The Barite Roses of Oklahoma

by David London

ConocoPhillips School of Geology and Geophysics
Mewbourne College of Earth and Energy
University of Oklahoma

Oklahoma Geological Survey Information Series 13

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G. Randy Keller, *Interim Director*

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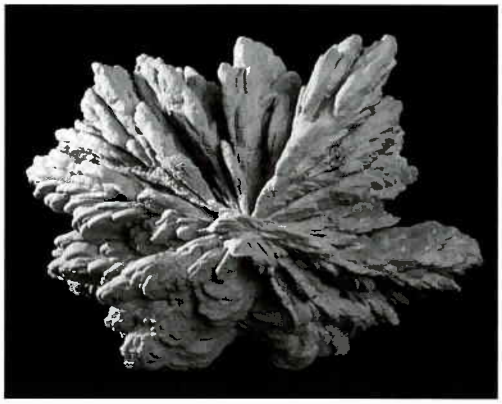

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2009

OGS Celebrates 100 Years of Service 1908-2008

The Oklahoma Geological Survey has the distinction of being the only geological survey provided for in a state constitution. The legislative mandate is to:

Investigate the state's land, water, mineral, and energy resources and disseminate the results of those investigations to promote the wise use consistent with sound environmental practices.

Governor Charles N. Haskell signed the Enabling Act: The OGS began work on May 29, 1908

The basic mission then as now is research, field work, and mapping to produce reports and maps that add to the body of knowledge about Oklahoma's geology and resources. In cooperation with academia and industry, this information is printed, disseminated in workshops, provided over the internet, and made public through contact with individuals, schools, scout, and civic groups.

Charles Newton Gould, Father of Oklahoma Geology Director 1908–1911 and 1924–1931

When he came to OU in 1900, drive, determination, and relentless energy made Dr. Charles Newton Gould the perfect person to found OU's geology program and, in 1907, to foster in the State Constitution what would become the Oklahoma Geological Survey.

Gould saw the need to blend academics, industry concerns, and public needs in a single research and public service agency that would bring together these areas to better serve Oklahoma. His actions and vision provided the foundation for Survey programs for the next 100 years.

Gould went into the oil industry in 1911, becoming one of the pioneering geologists to work in Oklahoma. He returned to the Survey, however, when needed in 1924.

Daniel W. Ohern, Director 1911–1914
Charles W. Shannon, Director 1914–1923

Because basic reconnaissance work still was needed, investigations of oil and gas, coal, glass sand, building stone, gypsum, lead and zinc, water, and building materials resulted in a number of publications and maps. The first full-color geologic map of Oklahoma was issued in 1926.

Shannon noted that "The need of conservation is apparent to members of the Survey," and pointed to wastes of coal, oil, natural gas, forests, and animal life. The Geological Survey still is mindful of the legislative mandate to conserve Oklahoma's natural resources and promote their wise use.

Dr. Gould, right, and Survey field party

Robert H. Dott, Director 1935–1952

Dott's Survey focused on non-fuel mineral resources suitable for manufacturing and worked to develop new uses for some of the most mundane resources, Dott's "humble materials." Manufacturing added monetary value to the resource, such as making pottery, tile, and brick from clay.

He saw the OGS through the depression era and World War II, and in 1935 conducted a state mineral survey that hired people to verify information for base maps, collect data on building materials, and examine industrial mineral deposits. The information and the jobs were much needed.

William E. Ham, Interim Director 1952–1954
Carl C. Branson, Director 1954–1967

Branson made significant contributions to the University of Oklahoma Geology Library. This effort continues today through a cooperative exchange program between the OGS and other agencies worldwide. The publications given to the OGS are donated to the Youngblood Geology Library.

Charles J. Mankin, Director 1967–2007

During Mankin's years, the OGS became more involved in cooperative studies with many state and federal agencies and concentrated on oil and gas activities that would help the small producers in Oklahoma. In 1978, a geophysical observatory southeast of Tulsa was added to the Survey. The Oklahoma Petroleum Information Center in Norman opened in 2002, and in 2006, the OGS officially became affiliated with The University of Oklahoma's Mewbourne College of Earth and Energy.

G. Randy Keller, Interim Director 2007 –Present

Keller, a professor of geophysics at OU, came to the Survey to assist in operations after Mankin's retirement. His interest in and enthusiasm for the OGS mission is evident. As ever, the Survey's goals remain *wise use and conservation.*

—Compiled by Connie Smith

INTRODUCTION AND BIOGRAPHICAL SKETCH

The barite rose is one of Oklahoma's most distinctive and recognizable icons and was named the state rock in 1967. Also commonly known as the rose rock, it has long been popular with collectors for decorative purposes. First described in the scientific literature in 1906, the barite rose or rose rock has been given a number of other names, including barite rosette, petrified rose, petrified walnut, sand barite, sand crystal, sand barite rosette, and sand barite crystals. Despite its long recognition and state status, there are surprisingly few geological studies of the barite rose and little agreement on how they form or why they are found in a relatively narrow belt through central Oklahoma. Dr. David London, professor of mineralogy at the University of Oklahoma, provides answers to many of the questions surrounding barite roses in this paper, which was originally published in The Mineralogical Record.

Dr. David London, Stubbeman-Drace Presidential Professor and Norman R. Gelphman Professor in the School of Geology and Geophysics at the University of Oklahoma, was born and raised in Ardmore, Oklahoma. He received his B.A. from Wesleyan University (Connecticut) in 1975 and M.S. and Ph.D. from Arizona State University in 1979 and 1981, respectively. He spent two years as a postdoctoral fellow at the Carnegie Institution's Geophysical Laboratory in Washington, D.C., before joining the OU faculty in 1983. Most of Dr. London's research pertains to the origin and chemical evolution of felsic magmas that solidify as granites, rhyolites, and pegmatites. His work over the years is summarized in his new book "Pegmatites," published in 2008 by the Mineralogical Association of Canada. In 1999, Dr. London was honored by having a new mineral, londonite ($CaAl_4Be_4[B_{11}Be]O_{28}$), named after him in recognition of his contributions to the geochemistry and origins of granitic pegmatites. In addition to his research, Dr. London teaches a number of graduate and undergraduate courses at OU.

Dr. London is also an avid mineral collector. His pursuit of Oklahoma's barite roses began when he returned to OU. In seeking a place to dig rocks, Dr. London visited many of the historic sites for the roses and met their owners, but only one individual, Mr. J.C. Hailey of Noble, granted him permission to excavate on his property. That offer, which spanned the years 1994-2007, led not only to the discovery of many fine rose rock specimens, but also influenced Dr. London's understanding of the geologic processes by which the barite roses might have formed. This article, which is a summary of London's observations to date, is a significant first step toward understanding these unusual mineral specimens.

ACKNOWLEDGMENTS

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Oklahoma Geological Survey

THE BARITE ROSES OF OKLAHOMA

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Oklahoma's centennial anniversary in 2007 marked an appropriate milestone to reconsider what is known about the geology and origins of the well-known "barite rose" crystal clusters. Few mineral specimens are as distinctly recognizable and traceable to source as the Oklahoma barite roses, also known as "rose rocks" and "barite-sand rosettes."

INTRODUCTION

In private and public collections around the world, the barite roses with sand inclusions from Oklahoma are cataloged and displayed as minerals (along with barite from other localities), not as rocks. This classification is correct—barite roses are mineral specimens, not rocks, because the shapes of rocks are indeterminate, whereas the shapes of minerals are determined by a combination of forms and habits derived from the interplay of crystal structure and environment of growth. Unfortunately, the barite rose became the official state ***rock*** of Oklahoma when Oklahoma House Bill 1277 was signed into law in 1968. Noble, Oklahoma was made the official rose rock capital (of Oklahoma, and by default, the world) via an "emergency" act of the Oklahoma House of Representatives in 1983. Oklahoma now has an official state crystal (the hour-glass sand gypsum crystals from the Salt Plains Wildlife Refuge near Jet, Oklahoma) as decreed by Oklahoma House Bill 4, signed into law in 2005, but no state mineral. The barite rose would have been a fitting candidate for that distinction.

BARITE ROSE LORE

The resemblance between barite roses and flowers or other common objects other than rock has evoked some colorful legends and myths about their origins. The most commonly cited legend has it that when the Cherokees were marched into Oklahoma on the Trail of Tears, the blood of Cherokee men and the tears of Cherokee women that fell in drops to the ground turned to stone roses, to remind the Cherokees of their real flower, the Cherokee rose, state flower of Georgia (Stine and Stine, 1993). No such myth appears in authoritative compendia of Cherokee legends (e.g., Underwood, 1956), and a consensus within the Cherokee Nation today is that the myth was fabricated by Anglo-Americans to sell barite roses. The Cherokees point out that barite roses do not occur on any of the lands granted to them.

In his study of the barite roses east of Salina, Kansas, Knerr (1898) uncovered an intriguing legend, which he offered to the Kansas Academy of Science as homespun, popular science. Knerr (1898) states:

> The explanation is that at one time there was located in this valley an Indian storehouse of goods, and a large portion of the stock on hand consisted of balls of rawhide. A tornado came along and destroyed the lodge containing the goods, burying its contents in the mud where the balls of rawhide thongs became petrified in the course of time. No mystery of natural formation in Kansas can be so deep but that it may be thoroughly cleared up, it seems, by the aid of the Indians and a cyclone.

COLLECTING: PAST AND PRESENT

If there was a heyday for barite roses, it was in the 1940s–1960s, when Frank Shobert (deceased) produced large quantities of fine barite roses from his farm in Slaughterville, Oklahoma (location 4, Fig. 11a). Today, like all other private locations, the Shobert farm is closed to collecting, and the Shobert descendants do not sell roses, either. I visited the locality on a sweltering summer day in 1995 with the current landowner, Randy Shobert. Under a stifling canopy of

Figure. 1. **A good example of a well-formed barite rose (8 cm, Hailey locality) showing uniformly round and symmetrical development of thin barite crystals with high luster, from the Hailey locality (see locations in Figure 11a). All photographs by the author, and all specimens from the author's collection unless specified otherwise.**

Figure. 2. **A cluster of barite roses (17 cm) from the Hailey locality. Note that the shapes of individual roses are less round, more tabular, as they have adopted more of the orthorhombic morphology that barite crystals normally exhibit.**

oaks, on ground thickly covered with poison ivy, and in the presence of an irascible black snake, I could determine that the locality still contains plentiful barite roses. A continuous barite rose cluster (~3 meters in length) was exposed in an outcrop following an east-west strike; efforts to dislodge the cluster with a large bulldozer had failed. Based on popular accounts, this would be the largest known cluster of barite roses. A stucco of barite roses on the old Shobert homestead stands as a roadside symbol of this once great locality (Fig. 12).

Tom Blair's "Oklahoma Rose Rock Farm" (location 3, Fig. 11a) gave the impression of a real farm thanks to the simple fact that Mr. Blair (deceased) produced barite roses only from the soil horizon; he harvested crop after crop for decades, and the roses were of remarkably uniform size and crudely shaped like potatoes. Blair also sold them at the price of potatoes (Fig. 13). Blair's plentiful and cheap barite roses must have served as a disincentive for neighbors to market their own. At the time I saw the locality, it appeared as mounds of hand-dug muck, with no signs of a working face or machinery-driven excavation.

Though his digging site was not far from Blair's Rose Rock Farm, Pete Peters (deceased) produced barite rose columns that were altogether different from Blair's single roses (location 2, Fig. 11a). Peters' specimens were barite-cemented pipes that contained tiny barite roses decorating the sides of the pipes (similar to Fig. 9). The most intriguing feature of the pipes was that the low-angle cross-bedding within the host Garber Sandstone was also preserved (discussed further below).

J. C. Hailey (deceased) sold roses that he picked up off the ground surface. When I met Mr. Hailey in 1994, he granted me permission to dig the locality in his back yard (location 5, Fig. 11a). From the start, the Hailey location produced abundant and well-formed barite roses, including clusters weighing approximately 320 kg (Fig. 14). I dug the location by hand continuously between 1994 and 2006. Much of the geology presented here was gleaned from this steady history of digging. Today, the locality is nearly mined out, and is closed to collecting.

Other than a few Internet auctioneers, only Joe and Nancy Stine continue to market barite roses for the public from their Timberlake Rose Rock Museum in Noble, Oklahoma (location 1, Fig. 11a). The Stines are known for their metal sculptures that employ barite roses as the base and as flowers at the tops of stems. Otherwise,

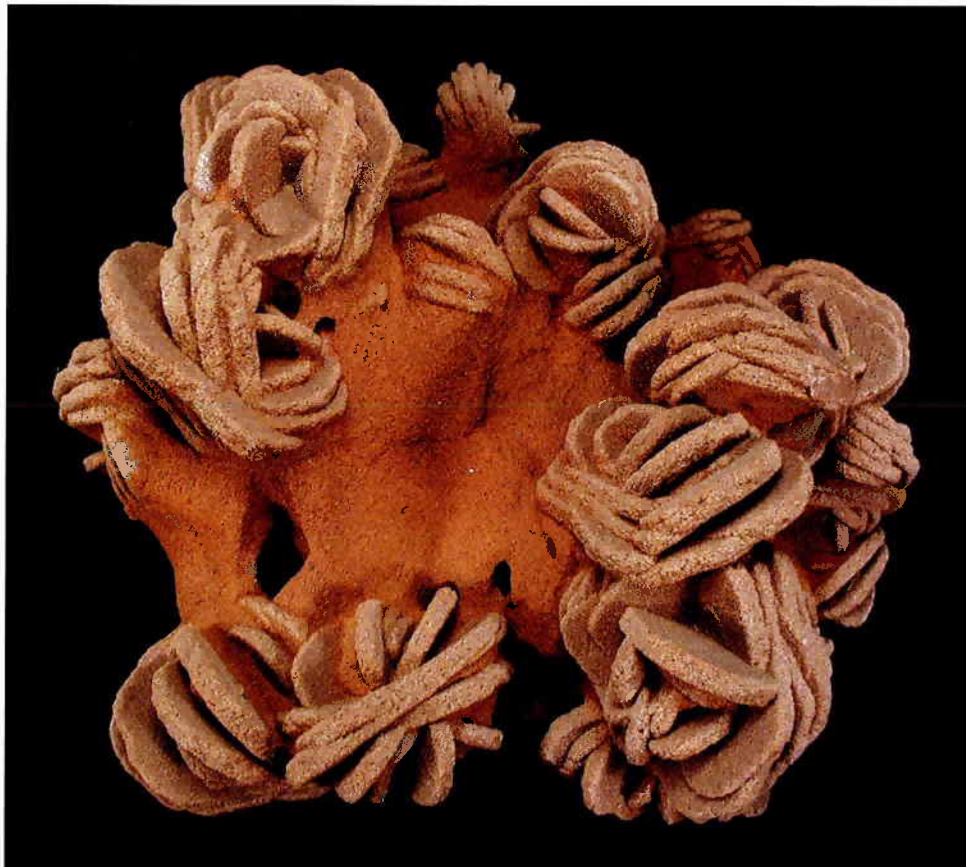


Figure. 3. **A cluster of barite roses (18 cm, Hailey locality) in which the enclosing Garber Sandstone has been only partially removed.**

Figure. 4. **Thin barite blades and good crystal separation impart high definition to barite roses (11 cm) from the Shobert locality (Fig. 11a). Individual barite crystals tend to be elongate (pointed) along the [100] direction, however, which makes them look less like flowers.**

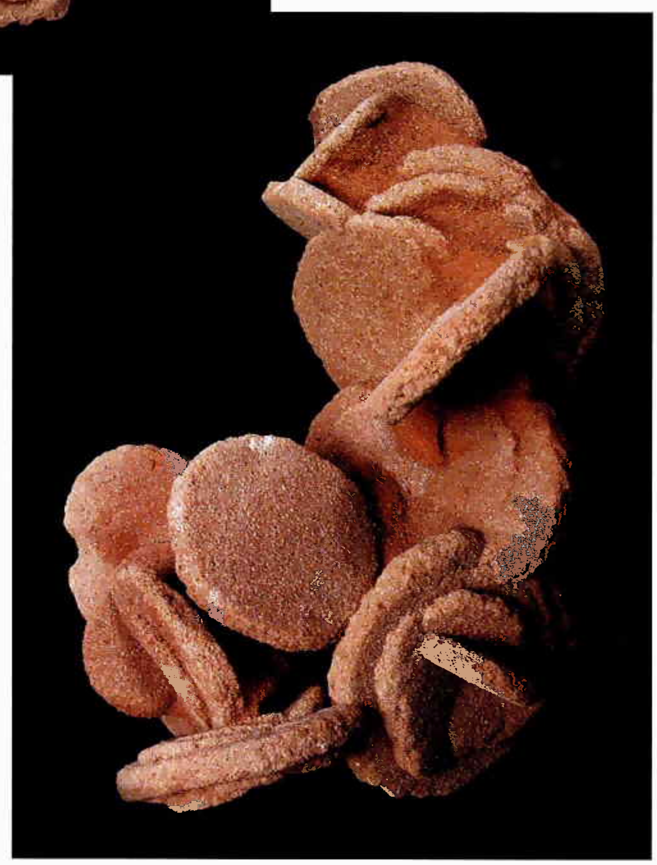


Figure. 5 **A specimen (12 cm, Hailey locality) containing roses plus several single, round disks of barite. The round barite disk, referred to in the text as the medial disk, commonly occurs by itself, without the development of attached barite crystals that create the rose shape.**

Figure. 6. **The crossing patterns of barite crystals on this specimen (15 cm, Hailey locality) may contribute to make the "fourling" pattern when two sets of crosses are intergrown but separated by 90 degrees of rotation.**

Figure. 7. **Resembling a military aviation medal, this barite rose cluster (9 cm, Hailey locality) grew in a vertical orientation. The central medial disk of the barite rose was aligned along a vertical fracture. The wing-like rose at the top was created as barite-depositing solutions moved out laterally along a more permeable layer in the host Garber Sandstone, approximately at right angles to the fracture surface.**

barite rose digging and marketing are in Oklahoma's past, with all of the important producers now deceased, and with no further production permitted from any of the historic sources. Locations where barite roses still occur in large abundance, however, are too numerous to count.

Barite rose-bearing horizons are exposed around the shorelines of two public lakes in the region: Lake Thunderbird and Stanley Draper Lake. Digging is not allowed at either location, but the exposures (during low stands of lake level) on the west and south sides of Stanley Draper Lake are both instructive and impressive (Figs. 11b, 15a,b). The Oklahoma City Police Department, which patrols Stanley Draper Lake, permits individuals to collect a few roses for personal use from the surface exposures.

MINERALOGY

The barite roses consist of multiple barite ($BaSO_4$) crystals arranged in a radial or rosette pattern (e.g., Fig. 1). They contain roughly equal proportions of barite and quartz sand, the latter representing grains of the Permian Garber Sandstone that were included when the barite crystals grew through the pore spaces in the rock (Fig. 16). The roses contain trace amounts of hematite (α-Fe_2O_3), enough to give them a pale red hue, but there is far less hematite in the roses than in the enclosing deep-maroon Garber Sandstone. Clay minerals that are abundant in the Garber also are present at trace levels in the roses. Otherwise, the barite roses are non-porous and lack fluid inclusions. Barite crystals have effectively occluded all of the original void space in the original Garber Sandstone.

Most individual barite roses range in size from ~1 cm to 10 cm in diameter. The largest single rosette known to date has dimensions of 51 × 56 × 53 cm and weighs 135 kg (Fig. 17).

The Garber Sandstone contains well-sorted but highly angular medium quartz sand that constitutes ~70–80 volume percent of the rock (Fig. 16). The remainder is mostly pore space (~15–20 volume percent), a few percent of hematite cement and clay minerals, and trace amounts of feldspars and other detrital minerals.

Barite roses are mostly confined to the strike of the Garber outcrop in central Oklahoma from northeast of Oklahoma City south to Lexington. Nodules of spherically radial barite crystals without sand are known from outcrops near Paoli and Lawton. Outside of Oklahoma, white barite-sand roses come from east of Salina, Kansas (Knerr, 1898), where they occur in Cretaceous sandstones (Fig. 18). Barite-sand rosettes are also reported from Permian red sandstones in southeastern Australia (Prof. Alan J. R. White, University of Melbourne, personal communication, 2001), and recently at Bou Lalou, Morocco (Sean Falkner, University of Massachussetts, personal communication, 2008). The few other reported locations for sand-filled barite roses (in Egypt and California) are more dubious because the barite roses are often referred to as "desert roses," which are the much more common gypsum rosettes that form true "desert roses" by near-surface evaporation of ground water.

The barite roses are found almost entirely within soils developed

Figure. 8. **Barite roses in miniature, delicate clusters like this one (12 cm, Hailey locality) and others shown in this article come only from outcrops within the Garber Sandstone. Such delicate clusters are crushed by overburden in erosional lag deposits. The two portions of this sample are bridged by greenish brown masses of limonite that are thought to be the oxidized remnants of framboidal pyrite or other iron sulfide.**

on the Garber. Occurrences of barite roses in rock outcrop (as at the Shobert and Hailey localities) are very rare, and of the thousands of water wells drilled into the Garber Sandstone, only one known well has reliably encountered barite roses at depth. In a detailed Master's thesis study of the Garber Sandstone in central Oklahoma, Baker (1951) found no barite cement in any of the scores of Garber outcrops sampled. Apparently, barite occurs only as discrete roses in the Garber Sandstone.

GEOLOGY

In the only published work on Oklahoma's barite deposits, Ham and Merritt (1944) proposed that the roses formed during the deposition of the Garber Sandstone in Permian time (~250 Ma), in an environment interpreted as a complex of arid fluvial fans, deltas, and restricted lagoonal deposits draining westward toward an open marine environment. Ham and Merritt (1944) envisioned that the barite roses formed by a "sabkha" process, wherein the percolation of hypersaline surface brines downward through a permeable sand body results in mineral-forming reactions between the surface brine and either fresh water or seawater that fills the pore spaces in the subsurface.

Geologic investigations by the author conducted mostly at the Hailey locality have revealed that where the barite roses crop out, they tend to be related to joints or fracture sets that strike approximately north-south and east-west and dip subvertically. At the Hailey locality, the east-west fracture sets are the most extensively and reliably mineralized, in zones of brecciated rock approximately 20–40 cm wide (Fig. 19). Hence, the barite roses postdate the deposition and lithification of the Garber Sandstone, though the ages of the geologic structures with which the barite roses are most closely associated are still unknown.

The barite roses are concentrated where the two joint sets meet, and these regions of intersecting fractures may be so permeated with barite roses that they form cylindrical cemented barite pipes (Figs. 9, 15a, 20a). In some locations, the pipes consist of massive hematite (a.k.a. ferricrete) with barite roses, or else of hematite only.

Away from the barite pipes, the roses are further concentrated along the strike of the east-west fracture surfaces (Fig. 20b). In this association, the barite roses contain a single, dominant barite crystal disk that is aligned parallel to the fracture surface (Fig. 20c). The radial barite crystals grow off this medial disk, and the rose structure tends to be predominant on one side of the disk (Fig. 20c). Internal cross-bedding within the Garber is often preserved in these roses, but some roses lack any indications of inherited bedding.

In horizons that are parallel to the bedding surfaces in the Garber, barite roses form lateral concentrations that are thickest and densest close to the vertical fracture surfaces and die out laterally away from them. Economic geologists refer to strata-bound mineral deposits formed by lateral flow of fluid away from fractures or pipes as "mantos" (Figs. 15b, 19a, 20d), and we can adopt the term here. The barite-cemented pipes form large clusters of roses, and similarly large clusters occur in the mantos. In the mantos, typically, a cluster has formed where a particularly permeable surface within the Garber became completely impregnated with interdigitating roses or massive seams of barite which represent the original fracture surface for the laterally migrating fluid (e.g., Fig. 10).

Figure. 9. **A barite rose pipe (32 cm, Shobert locality) shows the solid, cylindrical barite seam that becomes the pipe casing off which barite roses grew.**

Figure. 10. **A cluster of barite roses (31 cm, Hailey locality) from a horizontal manto. Larger clusters like this one formed tongue-shaped masses that generally contained a proliferation of smaller clusters and single roses that diminish in abundance away from the tip of the cluster. Barite roses commonly occur only on one side (top or bottom) of the horizontal bed or bedding surface that promoted the lateral flow of barite-mineralizing ground water.**

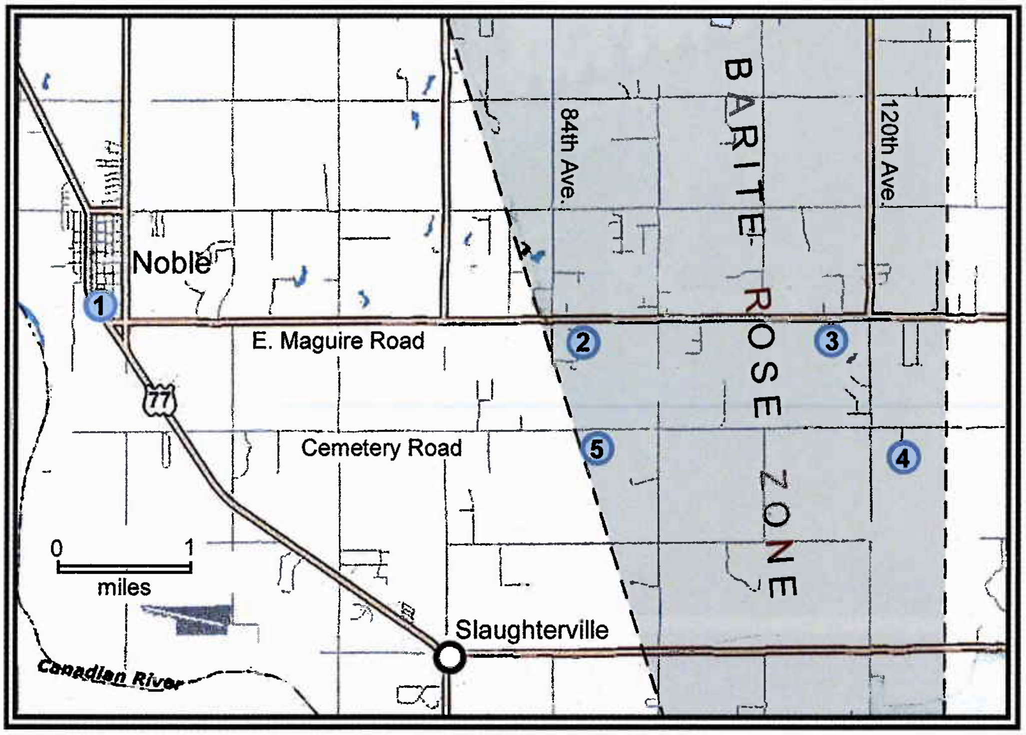


Figure. 11-a. **The historic "Rose Rock Trail," beginning near the junction of US 77 and East Maguire Road, where the Timberlake Rose Rock Museum (1) is the last remaining purveyor of barite roses in Noble, Oklahoma; (2) is the former Pete Peters locality; (3) is the former Tom Blair locality; (4) is the former Frank Shobert locality; and (5) is the former J. C. Hailey locality.**

Figure 11-b. **When the shoreline is exposed by lowered water levels, barite roses can still be found today at the two locations shown at Stanley Draper Lake in the southeastern Oklahoma City area.**

GEOLOGIC PECULIARITIES

Numerous basic questions surround Oklahoma's barite roses. Most of the questions lack definitive answers, and some are without answers of any kind.

(1) Why are the barite roses found only (with trivial exceptions) in Oklahoma?

Red sandstones of Permian age are widespread throughout the world. These sandstones have a common geological environment of formation, one that is semi-arid at the surface but near a large marine body and periodically inundated by marine brines. With the possible exception of an occurrence in Australia (cited above), these sandstones lack barite roses.

The barite roses apparently do not owe their origins to any process specifically related to the environment of deposition of the (now) red sandstones. If correct, this conclusion signifies that some other feature of the deep subsurface of Oklahoma distinguishes these

Figure. 12. **Frank Shobert homesite, containing individual barite roses and clusters in stucco.**

Figure. 13. **Tom Blair barite roses for sale. A typical fist-sized rose cost 25¢ to 50¢ in 1996.**

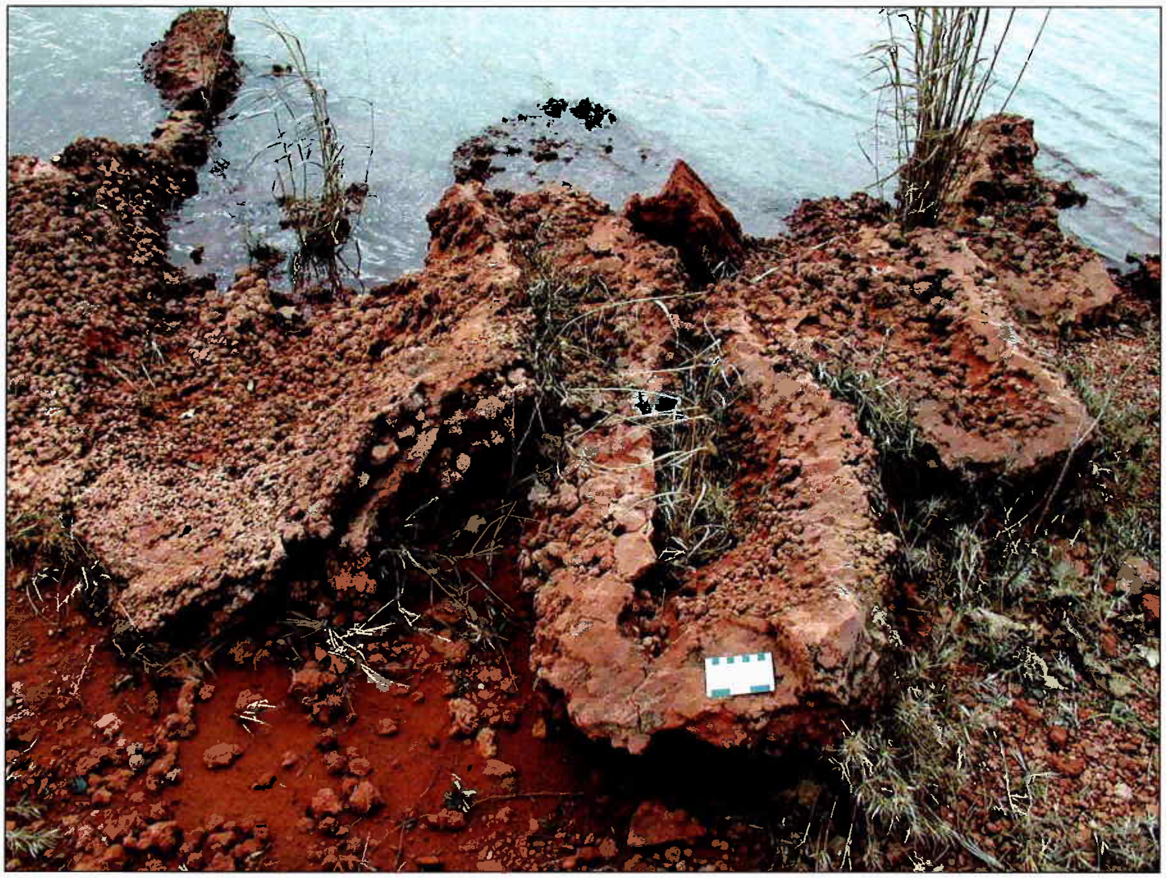
Figure. 14. **J. C. Hailey and a recently dug cluster of barite roses (now at the Goddard Youth Camp, Davis, OK) from his back yard, 1994.**

Permian red sandstones from others around the globe, or that a subsequent and significant geologic event that occurred in Oklahoma did not happen elsewhere.

The basement rocks in Oklahoma are granites and gabbros, which are common throughout the North American craton. One less common feature of Oklahoma's subsurface is the occurrence of deep basinal brines of the type that are associated with large oil fields. Those brines are somewhat exotic. In Oklahoma, the oil field brines contain abundant iodine, for example, which makes Oklahoma the only domestic producer of commercial iodine.

(2) How old are the barite roses?

In the model of Ham and Merritt (1944), the barite roses are the same age as the Garber Sandstone, ~250 Ma, i.e. Permian, and throughout the Midcontinent region of the U.S., mineralization events that formed the Viburnum Trend, the Tri-State lead-zinc



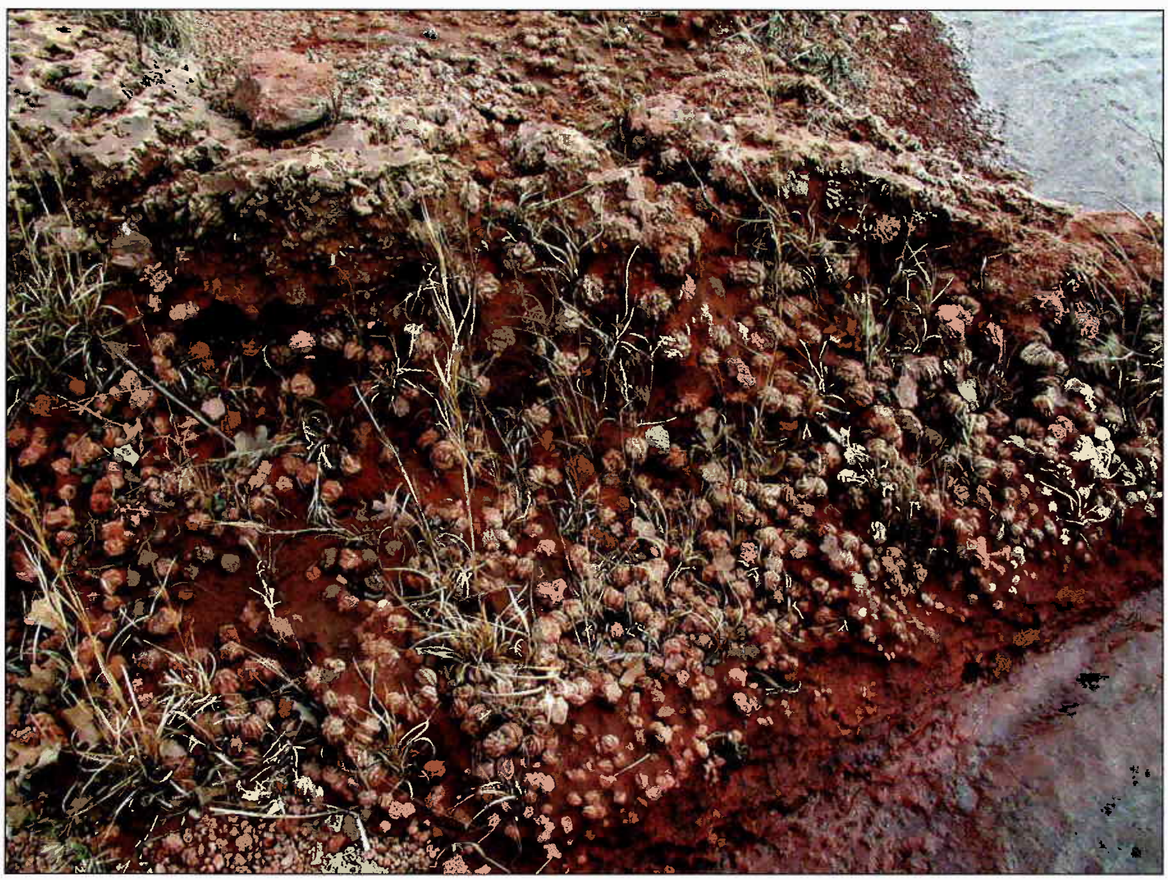


***Figure. 15. (top)* Barite-cemented pipes and *(bottom)* strata-bound barite manto at Lake Stanley Draper; see Fig. 11b for locations.**

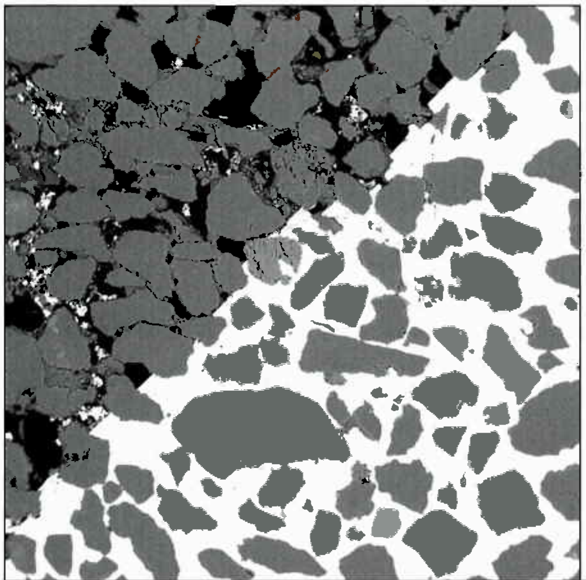


Figure. 16. **Back-scattered electron image of an interface between a barite rose crystal and the surrounding Garber Sandstone. The image contains a single crystalline blade of barite (bright white) defined by a sharp crystal boundary, angular quartz grains (gray), pores (void space) in the Garber Sandstone (black), which contain flecks of hematite (bright white) and traces of clay (fine-grained gray aggregates). Notice that quartz sand is in grain contact in the sandstone, but not in the barite crystal, signifying that the growth of the barite crystal either dissolved or shouldered aside some of the sand grains. The field of view is 1.5 × 1.5 mm.**

Figure. 17. **The largest single barite rosette known to date (56 cm, 135 kg).**

Figure. 18. **Heavily hematite-cemented sandstone (ferricrete) pipe, 20 cm across, lined with barite-sand roses. Collected east of Salina, Kansas, by Marie McDaniel Kennedy; now in the collection of the School of Geology & Geophysics, University of Oklahoma. Based on the trace of faint cross-bedding along the sides of the specimen, this pipe was originally formed as viewed, in a vertical orientation.**

deposits, the Southern Illinois fluorspar deposits, and the Pine Point district are strongly correlated with this time period.

The uplift associated with the Appalachian-Ozark-Ouachita-Arbuckle orogens was an important geologic event in Oklahoma and elsewhere in the Midcontinent of the U.S. That mountain-building event sent deep basinal fluids migrating north and west, and these migrating fluids are thought to be responsible for the galena, sphalerite, barite, and fluorite orebodies known throughout the region (including Oklahoma) as Mississippi-Valley-Type deposits. The mountain-building event that caused Mississippi-Valley-Type mineralization in the Midcontinent region began in Pennsylvanian time (~300 Ma) and may have continued into the Permian; however, the deposition of the Garber Sandstone and the Mississippi-Valley-Type mineralization cited above occurred as a consequence of, and hence after, these orogenies. Throughout the Midcontinent region, mineralization associated with the Mississippi-Valley-Type deposits, with

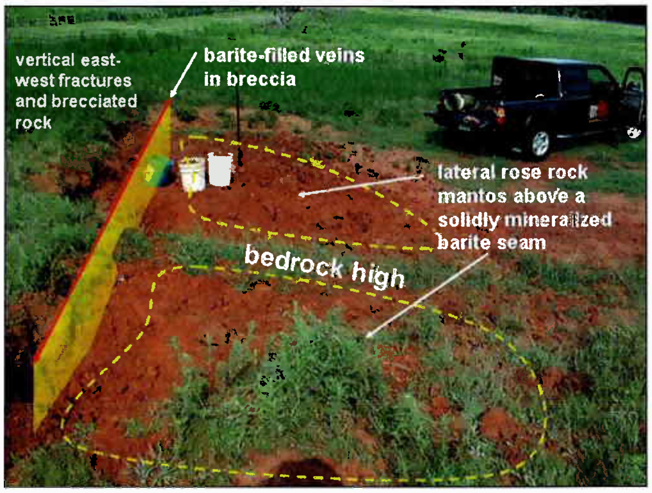
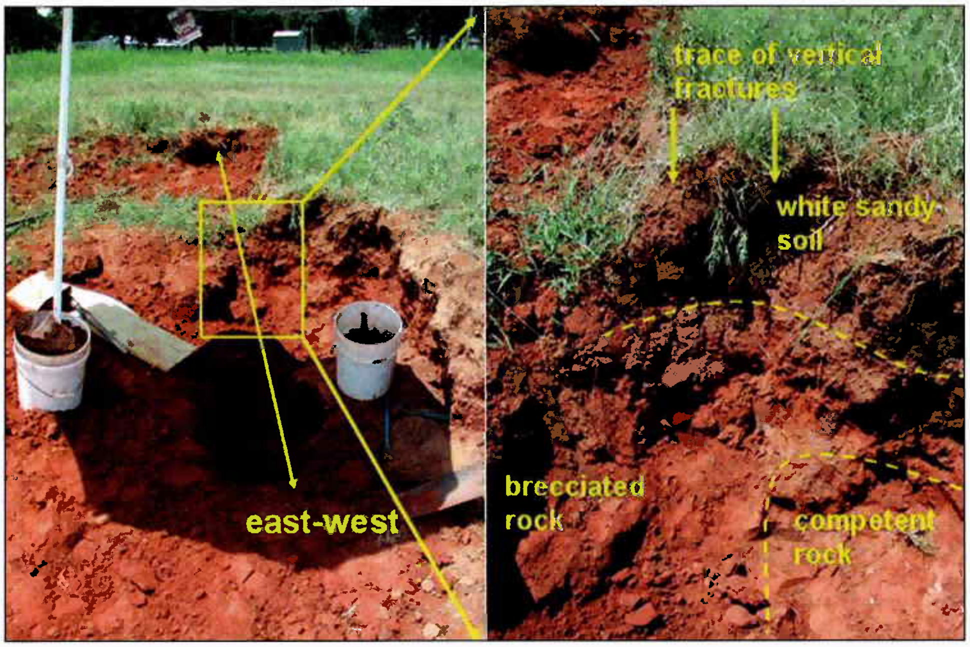


Figure. 19. **(a) A field exposure at the J. C. Hailey locality (2003) showing the shape of a lateral barite "manto" in relation to a pervasively mineralized vertical east-west fracture. (b) The vertical trace of the east-west fracture set is evident in weathered rock *and* in the overlying soil.**



roll-front copper deposits and with oil and basinal brine migration, all carry a mid-Permian to late-Permian age (e.g., 250–200 Ma). Surprisingly, although some Mississippi-Valley-Type deposits are as old as 215 Ma, other periods of Mississippi-Valley-Type mineral formation occurred sporadically over the ensuing 200 million years to a most recent event at 39 Ma (Coveney *et al.*, 1999). There are no known geologic events (i.e., uplift that would cause the migration of basinal fluids) associated with these younger mineralizations. Thus, lacking other controls, the barite roses could have formed in a single event, episodically, or continuously since the end of the Permian, and they may still be forming today.

(3) Why are the barite roses found mostly in soils, and why do they disappear in the Garber Sandstone below the soil horizon?

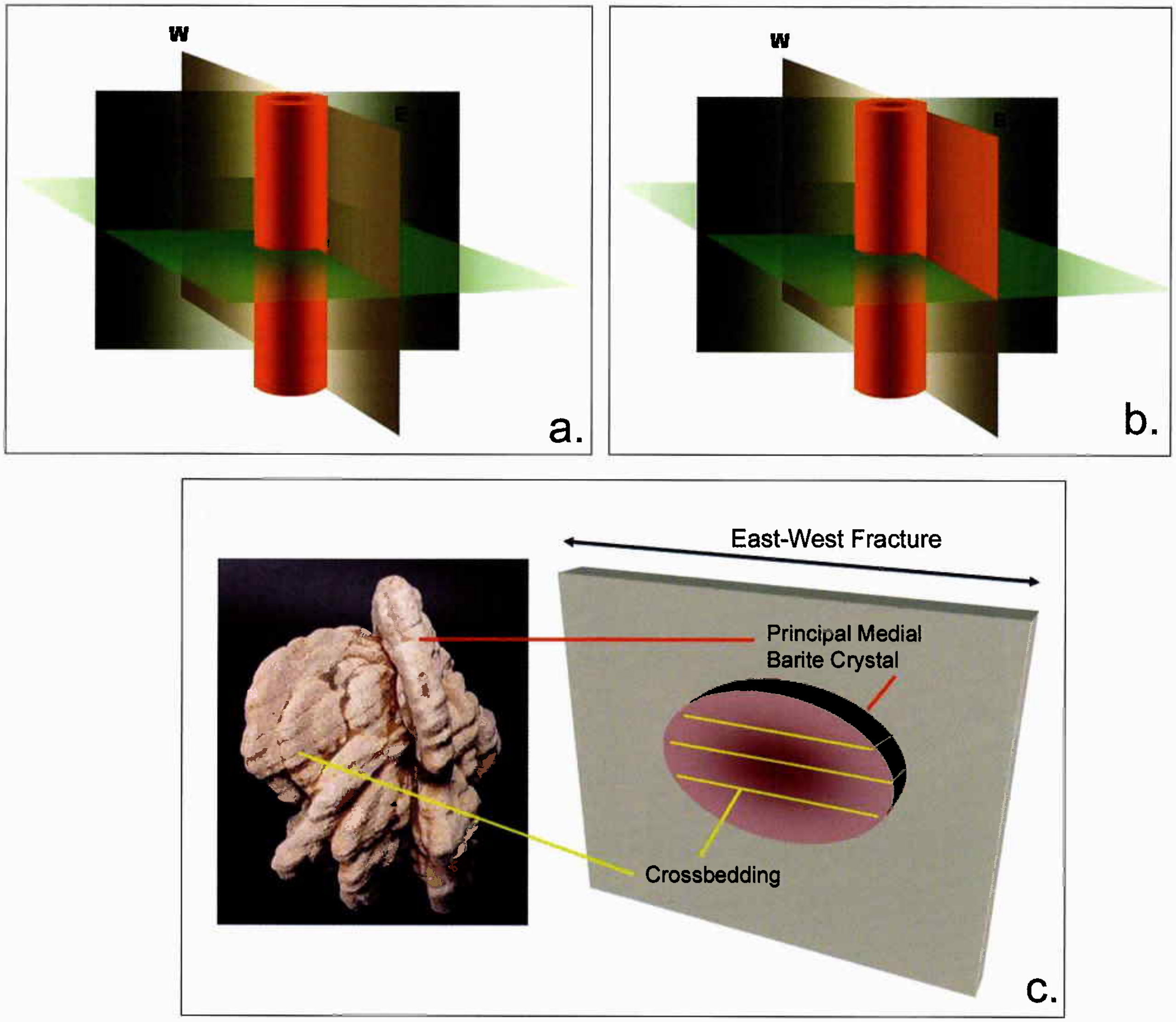
The barite roses formed in the Garber Sandstone. They are not a mineral product of modern soils. The reason that they are abundant in the modern soil zone, but generally absent in the underlying rock, is that they represent an accumulation of erosional remnants. Sedimentary geologists refer to this as a lag deposit or eluvial deposit. The high density and very low solubility of the barite leads the roses to accumulate in soils during the weathering of their host rock, and to remain behind when erosion removes most of the smaller and easily transported weathering products of the sandstone.

Pete Peters, a former vendor of barite roses in Noble, Oklahoma, reports that when he found barite-cemented pipes in soil, they were lying horizontally. The traces of sedimentary bedding that they contain, however, dictate that their original orientation was vertical. Thus, they have fallen over as they accumulated at the soil surface. Peters was mining an erosional lag deposit.

The barite roses are found near the lower (eastern) contact between the west-dipping Garber Sandstone and the Wellington Formation below. Because they are mostly erosional remnants, however, they actually came from the portions of the Garber Sandstone higher in the stratigraphic section, which are now eroded, but would extend toward the west in the subsurface. Exploration for barite roses *in situ* within the Garber, therefore, should be directed toward the west from the current accumulations in modern soils.

(4) How do the barite roses get their shapes?

Radial and rosette habits of crystals are common to many mineral species. The radial habit of growth in three dimensions (e.g., the spherical habit of adamite, rosasite, natrolite, etc.) or in two dimensions (e.g., pyrite "dollars" in shale) entails the nucleation of many crystals at a point source, and growth away from that source in the direction in which each crystal can remain in contact with the solution that nourishes its growth. Radial crystal growth



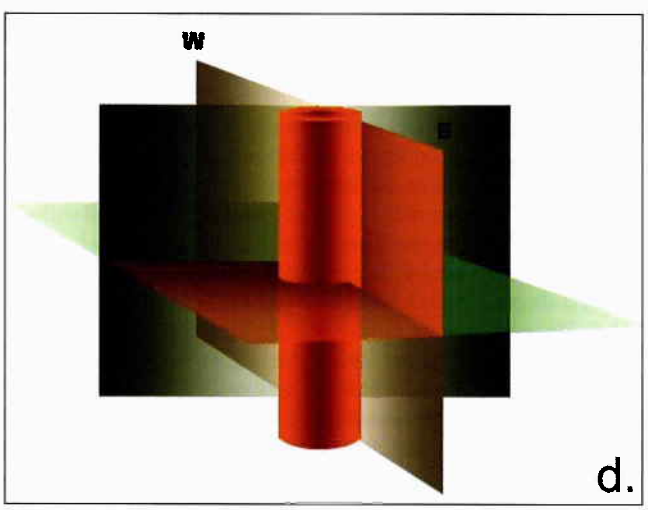


***Figure. 20.* Relations of barite roses to bedding and structure within the Garber Sandstone. (a) The intersection of subvertical east-west and north-south fractures creates a highly permeable zone that becomes cemented with barite (± hematite) pipes. (b) The east-west joints are the main structures that host barite mineralization. (c) In most instances, the large, medial disk of barite that is present in the roses grew along the vertical trace of the east-west fractures. When the medial disk is so oriented, then the angle of cross-bedding in the roses matches that found today in the flat-lying portions of the Garber Sandstone. (d) Mantos of barite formed by the lateral migration of groundwater along exceptionally permeable bedding surfaces in the Garber Sandstone.**

is essentially linear, and not necessarily in the direction of elongation that may be prevalent in euhedral crystals. Corners are the fast-growth directions in any crystals, and when corners grow out, they form lines in space (i.e., linear crystals). Rosettes are similar to radial habits in that a large number of crystals nucleate at a point and grow radially outward, but the crystals develop a tabular habit, which means that they grow along edges rather than just along corners. Linear crystals in radial habits and tabular crystals in rosette habits both reflect conditions of rapid crystal growth from highly supersaturated solutions.

Most barite roses form radial and rosette clusters of crystals. In the radial habit, individual crystals of barite diverge from around a

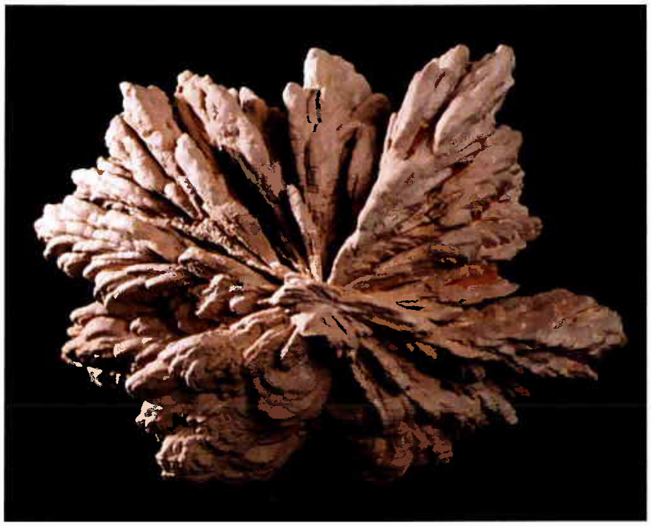


Figure. 21. **A barite rose (51 cm, Cleveland County, Oklahoma) showing radial growth of barite blades off a central axis. On the reverse side, a crudely defined barite rose is evident along the axis of the cluster.**

Figure. 22. **A barite rose (12 cm) from the Lexington Game Preserve, northeast of Lexington, Oklahoma, shows the "fourling" pattern of crystal growth around the axial center of the rose.**

central axis, much like blades around the shaft of a fan (Fig. 21). The rosettes possess the more flower-like habit of crystals (Figs. 1 and 5). Most contain the medial barite disk (parallel to the fracture surface) described above. In some cases, only the central disk develops, and the result is a single, round crystal of barite (Fig. 4). The centers of many roses consist of a conical arrangement of four barite crystals (or four sectors of composite crystals at right angles to one another) that form a square pyramid whose apex is the nucleation center for the rosette at the center of the medial disk (Fig. 22). Barite is not known to twin, and what might be construed as "fourling twins" could be a manifestation of organized habit in an environment that required rapid crystal growth. The "fourling" relationship, however, is prevalent in many barite roses. Where crystallographic directions can be ascertained, the barite crystals that comprise the central "fourling" pattern grew away from the center along the [100] zone (e.g., Fig. 5).

The one peculiarity of Oklahoma's barite roses that makes them most resemble flowers is this: the "petals" of the rose, which consist of individual barite crystals, grew as round disks rather than adopting the tabular orthorhombic crystal forms that are normally present in barite (Fig. 4). In most environments of rapid crystal growth, the corners and edges of crystals grow out in advance of the faces, creating skeletal crystals. For barite, which normally develops a prominently tabular combination of orthorhombic and other forms, fast growth at the corners would yield an "X" or "butterfly" shape, exactly as was produced by Prieto *et al.* (1992) through rapid growth at high supersaturation in silica gel. In the case of the barite roses, growth at the corners of the orthorhombic barite crystals was stunted, which is just the opposite of the normal fast-growth situation.

When growth surfaces or directions are stunted, crystal chemists usually look for an agent, called a "poison," that adheres to the surface of crystals and keeps them from growing by accretion. The probable cause of stunted growth at the corners of the barite roses is poisoning by organic compounds.

I have grown barite crystals at 25°C, 1 atm, via diffusion in an organic gel made from ordinary, sugar-free culinary gelatin. The organic composition of culinary gelatin is not specified, but it is high in water-soluble protein and free of organic fats or carbohydrates. The barium source was $BaCl_2$ solution, and the sulfate source was $MgSO_4$ solution, with three different concentrations used (25 wt%, 12.5 wt%, and 6.25 wt% each of $BaCl_2$ and $MgSO_4$ in aqueous solution). Barite grew in the zone of solution mixing within the gel (Fig. 23). Crystals on the barium-rich side of the mixing zone tended to be round in habit (Figs. 23a–c), whereas those on the sulfate-rich side developed more of the tabular orthorhombic forms that barite normally adopts (Figs. 23d,e). At the highest solute concentration, the rose-like rounded shapes of barite changed to those of the "X" or "butterfly" skeletal habit, though with unusual reentrants and rounded growth steps.

The barite crystals formed in this organic gel produced crystal habits and radial aggregates that are highly rounded. Some individuals formed radial and rosette clusters that grew off one side of a starting basal crystal (same as the "medial" crystal of the roses). It is evident that barite growth in an organic hydrogel produces crystal habits and aggregates that bear a striking resemblance to the barite roses, and these are wholly unlike the barite crystal morphologies observed when organics are removed from the gel or growth medium (Prieto *et al.*, 1992).

(5) How did the barite roses form?

Barite roses grew in the subsurface along fractures and permeable bedding directions away from those fractures in the Garber Sandstone. Though the barite must have been precipitated from an aqueous solution, water-soluble organic components are specifically implicated in the development of the rounded shapes of the crystals.

In this low-temperature environment, barite is one of the most insoluble minerals known (Putnis *et al.*, 1995). The vanishingly low solubility of barite explains why the roses can survive deep weathering of the Garber Sandstone, and why the roses can persist for possibly geologic-scale time durations in the modern-day soils. The low solubility of barite, however, poses problems for producing large concentrations of barite in a narrowly defined zone of fluid flow in the Garber.

In many geologic settings, high concentrations of normally insoluble minerals arise from mixing between solutions from dif-

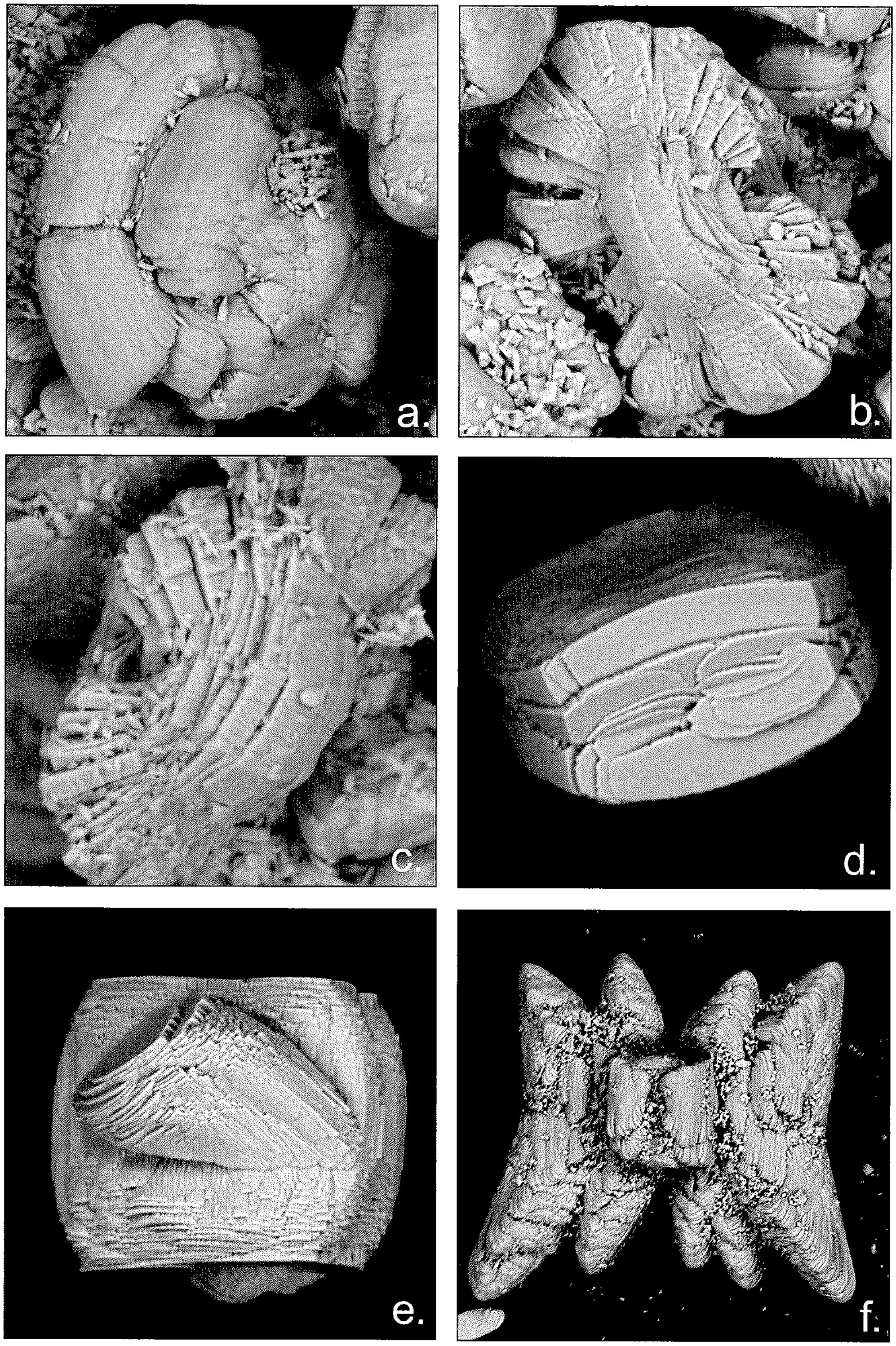


Figure. 23. **Backscattered electron images of synthetic barite crystals and rosettes grown by diffusion in organic gels. (a) The rounded habit of a single barite crystal. (b) A radial array of rounded crystals about a central core. (c) A rosette formed by a concentric array of barite crystals off a central medial crystal. (d) A high degree of curvature is evident in the stepped growth of this barite crystal; except for a few platelets at the end, this appears to represent a single crystal. (e) Overall rounding of individual crystals occurs because of the decreasing radius of growth steps in the [100] direction of barite growth. Interpenetrating crystals like these two are common in the experiments, but the angular relationship between the main crystal and its epitactic intergrowth are not the same as in the barite roses. (f) A single, stepped barite crystal exhibits the "butterfly" habit of accentuated growth along the [110] directions through the crystal; this is the habit anticipated by rapid growth along the corners of the crystal. Other reentrants into the crystal are unexpected consequences of rapid growth in the organic gel.**

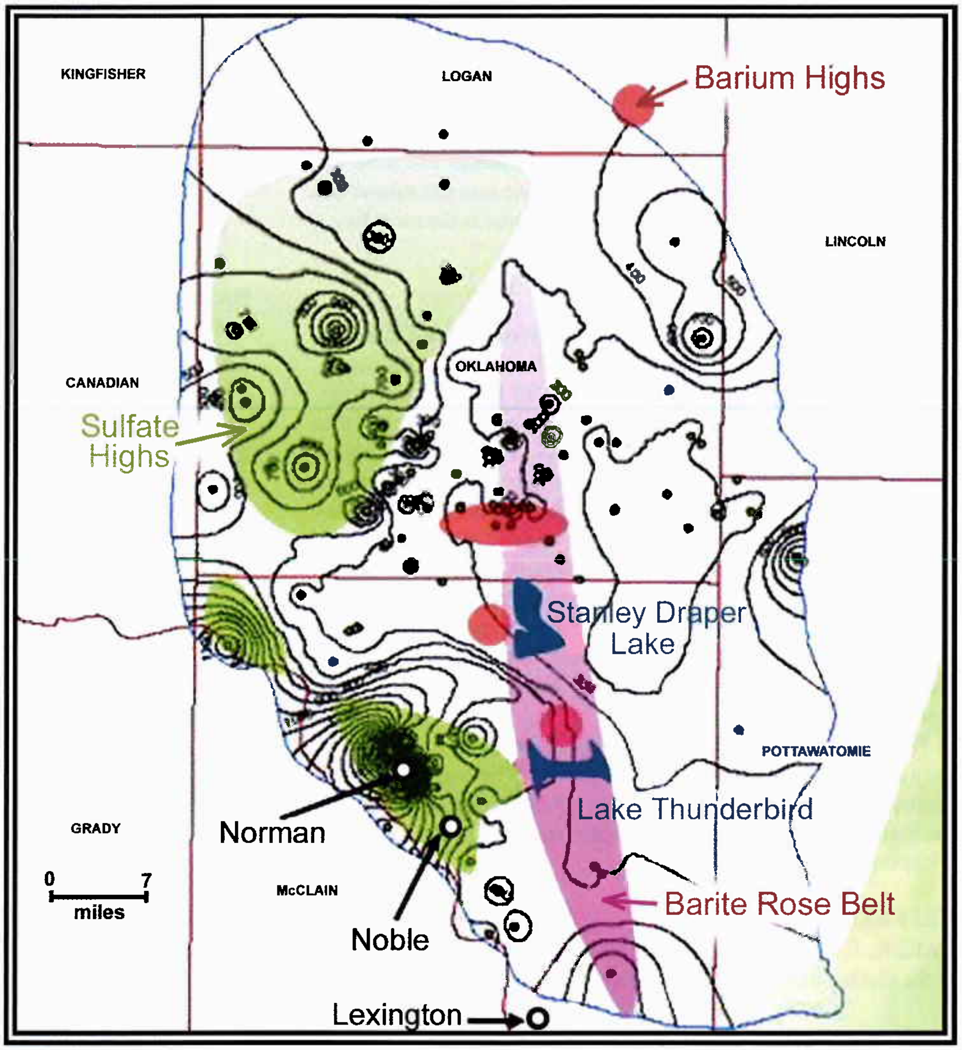


Figure. 24. **A map of total dissolved solids in subsurface wells of the Central Oklahoma Aquifer, also known as the Garber-Wellington Aquifer (Oklahoma Department of Environmental Quality). Superimposed on the map are regions of sulfate (green) and barium (red) highs from Parkhurst *et al.* (1994), as explained in the text, and the trace of the barite rose belt, in which the color saturation correlates with barite rose abundance.**

ferent sources, each carrying some but not all of the constituents needed to precipitate the insoluble mineral. In this case, the Garber Sandstone, which is a highly porous and permeable aquifer in central Oklahoma, could have carried solutions from different sources—one rich in barium and the other rich in sulfate—that mixed within fractures and precipitated barite. Within the modern Central Oklahoma Aquifer (Fig. 24), a broadly north-south band of sulfate-rich groundwater is distinct from but adjacent to a narrower band that contains anomalously high Ba (>1 ppm) in well water. Whether or not barite is precipitating today along the flow boundary between these two regions, the existence of spatially separate highs for Ba and for sulfate make the mixing model a viable one and hence a potential answer.

Barium and sulfur could have been carried together by groundwater in which the sulfur was reduced to sulfide. Deep oilfield brines in Oklahoma contain appreciable quantities of reduced sulfide as H_2S. The brines are acidic, which causes H_2S to dissociate to reactive HS^-. If deep oilfield brines containing heavy salt components (e.g., Ba, Br and I) and reduced sulfur (as HS^-) rise along fractures toward the surface, they will eventually encounter the vadose zone of oxygenated surface water. Upon oxidation of sulfide to sulfate, barite would precipitate immediately. High concentrations of barite could form at that interface between reduced and oxidized groundwater. The deep oilfield brines also contain water-soluble organic compounds, such as acetates and oxylates. I hypothesize that these have acted as organic poisons on selective barite growth surfaces (most notably, the {110} faces), leading to the formation of round crystals.

(6) Are the barite roses still growing?

We now know that the barite roses are younger than the depositional event that produced the Garber Sandstone. We do not know when (or precisely how) the quartz grains of the Garber became so angular, nor when the modern east-west and north-south fracture sets developed in the rock. Growth of the barite roses, however, postdates both of these events. The vast majority of the barite roses are not modern, either. They have been present in the soils of this region since they were eroded from the Garber Sandstone.

Modern groundwater in Oklahoma and Cleveland Counties is sulfate-rich (Fig. 24), with marked highs at locations beneath Norman, and Noble (Parkhurst *et al.*, 1994). Areas where barium anomalies exceed 1 mg/L of Ba (>1 ppm Ba) lie just to the east of the sulfate highs, and these few locations where Ba exceeds 1 ppm coincide with the trace of the rose rock belt. The highs in the sulfate map are likely to represent upwelling of deep, sulfur-rich water along highly channelized fracture zones. The high sulfate content (>250 ppm dissolved SO_4^{2-} in the green areas of Fig. 24) is sufficient to precipitate barite and hence keep the Ba concentrations below 1 ppm (cf. Putnis *et al.*, 1995). Therefore, barite could be precipitating as sulfide-rich waters rise into the aerated vadose zone near the surface, or else at the boundary of mixing between sulfate-rich and Ba-rich groundwaters. At least to a small degree, barite roses could be growing today.

At Zodeltone Mountain in southwestern Oklahoma, artesian springs are depositing barite at the surface today. This is one of only four springs known to be precipitating barite at the surface anywhere in the world (Sanders, 1998). The chemistry of water samples from the spring contains a component of Oklahoma's deep oilfield brines (Sanders, 1998), which are rich in Ba (~600 ppm), and are highly reduced, with 99.99% of total dissolved sulfur as reduced HS^- rather than as oxidized SO_4^{2-} (Collins, 1975). Zodeltone is a likely modern analog to the organic-rich springs that have fed (and may still feed) barium and reduced sulfide into the subsurface rocks in central Oklahoma. At present, this model is the most likely scenario for the formation of the barite roses.

CONCLUDING REMARKS

Barite roses are so plentiful in the soils from eastern Oklahoma County to the southern tip of Cleveland County that their supply should be regarded as limitless. In almost all instances, however, they occur on privately-owned land that is not in production and that is closed to collecting. The current owners of the historic localities cited above are adamant in their refusal to accept or even consider requests for digging. One problem with the market for barite roses is that the vast majority of them are small and rather poorly formed, and hence they have little value except in bulk quantities. Another problem is that most land owners are unaware of potential markets for selling barite roses outside of their own immediate locations. If all of your neighbors have barite roses, then you have no local market, and this fact and the historically low prices for barite roses conspire to deter digging and selling.

When they are good, however, the barite roses can form particularly aesthetic sculptural clusters and groups. Whether as individual rosettes, pairs, or an endless diversity of arrangement in clusters, the best of the barite roses are distinctly beautiful, and distinctively Oklahoman.

REFERENCES

BAKER, F. E. (1951) A mechanical and petrographic analysis of the Garber Sandstone in Cleveland and Pottawatomie Counties. Unpublished Masters thesis, University of Oklahoma, Norman, OK, 68 p.

COLLINS, G. A. (1975) *Geochemistry of Oilfield Waters. Developments in Petroleum Science 1.* Elsevier Scientific Publishing Company, New York, 496 p.

COVENEY, R. M., Jr., RAGAN, V. M., and BRANNON, J. C. (1999) Radiometric ages of ancient hydrothermal flow and hydrocarbon transport in the Midwest. (abstr.) *Geological Society of America Abstracts with Programs*, **31** (7), p. 31.

HAM, W. E. and MERRITT, C. A. (1944) Barite in Oklahoma. *Oklahoma Geological Survey Circular* **23**, 44 p.

KNERR, E. B. (1898) Silico barite nodules from near Salina, Kan. *Transactions of the Annual Meetings of the Kansas Academy of Science*, **1897**, 43–44.

PARKHURST, D. L., CHRISTENSON, S. C., and SCHLOTTMANN, J. L. (1994) Ground-water-quality assessment of the Central Oklahoma Aquifer, Oklahoma; analysis of available water-quality data through 1987. *U.S. Geological Survey Water-Supply Paper, Report:* **W 2357-B**, B1–B74.

PRIETO, M., PUTNIS, A., ARRIBAS, J., and FERNANDEZ-DIAZ, L. (1992) Ontogeny of baryte crystals grown in a porous medium. *Mineralogical Magazine*, **56** (4) (385), 587–598.

PUTNIS, A., PRIETO, M., and FERNANDEZ-DIAZ, L. (1995) Fluid supersaturation and crystallization in porous media. *Geological Magazine*, **132** (1), 1–13.

SANDERS, W. A. (1998) Rate and mechanism of barite mineralization at Zodletone Mountain, southwestern Oklahoma. Unpublished Masters thesis, University of Oklahoma, Norman, Oklahoma, 150 p.

UNDERWOOD, T. B. (1956) Cherokee legends and the trail of tears. *Nineteenth annual report of the Bureau of American Ethnology.* Stephens Publishing, Asheville, North Carolina, 32 p.

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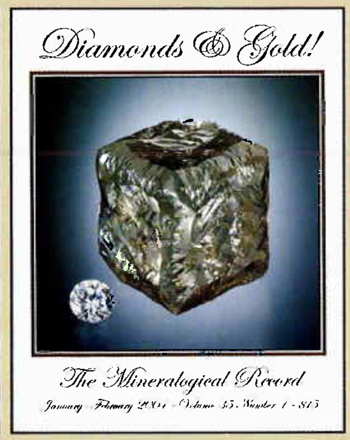

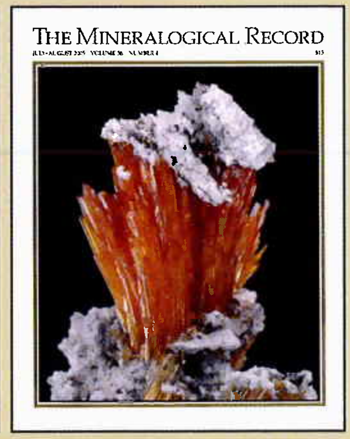

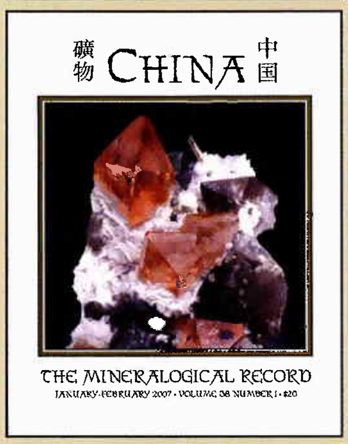

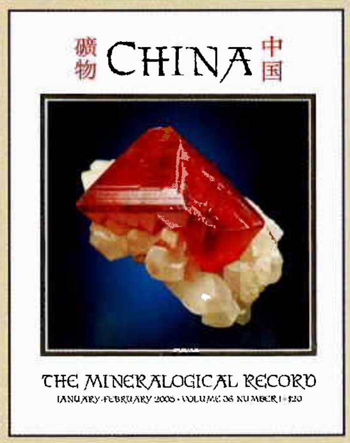

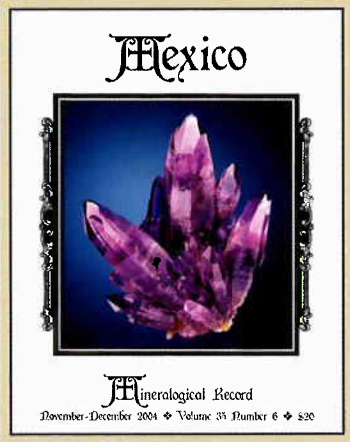

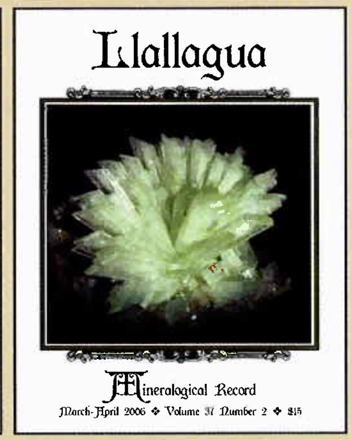

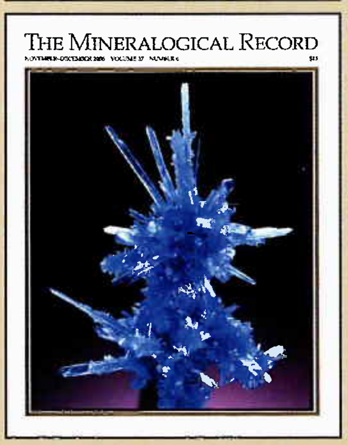

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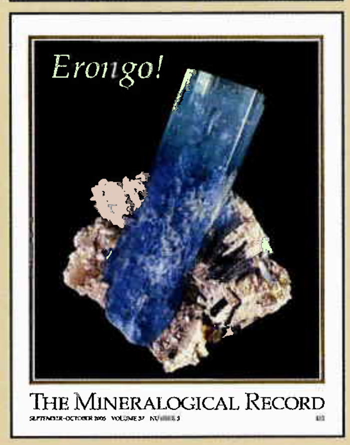

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