, a failed Cambrian intracratonic rift (Hildenbrand 1984). All of the intrusions produce roughly circular, coincident gravity and magnetic highs. The exposed part of the Little Rock (Ark.) pluton is nepheline syenite of Late Cretaceous age (Moody 1949). The Newport pluton in northeast Arkansas is inferred to be Late Cretaceous or Paleocene; manganese deposits and silicified Paleocene limestone are associated with this pluton (Glick 1982). These deposits are evidence of hydrothermal action several km above the pluton.

Northeast-striking faults of the Reelfoot rift, NW-striking faults of the Ozark dome, and N-striking normal faults converge in southernmost Illinois. Perhaps emplacement of the inferred plutons beneath the Wolf Lake and Elco districts was controlled by these faults. Groundwater, perhaps mixing with magmatic fluids, circulated through the fracture system, leaching out carbonates and remobilizing silica. Igneous and hydrothermal activity in southern Illinois, as in Arkansas, most likely took place in late Cretaceous or early Tertiary time.

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LIST OF FIGURES

1. Map showing Elco and Wolf Lake tripoli districts and major structural features. Innumerable small faults in the

tripoli districts cannot be portrayed at the scale of this map.

2. Stratigraphic column for Elco and Wolf Lake tripoli districts. Unaltered lithologies depicted.

3. Scanning electron photomicrograph of tripoli from the Elco district, showing that the rock is composed largely of euhedral quartz crystals.

4. Map showing magnetic intensity contours in relation to Elco and Wolf Lake silica districts (from Heigold, 1976).

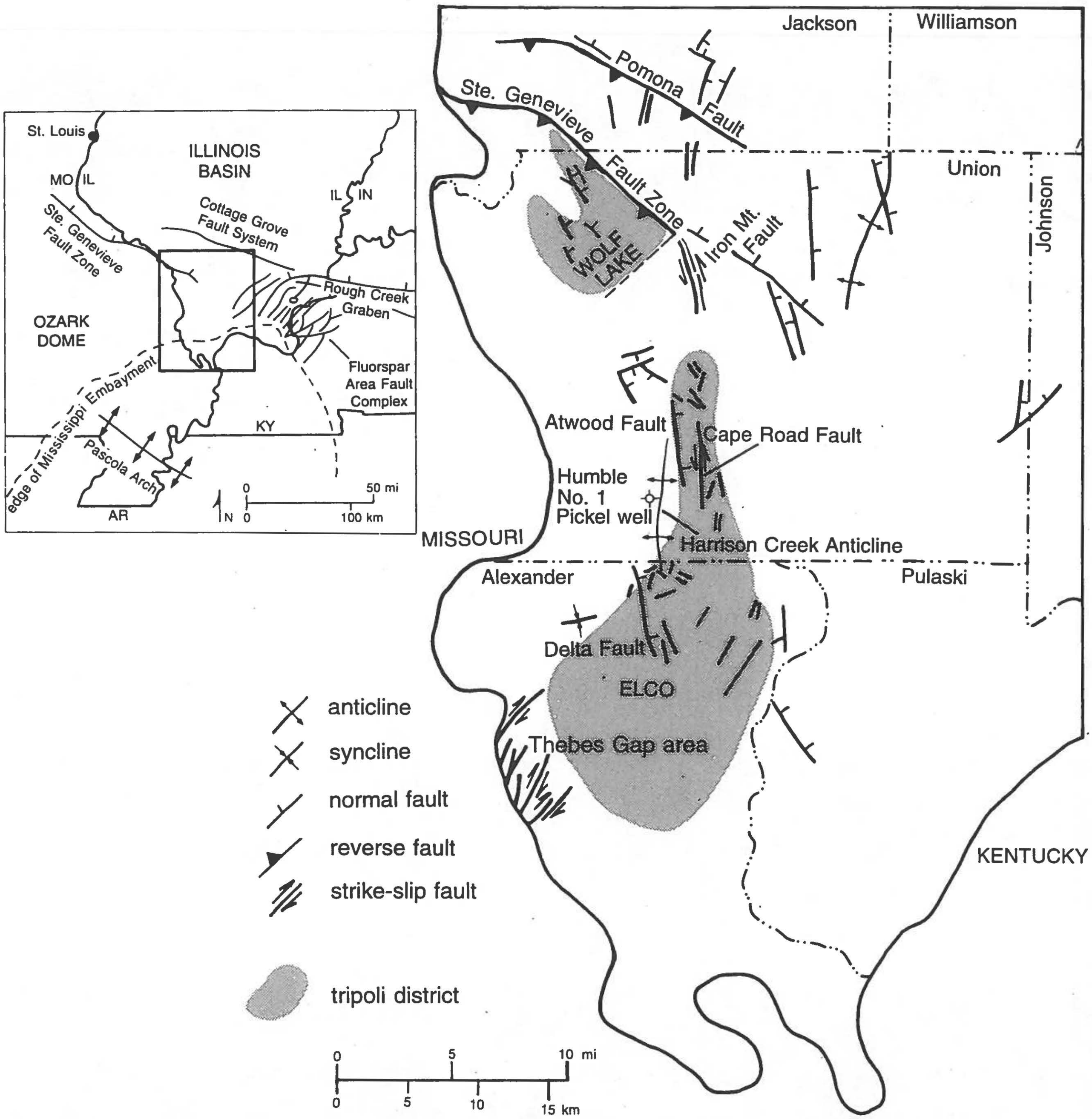
5. Map showing known and inferred mafic plutons of the Mississippi embayment; modified from Hildenbrand (1984).

Table 1. Normal and altered lithologies of rock units in southwestern Illinois.

Table 1.

FORMATION	NORMAL LITHOLOGY	WHERE ALTERED LITHOLOGY
Ullin Limestone	Crinoid-bryozoan packstone	Dissolved; chert-clay residuum
Fort Payne	Siliceous, cherty lime mudstone	Bedded chert, ganister*
Springville Shale	Silty shale to siltstone	"Calico rock"*, bedded chert
New Albany Shale	Black fissile shale	Absent in altered area
St. Laurent	Silty carbonate, shale, siltstone	Bedded tripolitic chert; cherty shale
Grand Tower	Skeletal grainstone, quartz arenite	Limestone dissolved, sandstone brecciated
Clear Creek	Siliceous, cherty lime mudstone	chert, tripoli**
Backbone Limestone	Crinoidal grainstone	Dissolved, if ever present
Grassy Knob Chert	Bedded chert, cherty carbonate	Chert, tripoli*
Bailey	Cherty, argillaceous lime mudstone	Chert, tripoli*

*Economic product



St. Louis
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Ste. Genevieve
Fault Zone
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Graben
OZARK
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Fluorspar
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Complex
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Pascola Arch
AR
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Jackson
Williamson
Pomona
Fault
Ste. Genevieve
Fault Zone
Union
Johnson
WOLF
LAKE
Iron Mt.
Fault
Atwood Fault
Cape Road Fault
Humble
No. 1
Pickel well
Harrison Creek Anticline
MISSOURI
Alexander
Pulaski
Delta Fault
ELCO
Thebes Gap area
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tripoli district
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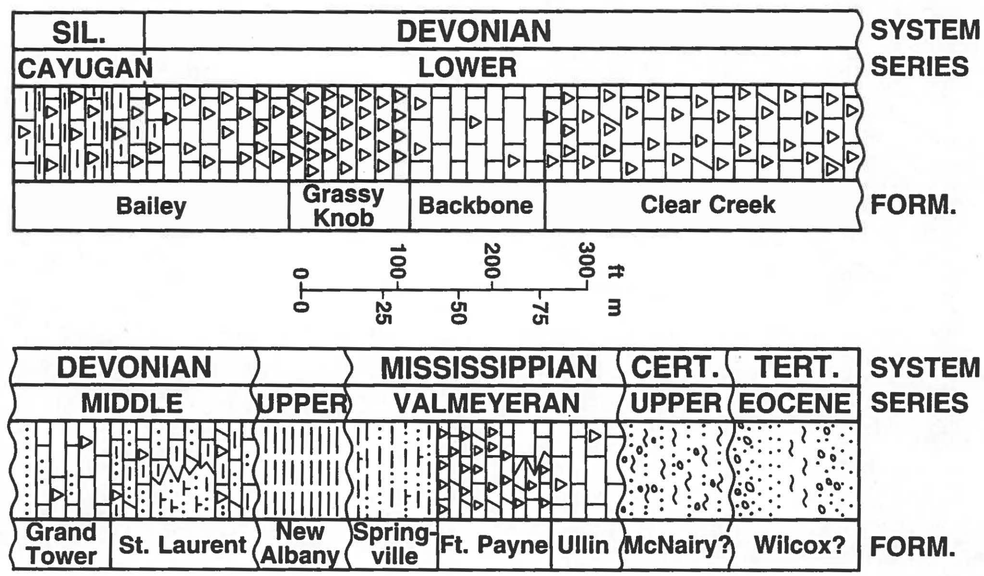
Figure 1



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VALMEYERAN
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Grand Tower
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New Albany
Spring-ville
Ft. Payne
Ullin
McNairy?
Wilcox?
FORM.

Figure 2

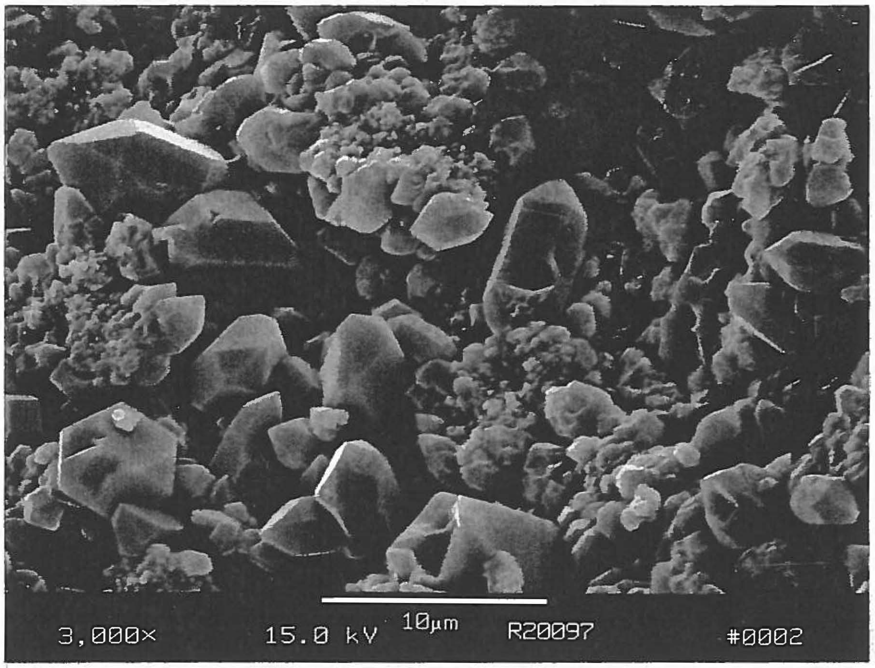
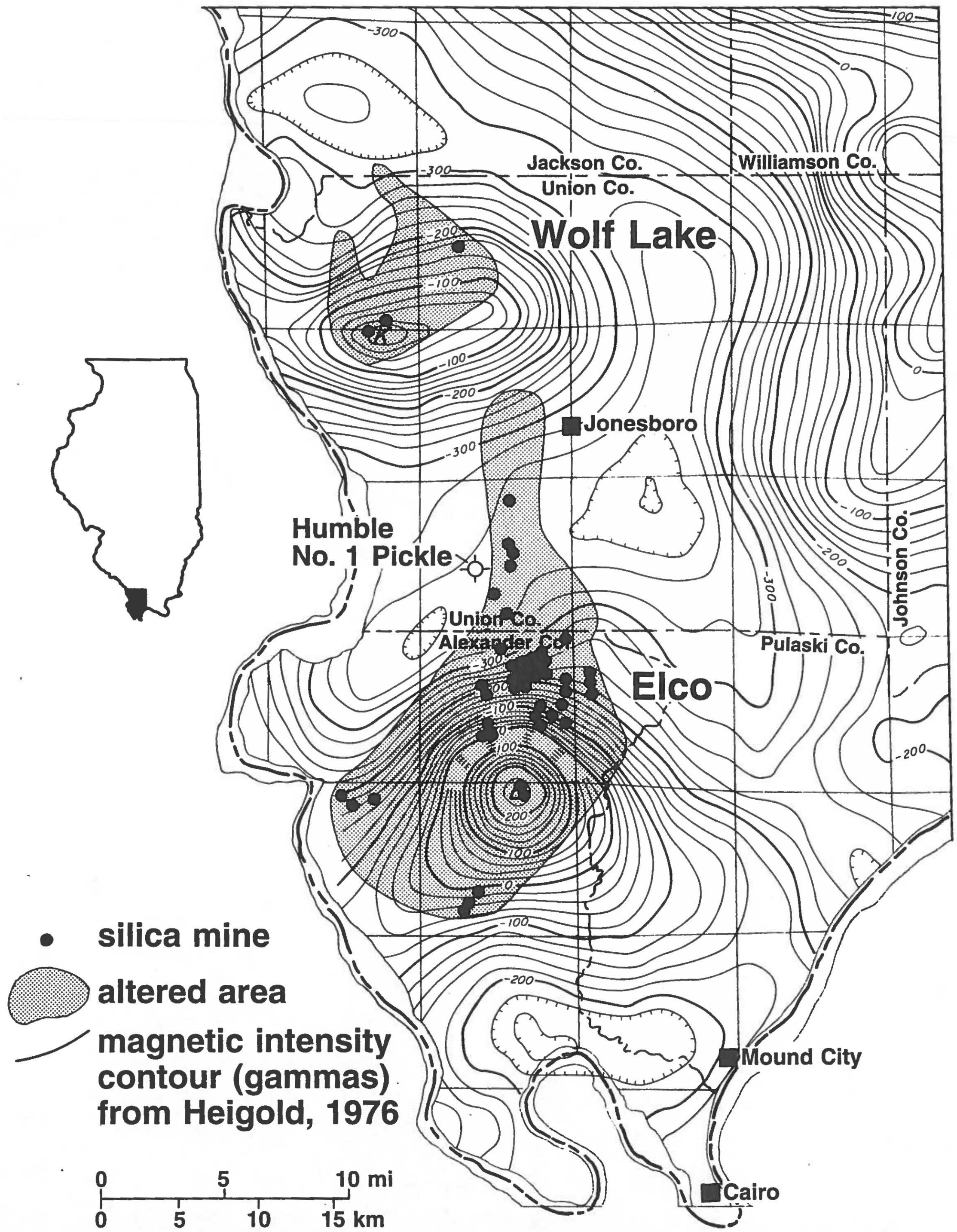


Figure 3


Jackson Co.
Union Co.
Williamson Co.
Wolf Lake
Jonesboro
Humble
No. 1 Pickle
Union Co.
Alexander Co.
Johnson Co.
Pulaski Co.
Elco
Mound City
Cairo
silica mine
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from Heigold, 1976
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Figure 4

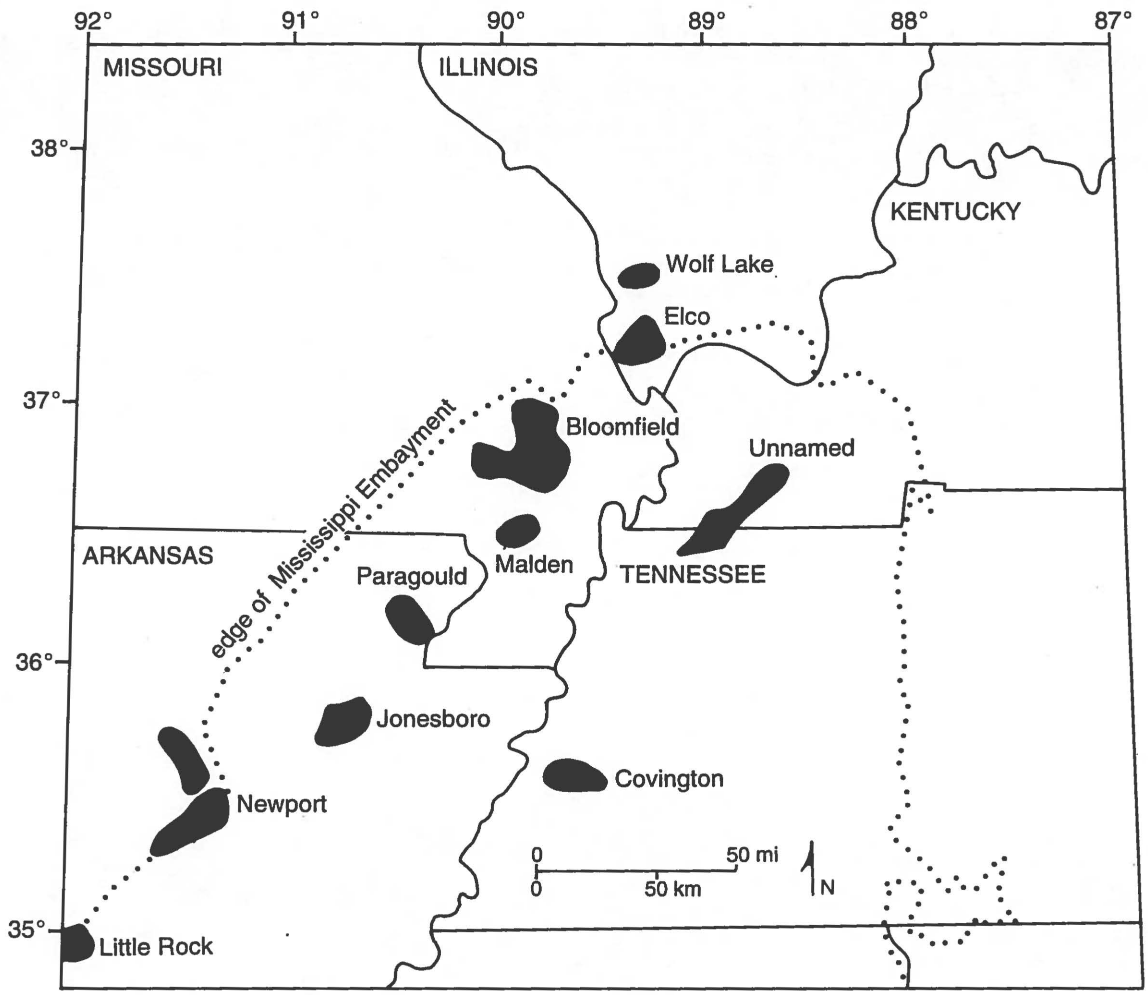

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Figure 5

ECONOMIC GEOLOGY

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Dear Dr. Nelson:

Enclosed are reviews of your manuscript with Richard Berg and John Masters entitled "Hydrothermal tripoli deposits in southernmost Illinois." Both reviewers are familiar with the geology of southern Illinois and non-metallic mineral deposits, and they agree that while the paper contains limited new data on the tripoli districts it should be of interest to readers of *Economic Geology*. They both recommended, and I concur, that the manuscript should be resubmitted as a Scientific Communication rather than as a Paper, and should be published following moderate revisions.

Reviewer #2 has suggested that much of the data supporting a hydrothermal origin for the tripoli deposits is indirect and that the evidence for this model needs to be strengthened. The fluid inclusion evidence while potentially powerful is, in its present form, inadequate to support the involvement of hydrothermal fluids in the formation of tripoli. This section needs to be expanded and the details of the study provided. A table incorporating the fluid inclusion data needs to be added. Reviewer #2 recommends that the paper can be reduced in size considerably without losing scientific content. The structural section is rather unwieldy and contains information that is not directly relevant to the tenet of the paper concerning a hydrothermal origin for the tripoli deposits. With some judicious writing the paper can be reduced by 20-30%.

Please carefully consider all of the reviewers' comments. I look forward to receiving three copies of your revised manuscript.

Sincerely,

Brian J. Skinner
HH

Brian J. Skinner
Editor

BJS\hh

Review of "Hydrothermal Tripoli Deposits in Southernmost Illinois"

Authors: W. John Nelson, Richard B. Berg, and John M. Masters

This paper presents a plausible alternative hypothesis for the origin of tripoli deposits in southernmost Illinois. It does not, however, contain much new and original data of sufficient quality to warrant publication as a paper. In its present form, it is acceptable for publication as a Scientific Communication in Economic Geology. It is my recommendation that it be accepted as such.

L. Taras Bryndzia
January 11, 1996

Reviewer #2

Hydrothermal Tripoli Deposits in Southernmost Illinois
By W. John Nelson, Richard B. Berg, and John M. Masters

General Comment

This paper discusses the origin of commercial tripoli deposits in southern Illinois. It contains the results of new field data, is generally well-written, and should be of interest to readers of Economic Geology. However, the new data are limited in number, especially fluid inclusion data, and as a consequence does not warrant being published as a full paper. I would recommend that the paper be accepted as a "Scientific Communication". There are places in the paper (e.g. structural section between pages 7 and 11) that can be shortened without taking away any of the scientific content. I would also recommend that the fluid inclusion section be developed and the reader be given details of this aspect of the study. In addition the Introduction should be expanded to include a very brief summary as to proposed origins (world-wide) of tripoli deposits. Most of the readers of Economic Geology will be unfamiliar with the geology of tripoli deposits and how they form. Readers should be provided with more information especially on deposits elsewhere.

Detailed Comments

1. The "Abstract" must be omitted if the paper is to be accepted as a "Scientific Communication".

2. The Introduction should contain some general information on tripoli deposits (i.e. important world-wide locations, origins, sizes) as most readers will be unfamiliar with the geology of this type of deposit. Are the southern Illinois deposits large or small by world standards? The Introduction should also include the aims of the paper.

3. I appreciate that the spatial relationship of the tripoli deposits to faults is an integral component of the argument that the deposits were hydrothermally derived. However, there is way too much unnecessary structural information that has no bearing on the origin of the deposits. This section (pages 7-11) can be cut by 50% and not lose any information that is germane to the concept that these are hydrothermal deposits.

4. I am unsure of the significance of Figure 3. The euhedral nature of quartz crystals in tripoli deposits merely shows that they have morphologies different to those crystals that compose cherts. Why do euhedral crystals have to be related to a hydrothermal process? Could these crystals not have formed by dissolution of the host-rock and subsequently precipitated from local meteoric water (i.e. unrelated to hydrothermal processes).

5. Compelling evidence in support of a hydrothermal origin for the tripoli deposits could be derived from fluid inclusion studies. However, in its present form, the discussion of the fluid inclusion study is inadequate. The reader should be provided with considerably more information. If the euhedral quartz crystals range from 0.5 to 6 micrometers in length, the maximum size of fluid inclusions is <6 micrometers. Please state whether fluid inclusions are

common or sparse and if they are considered primary or secondary. You should provide a table showing sample numbers, the range of homogenization temperatures (with the number of inclusions measured) for each sample, the range of freezing point depressions (with the number of inclusions analyzed) for each sample. Salinities should also be included. You state that "a fluid of low salinity" was identified. What are the salinities? These inclusions must be small and it must have been extremely difficult to observe phase changes during freezing experiments.

6. The significance of the anomalously high concentration of metals in the Humble No. 1 Pickel borehole is unclear to me. I presume the authors are implying these high concentrations provide evidence for hydrothermal fluids being active in the area. However this may bear no temporal, spatial, or genetic relationship to the proposed hydrothermal activity apparently responsible for the formation of tripoli. Minor amounts of base metals, in uneconomic quantities, have been reported in Paleozoic rocks of varying ages throughout the Midwest (Garvin et al., 1987, Econ. Geol., v. 82, 1386-1394; Coveney et al., 1987, Econ. Geol., v. 82, 740-751; Kutz and Spry, 1989, Econ. Geol., v. 84, 2139-2154).

7. At the bottom of page 12 you mention the closest previously recognized area of hydrothermal activity to the Elco district is the Illinois-Kentucky fluorspar district. I am not sure why a comparison of fluid inclusion data from these two districts was mentioned. Recent age determinations of intrusives in the Illinois-Kentucky fluorspar district suggest a Permian age (approximately 272 Ma; Snee and Hayes, 1992, U.S.G.S. Open File Rpt, 92-1, 59-60). Direct dating of the fluorspar mineralization also yields a Permian age of 277±16 Ma (Chesley et al., 1994, Econ. Geol., v. 89, 1192-1199). These ages are considerably older than Cretaceous-Tertiary ages assigned to the proposed hydrothermal event related to the Elco tripoli district.

As an aside, you cite the work of Richardson et al. (1988) as a source of fluid inclusion data for the Illinois-Kentucky fluorspar district. This paper focusses on stable isotope data and does not present the results of fluid inclusion studies. Recent fluid inclusion studies for the district include the investigations of Taylor et al. (1992) U.S.G.S. Open File Rpt. 92-1, 62-64, and Spry and Fuhrmann (1994) Econ. Geol., v. 89, 288-306.