Barite Deposits in the Cartersville Mining District and the Stone Mountain Pluton

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Barite Deposits in the Cartersville Mining District and the Stone Mountain Pluton

A Field Trip of the Southeastern Geological Society

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Introduction and Acknowledgments
The Southeastern Geological Society returns to Georgia—first to the Cartersville Mining District, then to the Stone Mountain Granite pluton. On Friday evening (3 Nov) we will enjoy dinner in Cartersville followed by a presentation by New Riverside Ochre mining geologist, Stan Bearden. On Saturday morning we will visit one of the NRO quarries in Emerson to collect barite—a high-density sulfate mineral with numerous industrial applications. After lunch we visit the nearby Tellus Museum, new home for famous Weinman Mineral Museum collection, and many spectacular fossil displays. In the afternoon we head south on I-75 to the East Quarry of Stone Mountain, Georgia, where we will see fantastic evidence of the magmatic history of this granitic pluton (stock) and geomorphic monadnock (and a great photo-op for geologic features and beautiful fall landscapes of the Appalachian Piedmont!).

Special thanks are owed to Mr. Stan Bearden of New Riverside Ochre for agreeing to host SEGS and geology students from Northwest Florida State College, and for meeting with us on Friday evening for dinner and an introduction to barite and ochre mining in the Cartersville Mining District. This is not the first time Mr. Bearden has opened the New Riverside Ochre mines to students and geologists. Thank you, Stan! Thanks also to Ms. Terry Commeau of NWFSC for assisting in the production of this field guide. This is the third SEGS guide book Terry has formatted and printed. Thanks again, Terry!

STOP 1: New Riverside Ochre Company—Barite and Ochre Mining in the Cartersville Mining District
The Cartersville Mining District (CMD) has been the source of a variety of economic minerals for more than 175 years, and is the oldest, continuously active mining district in the southeastern United States. Ores include gold; iron; manganese oxides; specular hematite; graphite; barite; and varieties of the mineraloid limonite—ochre (goethite) and umber (a Mn-rich limonite). The mineral wealth of the CMD is due in part to the geological good fortune of its location at the confluence of the Valley and Ridge, Blue Ridge, and Piedmont provinces of the Southern Appalachians. The area is bounded by several faults, including the Cartersville/Great Smoky Fault.

Mining geologist Stan Bearden of New Riverside Ochre Company will brief us on barite and ochre mining on Friday evening, and host us at the Emerson Barite Mine on Saturday morning. New Riverside Ochre has engaged in open pit mining for barite and limonite in the Cartersville Mining District since 1911. Both ochre and barite are residuum products, associated with deep weathering of the Cambrian Shady Dolomite (Figure 1). Archaeocyathid sponges, hyoliths, and brachiopods can be found in some areas in the Shady residuum.

The unusual mineral barite (barium sulfate, $\text{BaSO}_4$) is known for its softness ($H = 2.5-3.5$) yet surprisingly high density (specific gravity = 4.5), an unusual quality for a light-
colored mineral. The high density of barite is the key to its many industrial and economic uses. Most barite is used in oil wells as a heavy drilling mud, but it is used in the production of glass, rubber, paper, paints, ceramics, brakes, TV screens, etc. It is said that barium products have more than 2,000 uses! Ochre and umber also have many applications, but are currently mined primarily for use as a pigment (for earth tones) in masonry and roofing materials. Additional information on barite and ochre mining at New Riverside Ochre has been provided by Mr. Bearden in several articles, which are included as an appendix to this field guide.

Figure 1—Profile of Cambrian strata and residuum in the Cartersville Mining District. Both limonite and barite occur in the residuum over deeply weathered dolostone (from Kesler, 1950, fig. 5).

STOP 2: Tellus Museum
The Tellus Museum opened in 2008 on the site of the old Weinman Mineral Museum. Tellus displays the mineral collection in its Weinman Gallery, but has greatly expanded it interpretive and educational programs.
STOP 3: The Stone Mountain Pluton
Stone Mountain Park is located 16 miles east of downtown Atlanta. We will be approaching it on I-75 southbound (from Cartersville), taking I-285 east to Highway 78 East (Exit 39 B on I-285), to the park.

Physiography and Geomorphology. Stone Mountain is a granite monadnock (an isolated, erosion-resistant rock formation standing prominently above a lower terrain) and exfoliation dome that rises about 700 feet (213 m) above the deeply eroded, high-grade metamorphic terrain of the inner Piedmont Province of the Appalachian Mountains (Figure 2). The summit stands at 1686 feet (514 m) above sea level (Figure 3). The asymmetrical, elongated dome is oriented in a N70W direction, and covers approximately 2 km² (1.2 mi²) in plan, with a circumference of about 5.4 km (7 miles). The dome is nearly vertical on its north face, more gently sloping on its western face, and moderately steep on the eastern and southern faces. The lack of significant tectonic jointing (not to be confused with exfoliation jointing) is suspected as being a major reason for the development of the monadnock. Abundant joints would have greatly facilitated deeper weathering of the structure, and indeed deeply-weathered granite is found both north and east of Stone Mountain Park.

Figure 2—Portion of USGS Stone Mountain Quadrangle (7.5 Minute Series Topographic Map), showing the Stone Mountain monadnock, with a maximum elevation at the summit of 1686 feet above sea level.
Figure 3 — Two brass benchmarks from the top of Stone Mountain. Note the original 1873 date of the plate on the left.

The dome shape of the mountain results from a mechanical weathering process called pressure-release fracturing in which the burial pressure of overburden rock is relieved by erosion. As the granite is exhumed, it simultaneously rises isostatically to the surface, expands, and fractures. This fracturing, called exfoliation (or dilation jointing) results in the spalling-off of thin sheets of granite (like layers of an onion). The jointing is facilitated by ice-wedging and biologic weathering (tree roots) as well. Exfoliation is thought to be the primary weathering process that shaped the otherwise unjointed and massive granite. Even the large boulders on the mountain are the result of exfoliation (with chemical weathering sculpting the rounded edges of the boulders). It is estimated that the granite has been uplifted up to 12 km (more than 7 miles) over the past 70 million years.

Chemical and biological weathering are also very evident across the top of the mountain. One of the prominent weathering features across the mountain is broad, shallow, solution pits. Still often rumored to have resulted from lightning strikes, they are rather the cavities left under exfoliation sheets. These naturally hold water, which facilitates chemical weathering and the production of sediment residue. This allows soil formation and a variety of unique lichens and plant species to colonize these microhabitats. Fall usually hosts the blooming of yellow confederate daisies.

Weathering Sequence at Stone Mountain. Sampling of the Stone Mountain Granite in various stages of weathering can provide an outstanding suite of samples to illustrate progressive weathering of granite into sediment. Such a collection of hand-samples is
invaluable in introductory college courses and educational demonstrations (K-12, Scouts, etc.). (1) *Fresh granite* is best collected from an exfoliation sheet in East Quarry. (2) *Partially-weathered granite* that is easily crumbled by hand, can be found across the top of the mountain (during your walk up or down the western face). (3) *Completely weathered granite* (regolith) is common in solution pits, where dried rainwater puddles typically leave clay, mica, and sand-sized quartz crystals (a result of hydrolysis, a form of chemical weathering). It can be easily scooped up and collected in a zip-lock plastic bag. (4) *Pure quartz sand* is a final sample to be added to this sequence. At Northwest Florida State College, I use some of the sugar-white quartz sand from the beaches of the Florida Panhandle. The weathering sequence of: fresh granite—partially weathered granite—completely decomposed granite—quartz sand, shows how the resistant quartz (H = 7) is liberated from granite, and transported from its source by rain and rivers, and ultimately ends up at the coast of the Gulf of Mexico or Atlantic Ocean. When the feldspars and micas are chemically dissolved or reduced to clay, quartz remains. This is an especially useful demonstration because it is popularly assumed that sand is merely the product of abrasion of large rocks, to small rocks, to sand. In fact, chemical weathering releases quartz crystals from their igneous or metamorphic source rock, to produce siliciclastic sediments for transport. In addition, reasonably-sized and thin *exfoliation sheets* (~8-14 inches in size, or larger) are easily collected in the East Quarry. These are also a very informative sample for the educational demonstration of rock weathering.

*Age and Origin.* The exact age of granite is not certain, but various radiometric age determinations give a range between 281 to 325 million years. This disparity may reflect various magmatic sources, fractionation history, and intrusive events, but all the dates fall within those of other Piedmont granites and their late Paleozoic (Pennsylvanian-Permian) emplacement during the Appalachian Orogeny and final assembly of Pangaea.

The Piedmont Province of the Southern Appalachian Mountains is a metamorphic terrane bounded by the Brevard Fault Zone to the north and the Coastal Plain to the east and south. Within the Piedmont are many post-metamorphic plutons of slightly varying age. Stone Mountain belongs to a slightly older group of plutons found in the Inner Piedmont, near the northern boundary of the terrane. These Appalachian plutons are much smaller than those of most tectonic regions (e.g., the Andes or Sierra Nevada), and are technically classified as *stocks*. The Stone Mountain pluton formed by relatively low temperature (650-725°C), water-rich *anatexis* (i.e., partial-melting) of crustal rock. Isotopic and mineralogical data suggest that the protolith from which the Stone Mountain pluton formed was metasedimentary.
It is estimated that the pluton was emplaced at a depth of 12-16 km, although the magma itself may have its origins even deeper, from 22 to 28 km depth. One or two intrusion events have been postulated based on the occurrence of granitic autoliths (inclusions) and cross-cutting granitic dikes (both of which vary only slightly in composition from the host granite). The high-grade metamorphic country rock into which the granite intrudes is primarily a biotite-plagioclase gneiss, with some interlayered amphibolite and lesser mica schist. This country rock is easily observed in the largest xenolith in East Quarry (see cover of field book). The Stone Mountain intrusion extends several miles further east of the mountain, proper (Figures 4, 5). The entire pluton is in fact very sheet-like, and is thought to have been emplaced from the east by a growing fold system, that propagated in a N65W direction (parallel to the long axis of the mountain). It is postulated that the granite was intruded as a “crystal mush” between thin layers of simultaneously-folding country rock. Magma intrusion broke the folding layers of country rock, incorporating xenoliths into the intrusion. Nearby, Mesozoic age diabase dikes (associated with the rifting of Pangaea) intrude the Stone Mountain granite and surrounding lithologies.

Figure 4—Geologic map of the Stone Mountain area showing the distribution of Stone Mountain Granite, Lithonia Gneiss, and Triassic-age diabase dikes. From Atkins and Joyce (1980).
Mineralogy. The granite is composed of several minerals: 26-43% oligoclase (a pale, Ca-Na-rich plagioclase), 16-34% microcline (a K-feldspar), 30-37% quartz (clear crystals), ~9% muscovite mica (flaky, olive crystals), and ~1% biotite mica (flaky, black crystals). Accessory mineral include epidote, apatite, tourmaline, sphene (titanite), zircon, and garnet. Petrographically, Stone Mountain is a light gray (leucocratic, or pale color), fine-to medium-grained granite (on quartz—K-feldspar—plagioclase ternary diagrams, the SMG plots near, and slightly within the granodiorite field).
A prominent and popular feature, especially common at the top of the mountain and in East Quarry, are “cat paws”—small oval clusters of black tourmaline (schorl) crystals (with some quartz), surrounded by a “bleached” white zone. The white zone consists of an inner zone of quartz and feldspar; and an outer zone of quartz, feldspar, and muscovite. Cat paws (or, “tourmaline-rich clots”) may be metasomatic in origin. As tourmaline crystals formed (perhaps in bubbles or pockets), Al, Fe, and Mg migrated by solid-state diffusion into the growing tourmaline crystals, thus leaching the immediate area of these elements and creating the white halo. In some areas the cat paw tourmaline clusters may be slightly more resistant to chemical weathering, and display some relief (Figure 6).

**Figure 6**—Surface of Stone Mountain Granite showing raised relief of slightly weathering-resistant “cat paws”.

*Triassic Diabase Dikes.* Located several miles east of Stone Mountain is a dike swarm of diabase intrusions (see Figure 4) of Triassic age. These are common along the entire eastern seaboard of the U.S., and their origin is related to the initial rifting of the Pangaean supercontinent. A small, deeply-weathered diabase dike is present in Stone Mountain park on the eastern side of the mountain, near the intersection of Old GA 78 and Robert E. Lee Boulevard (on Old 78, about 500 feet east of R.E.L. Blvd., but the road is restricted). The dike is deeply weathered to an orange brown by iron-oxidation, and is in sharp contrast to the deeply-weathered, white saprolite of the granite.
East Quarry. Because of its recent mining history, the East Quarry (Figure 7) is far less weathered than most of the mountain so it displays some outstanding and easily accessibly features that clearly demonstrate the magmatic origin of the pluton, including flow structures and folding. At the entrance of the quarry is a walkway and informative exhibit on the history of quarrying this stone called, Raising a Ledge. Granite was quarried here from as early as 1845, and continued until the 1970’s. The exfoliated granite slabs are rather easily quarried from the surface. Initially used mostly for gravestones and monuments (especially during the Civil War), the uniformly-textured stone was later valued for ornamental construction of buildings (at first, for rebuilding the war-ravaged South). Much Stone Mountain Granite was quarried for post-Depression era projects of the Works Progress Administration. The granite adorns many buildings around the country. It is said that more than 7.6 million cubic feet of Stone Mountain Granite has been removed from the mountain—sufficient to provide enough 1-foot wide paving stones to reach from the North Pole to the South Pole (12,444 miles).

Figure 7 — View of the eastern side of Stone Mountain, roughly half way to the summit. The abandoned East Quarry, where most granite slabs were cut, is in the background area near the tree line.
Plutonic features in East Quarry include the following (see Figure 8):

(a) **Flow banding structures**—these are stripes on the granite that formed when the granite was molten and flowing in the magma chamber;

(b) **Quartz and granite dikes** within the granite—these indicate multiple intrusions and a complex crystallization and emplacement history. Most of these are in the northern part of East Quarry on the path up from the *Raising a Ledge* display. This is the oldest granite. Look for cross-cutting and offsets (*microfaults*) in the dikes, and granitic *autoliths* (granite inclusions, thought to be *in situ*/within-pluton, in origin);

(c) **Xenoliths**—Xenoliths (“foreign” rock inclusions) are common in East Quarry. The largest and most prominent is a biotite-plagioclase gneiss, clearly derived from the country rock (see cover of field guide). But most xenoliths are lens-shaped, composed of biotite schist, and are oriented parallel to magmatic flow structures. Xenoliths plunge up to 30°, with bearings of N60E to S5W;

(d) **Flowage folds**—these are prominent at the south end of East Quarry. Some are doubly-plunging. Their orientation indicates that this folding event came from the east;

(e) **Pegmatite dikes**—locally cross-cut the otherwise massive granite; and

(f) **Tourmaline aplites**—thin veins with small crystals (aplite) of tourmaline in a quartz-feldspar groundmass (much like the “cat paws”, but vein-like).
Confederate Hall and West Quarry

Confederate Hall is at the foot of the west side of the mountain, and houses an exceptional natural history museum and interpretive center. The comparatively flat area at the base of the west side of the mountain is the old West Quarry, the location of several former quarries. Immediately east of the railroad station and track marks the beginning of the 1.6-mile Walk Up Trail to the top of the mountain. The first 600 feet or so of the trail displays many dikes, some of which are cross-cutting. Like those in the East Quarry, most are composed of aplite, a very fine-grained (but still phaneritic) form a granite, but there are common pegmatitic dikes as well. Some of the dikes have sharp boundaries and are thought to have been intruded within brittle fractures as the granite crystallized. Other dikes seem to have more diffuse borders, suggesting that some intrusions were into a softer, still cooling/crystallizing granite.

About 30 m (100 ft) up the path from the railroad track, pear-shaped flow folds are visible (especially on darker, wet days, when glare is reduced). Vertical joints and solution pits are common in the West Quarry area. Dikes within the otherwise massive granite must have intruded into “freshly” crystallized granite. Within the magma chamber, magma that was in contact with the surrounding country rock probably cooled and crystallized first. As it cooled slightly, shrinkage fractures would have formed, and fresh magma could have intruded these new openings, forming dikes. Similar dike injection might have occurred throughout the pluton during various stages of crystallization. Schlieren, elongated, streaks of biotite crystals are found locally and appear to grade into xenoliths. They are regarded as stretched xenoliths (rather than magmatic in origin), and in some cases can be traced to their “parent” xenoliths.
References


**Appendix — Articles by Stan D. Bearden, New Riverside Ochre Company**
PROCEEDINGS

24th FORUM ON THE GEOLOGY OF INDUSTRIAL MINERALS

MAY 2-5, 1988

GREENVILLE, SOUTH CAROLINA

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OCCURRENCE AND EXPLOITATION OF ORE DEPOSITS IN THE SHADY DOLOMITE, CARTERSVILLE MINING DISTRICT, GEORGIA

BEARDEN, Stan D., New Riverside Ochre Company, P.O. Box 367, River Road, Cartersville, GA 30120

ABSTRACT

The Cartersville district is the oldest continuously active mining district in the southeastern United States and has recorded production of gold, iron ore, manganese, specular hematite, ochre, umber, barite and graphite. Of these materials, only ochre, umber and barite currently are produced. These minerals are extracted from the Shady Dolomite (Cambrian). Production from this mining district places Georgia first in the nation in ochre and in chemical- and filler-grade barite.

INTRODUCTION

New Riverside Ochre Company (NRO), established in 1911, is a privately owned mining organization engaged in the open pit mining and beneficiation of barite and iron oxide clays. The company has mines located in the Cartersville mining district (Figure 1).

This is the oldest continuously active mining district in the southeastern United States. Both ores are mined from residuum of the Shady Dolomite of Cambrian age. Essentially all of the barite concentrate is sold to Chemical Products Corporation (CPC) which is now the only major producer of barium chemicals in the United States. Except for the small intermittent mining of iron oxides by Hoover Color Company in Hiwassee, Virginia, NRO is the only producer of iron oxide clays in the United States. The iron oxide clays are used as pigmenting agents in masonry products.

Bartow County is second only to Cherokee County in having the greatest number of reported mineral occurrences in Georgia (Cherokee-52; Bartow-43; Cook, 1978). Acknowledgement of mineral wealth in this area predates 1832 when the Georgia legislature authorized a large portion of land acquired from the Cherokee Indian Nation to be surveyed into lots of 40 and 160 acres. The 40 acre lots were to be squares of 1/4 mile on each side and the 160 acre lots were to be squares of 1/2 mile on each side. Lands which were thought to have valuable mineral resources were surveyed into the smaller lots. All land lots in the southern third of what is now Bartow County were surveyed into the smaller 40 acre lots (Mahan, 1976). The surveys of the early 18th century were correct in their assessments of this portion of the state because since their time ores of gold, iron, manganese and barite have been mined. The Cartersville mining district has produced minerals for more than 140 years. NRO has been an active participant for over 70 years.

Table 1. Production of minerals from the Cartersville mining district (Kessler, 1950).

<table>
<thead>
<tr>
<th>MINERAL</th>
<th>DATE PRODUCTION BEGAN</th>
<th>SHORT TONS PRODUCED</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOLD</td>
<td>1835</td>
<td>?</td>
</tr>
<tr>
<td>IRON ORE</td>
<td>1840</td>
<td>50,000,000</td>
</tr>
<tr>
<td>MANGANESE ORE</td>
<td>1866</td>
<td>500,000</td>
</tr>
<tr>
<td>SPECULAR HEMATITE</td>
<td>1875</td>
<td>60,000</td>
</tr>
<tr>
<td>OCHRE AND UMBER</td>
<td>1877</td>
<td>500,000</td>
</tr>
<tr>
<td>BARITE</td>
<td>1894</td>
<td>5,000,000</td>
</tr>
<tr>
<td>GRAPHITE</td>
<td>1907</td>
<td>?</td>
</tr>
</tbody>
</table>

Ochre, umber and barite are the only minerals in the above table which currently are mined. The ochre and barite mined from the Cartersville mining district ranks Georgia first and second, respectively, in the production of these mineral commodities in the United States.

GEOLOGY OF THE MINING DISTRICT

The area containing the ochre and barite deposits is underlain by Lower to Upper Cambrian rocks and their weathered residua. These rocks, in ascending order, are the Chilhowee Group, the Shady Dolomite, the Rome Formation, the Conasauga Group and the Knox Group (Figure 2).

The rocks of the Chilhowee Group are the oldest present in the Valley and Ridge of Georgia. The upper...
Figure 2. Generalized stratigraphic section in which the ochre and barite deposits occur.

portion of the Chilhowee Group consists of the Weisner Formation and underlying Wilson Ridge Formation. This succession has been interpreted (Mack, 1980) as a marine transgressive phase that brought crossbedded and horizontally laminated beach-barrier island sands and conglomerates (Weisner Formation) over tidal flat sediments (Wilson Ridge Formation). This group is more than 1,000 feet thick in the Cartersville mining district, and the base is not exposed. The Weisner Formation is most resistant to weathering and is responsible for the ridges that characterize the area. Rocks in this group have undergone low-grade metamorphism.

The Shady Dolomite conformably overlies the Weisner Formation. The boundaries of the Shady Dolomite in the Cartersville area are subject to some disagreement. Kesler (1950) and Reade and others (1980) believed that the Shady Dolomite should be restricted to a basal, thin, black or dark-gray, fine-grained dolostone having paper-thin shale lamellae. In their interpretation, Reade and others (1980) placed the overlying gray dolostone and interlayered dolostone and shale in the Rome Formation. In contrast, Cressler and others (1979), and this author, place all of the dolostones above the Chilhowee and below the Rome shales in the Shady Dolomite. This writer maintains that the Shady Dolomite consists of three distinct units.

1) The oldest unit is the limonitic horizon currently mined as ochre. This ore zone appears to be a primary stratiform deposit which conformably overlies the Weisner Quartzite of the Chilhowee Group (Bearden, 1981). It is lenticular and, therefore, not present everywhere. The weathered residuum from this unit is a ferruginous clay horizon which is texturally and mineralogically distinct from the dolomitic residuum of the younger units. Manganese oxides are common throughout this unit and are concentrated in the upper portion. Therefore, the most desirable light yellow ochres which have lesser amounts of MnO₂ are always found at or very near the Weisner-Shady contact.

2) The middle unit is thin, black or dark-gray, line-grained dolostone having paper-thin shale lamellae. This middle unit corresponds to Unit 3 of Reade and others (1980).

3) The youngest unit of the Shady Dolomite is the primary source of residual barite deposits. It is a light-gray dolostone and is the same unit as Unit 4 of Reade and others (1980).

Archaeocyathids have been reported in both dolostones described above as the middle unit and the youngest unit. A paleoenvironmental reconstruction of the Shady Dolomite based on the Archaeocyatha has concluded that the water depth of the depositional basin was about 100 meters (Maples, 1983).

Suggestions on the source or sources of the barium containing fluids responsible for barite precipitation will not be presented here. Fluid inclusion studies have produced support of a hydrothermal replacement with solutions in the temperature range of 125 to 300°C. Barite mineralization in the district is considered to have taken place at a depth of from 5,000 to 8,000 feet (Rife, 1971).

The Rome Formation is composed of thinly bedded shales, siltstones, sandstones and occasional limestones that overlie the dolostones of the Shady Dolomite and extends northwestwards from Cartersville through White and Rydel (Chown, 1979). This formation represents a clastic depositional environment which separates the carbonates of the Shady Dolomite from those of the Conasauga Group. The unit marks the end of barite mineralization.

The Conasauga Group brings yet another change in the conformable depositional environment. The predominance of the clastic characteristics of the Rome Formation give way to another carbonate sequence. The Conasauga Group is composed of thick sequences of limestones and dolostones and shales. Units within the group have been reported as, in ascending order, Rutledge Dolostone, Rogersville Shale, Maryville Limestone, Nolichucky Shale and Maynardville Limestone (McLemore, 1970). As in the Rome, no commercial deposits of barite have been found here. This formation has been, and will continue to be, an important source of magnesian limestone, dolostone and limestone.

The Knox Group is included in this discussion due to its geologic familiarity and its geographic outcrop proximity to the barite ore deposits of the Cartersville mining district. The Knox Group does not host economic barite deposits but it has the largest areal extent
OCHRE OPERATIONS

Ochre is mined from the basal unit of the Shady Dolomite which conformably overlies the Weisner Quartzite of the Chilhowee Group. The ochre producing part of the Cartersville mining district is roughly bisected by Interstate 75 having a north to south distance of 11 miles and a width of 2 miles. The ochre and umber clays here have an average particle size of less than 10 microns. Fe₂O₃ content ranges from 55 to 65 percent. MnO₂ content ranges from 0.5 percent in the brightest yellow ochres to more than 5 percent in the darkest umbers. These ore deposits occur as lenticular bodies which average 30 feet in thickness and only a few hundred feet in length. The basal unit of the Shady Dolomite grades upward into the dolomitic residuum which in places contains the barite deposits described later. Mining of ochre progresses down dip and along the conformable contact of the Shady Dolomite with the Weisner Quartzite. This weathered contact is known to the miners as the "sand wall". Commercial deposits contain approximately 10,000 to 100,000 short tons of crude ochre at an in-situ density averaging 160 pounds per cubic foot. A schematic of a typical ochre mine is given in Figure 3.

Prior to World War II, much of the ochre mining was done underground and a few of these workings are identifiable today. Presently, all ochre mining is by open pit with grade selection by color determined visually. Blending methods are utilized in both the crude and slurried ores to minimize the natural variations in color.

Beneficiation of ochre is a wet process wherein the clay is washed to remove the plus 325 mesh (plus 44 micron) fraction. The ochre is then concentrated in settling tanks and filtered, dried, deagglomerated and packaged.

The ochre pigments are naturally hydrated ferric oxides, known mineralogically as limonite. NRO's pigment is unique in that it has properties of both ochre and sienna pigments. Like siennas, it is darker in color and higher in iron oxide content than a true ochre, but, unlike a true sienna, it exhibits excellent tinting strength. For many years, the main markets for NRO's ochre was a buff coloring pigment in linoleum, concrete, paint, paper, canvas, fertilizer, grouts and feeds for large animals. Today, the chief markets are as a pigmenting agent in masonry products and roofing granules where earth tone colors are preferred. This pigment competes economically with the synthetic iron oxides and is used extensively by other pigment producers and blenders as an extender. The cost of synthetic iron oxides is about ten times the cost of natural iron oxides.

BARITE OPERATIONS

The barite producing part of the Cartersville mining district is smaller than that of ochre. It has a north to south length of 4.5 miles and a width of 2 miles. Culturally it is bound by Interstate 75 to the east, U.S. Highway 41 to the west, Georgia 20 to the north and by the town of Emerson to the south. Barite deposits occur stratigraphically above the ochre deposits. Barite was originally deposited in and near faults in the Shady Dolomite during or after the Appalachian orogeny in late Carboniferous time. Barium-containing solutions invaded the carbonate and deposited barite in solution cavities and along open spaces in shattered fault zones. Replacement of carbonate by barite also occurred. The barite now in the clays was freed from the dolomite by ground-water leaching. In other words, nature has made the task of mining barite much easier by allowing the extraction of enriched clay containing barite (dolomitic residuum) instead of quarrying a leaner and an unweathered dolomite containing barite.

The residual clay that forms the matrix of the barite ranges in color from yellowish to chocolate brown in contrast with the overlying red colluvial clay. The brown clay averages about 140 pounds per cubic foot in-situ. Mine run barite content of this clay averages about 8 to 20 percent by weight. Particle size of the ore ranges from submicron to as large as a cubic yard. The average recovery of barite concentrate is approximately one ton per 5 cubic yards of bank ore. This equates to about 10,000 tons of concentrate per one acre of mineralized clay having a thickness of 30 feet. A generalized cross section of a typical barite mine is given in Figure 4.

Beneficiation of the mineralized residuum is a wet process. Crude ore is washed and from the resulting slurry, a separation of barite and gangue is made. This separation is based upon particle size and the higher
specific gravity of barite as compared to the gangue. Beneficiation hardware used are breaker screens, trommel screens, roll and jaw crushers, log washers, mineral jigs, hydrocyclones, froth flotation equipment, elevators and screw conveyors and high intensity magnetic separators. Small particles of ore are recovered by froth flotation. About 20 percent, by weight, of the crude ore matrix is recovered as ore concentrate and by-product gravels which are recovered as road base aggregate. The remaining 80 percent is disposed of in settling ponds where the effluent water is treated and reclaimed as surface river water and is recycled.

Barite production in Georgia is limited to the Cartersville mining district. Paga Mining Company, a subsidiary of Thompson-Weinman Company, which is owned by Cyprus Minerals, produces barite for the filler-extender market. NRO produces barite for the barium chemical market. These two barite mining companies of the Cartersville mining district are producing at least 80 percent of the domestic requirements of barite used in applications other than well drilling fluids.

United States consumption of barite concentrate in 1986 was about 3,000,000 tons. Approximately 2/3 of this requirement was imported as the domestic mine production was only about 1,000,000 tons. About 90 percent of the barite consumed in the United States was used as a weighting agent in oil and gas drilling fluids mostly in the Gulf Coast area (U.S. Bureau of Mines, 1986).

Domestic resources of barite could geologically sustain United States requirements but economics make foreign barite ores more attractive. Therefore, foreign sources, mainly from China, Morocco, Chile and Peru, are rendering domestic resources of barite currently unexploitable, due to economic rather than geologic reasons.

REFERENCES


Figure 4. Generalized cross section of a typical barite mine.
Ochre: a natural iron oxide in the coloured pigment market

STAN D. BEARDEN

New Riverside Ochre Company, Inc., P.O. Box 460, Cartersville, GA 30120, USA

Abstract: It is fortunate that the world is not all colourless. Colour enhances expression and communication in all physical objects experienced in life. Pigments provide colour and in some applications have a specific additional function. Iron oxide ores are widely distributed throughout the world but only a few deposits are sufficiently pure and possess acceptable colour and brightness properties to merit their processing into pigment form. Ochre, the common name for goethite ore, is the best and most under used material in the buff coloured pigment market. The geological occurrence of ochre in the basal Shady Formation of the Cartersville district is described. Exploration, processing, and product applications of New Riverside Ochre Company, Inc., Cartersville, Georgia, USA, are discussed. A brief overview of the worldwide pigment market is presented with emphasis placed upon the North American activity in iron oxide production and application. The purpose of this paper is to increase the awareness of ochre and its potential market in the coloured iron oxide pigment industry, encourage research on the origin of ochre deposits, and stimulate interest in new applications of this unique substance.

Many specific ores have been described and discussed in the last 35 years in which the Forum on the Geology of Industrial Minerals has been held. Interestingly, this presentation is the first on ochre although this ore has one of the longest histories of any industrial mineral. It is also ironic that this presentation by New Riverside Ochre Company, Inc. (NRO) is given to the 11th Extractive Industry Geology Conference in Bath, UK, because the ochre industry in Cartersville, Georgia began around 1877 by exporting the finished product to Western Europe.

Geology of the Cartersville mining district

The Cartersville mining district is the oldest continuously active mining district in the southeastern United States. The District includes parts of three physiographic provinces: Valley and Ridge, Piedmont, and Blue Ridge. Recorded production of ores include gold and graphite from the crystalline rocks south and east of the Cartersville-Great Smokey Fault in the Blue Ridge Province, and iron, manganese, specular hematite, graphite, ochre (Watson 1906),umber and barite from sedimentary rocks and meta-sedimentary rocks located north and west of the fault in the Valley and Ridge Province. Crushed aggregates have been produced from all three provinces. The rock units range from Precambrian to early Ordovician age. These rocks have experienced multiple orogenetic events during the Palaeozoic including the Taconic (Ordovician), Acadian (Devonian), and Alleghenian (terminal Palaeozoic). Fresh outcrops are practically nonexistent in the Palaeozoic Valley and Ridge part of the district. Due to the extensive weathering that in places has been measured to 100 m below the surface, mapping is most often based upon colour and mineral composition of residuum. The situation is aggravated further because most areas, except topographic highs and some stream channels, are covered by a thick mantle of colluvium.

The stratigraphy of the oldest Palaeozoic portion of the district is the Lower Cambrian Chilhowee Group consisting of the Wilson Ridge Formation and Weisner Formation which form the cover rocks on the Blue Ridge massif. The Wilson Ridge Formation was laid down as a series of clays and sands deposited in a broad, expansive tidal flat environment and, although not fully exposed, has been estimated at least 500 m thick. The Wilson Ridge Formation is overlain conformably by the Weisner Formation. The upper unit of the Weisner is a 1-5 m thick sandstone that is occasionally conglomeratic and cross bedded. The Wilson Ridge and Weisner Formations have been metamorphosed to phyllites and quartzites. The Weisner Formation is the most weather resistant lithology in the district and produces abundant float fragments useful in surface mapping. The Shady Formation, consisting of ochre and dolostone, rests unconformably on the Weisner Formation. The ochre horizon is a stratigraphic marker bed which follows the contact between the Shady Formation and Chilhowee Group but is absent or very thin in some localities. The ochre horizon grades upward into a dark grey dolostone containing paper-thin shale laminae and concordant black chert nodules. This dark grey dolostone grades upward into a massive light grey platform dolostone. The Shady Formation is covered by Early to Late Cambrian shales including the Rome and Conasauga Formations. Archaeocysthids, index fossils for the Lower Cambrian, are found replaced by silica and less commonly by barite in the ochre ore and overlying carbonates (Maples & Waters 1983).

It is now widely accepted that Mississippi Valley-Type (MVT) mineralization produced the epigenetic barite deposits as fillings of secondary porosity in the light grey dolostone (Kesler 1997). These deposits formed from barium enriched sedimentary brines that migrated out of basins due to deep burial and heating upon loading by thrust sheets. Fluid inclusion studies indicate emplacement temperatures to be in the range 126–297°C at 1.7 km depth of burial (Rife 1971). The overlying shales restricted movement of the solutions into overlying parts of the section. This palaeoquifer MVT model is suggested by the author as the mechanism for the introduction of iron into the basal Shady Formation. Iron mineralization as pyrite was selective to the basal dolostone at the nonconformable Chilhowee contact. This event predates barite mineralization as minor barite occurs discordantly within the ochre horizon. The development of jasperoid is later than that of both the basal iron and barite mineralization.

Ochre mining and beneficiation

Ochre ore occurs as an unconsolidated lithostratigraphic unit of unconsolidated goethite with a maximum thickness of about 10 m. Minable strike length of individual bodies ranges 100–700 m. The open pit surface mining of these ore deposits incorporates gangue of sand size quartz, pebble size pyrolusite, dornick size masses of gossan and jasperoid, and dolomitic residuum. Crude ores are visually selected and classified at the mine based upon colour and texture and then stockpiles are segregated in the plant area according to colour. Crude ores from the various stockpiles are mixed in predetermined ratios based upon the colour characteristics required in the finished product. Processing of the crude mixture is by hydraulic
classification, filtering, colour modification if needed, drying, and packaging. All materials handling and process action lines are managed by the ISO 9002 quality system of NRO.

Mineralogically, ochre is goethite. The crystalline structure provides a very efficient light scattering capability. In commerce, ochre is one of the less significant industrial mineral commodities in terms of both tonnage and value. Advances in the mining, processing, marketing, and applications of ochres produced by New Riverside Ochre Company during the last ten years have established this natural iron oxide as the best value and most under utilized colourant in the iron oxide industry today.

Colourants, pigments, iron oxides

Materials which can impart colour to other materials are colourants. These are subdivided into dyes and pigments. Dyes are colourants that are soluble in application, whereas pigments are not. The world market for pigments is approximately 5 million tonnes per annum. White pigments (titanium dioxide, zinc oxide and lithopone) account for 66% of this total, carbon black 9%, and coloured pigments 25%. The coloured pigment market alone has a value of about 7 billion dollars (Bangert 1999). Considering coloured pigments as a group, iron oxides, natural and synthetic together, are used three times more often than all other coloured pigments combined and are clearly the most popular, accounting for about 70% of coloured pigment volume consumed. Because of their low cost, iron oxides make up less than 20% of the market value for coloured pigments (McCormack 1997). Almost one million tonnes of iron oxides are currently produced annually: about 70% are synthetic iron oxides (SIO) and about 30% natural iron oxides (NIO). Table 1 gives the world consumption of SIO and NIO pigments by region. Table 2 gives details of the end uses (Adams 2000). Coloured concrete and masonry cement products continue to be the largest application area. Europe is the largest iron oxide producer and user due in large part to the popularity of coloured concrete products in the construction industry. Based on USGS 1998 data, total world production of NIO has been estimated at about 500,000 tonnes. Leading production countries, expressed as a rounded percentage of the total, are India 65%, USA 20%, Spain 5%, Chile 3%, Austria 2%, Brazil, Cyprus, Germany, and Pakistan around 1% each (Potter 1999). The main sources of supply of SIO are Germany, USA, UK, Italy, Japan, China, India, South Korea, Thailand, the Philippines, and Brazil.

Table 1. World consumption of iron oxide pigments by region

<table>
<thead>
<tr>
<th>Region</th>
<th>Synthetic iron oxides (%)</th>
<th>Natural iron oxides (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Europe</td>
<td>39</td>
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</tr>
<tr>
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<td>19</td>
</tr>
<tr>
<td>Rest of world</td>
<td>12</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2. World consumption of iron oxide pigments by end use application

<table>
<thead>
<tr>
<th>Application</th>
<th>Synthetic iron oxide (%)</th>
<th>Natural iron oxide (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>52</td>
<td>48</td>
</tr>
<tr>
<td>Paint</td>
<td>34</td>
<td>23</td>
</tr>
<tr>
<td>Paper, plastics and rubber</td>
<td>8</td>
<td>--</td>
</tr>
<tr>
<td>Other</td>
<td>6</td>
<td>29</td>
</tr>
</tbody>
</table>

Colour measurement

There exists a lot of different opinions on colour and its measurement and one of the most commonly used is the CIELab system (Hunter Lab). Colour values are measured by a colour meter or spectrophotometer on three linear spectra axes: 'L' value on the black/white, 'a' on the red/green and 'b' on the yellow/blue. A three-dimensional value 'delta E' (dE) is a numeric representation of the spectral reflectance of all three axes. In general a delta E in cement lower than 1 is not possible to see, lower than 1.5 only by an experienced eye, and above 2 colour deviations could be distinguished even by a layman. NRO ochre products have a maximum of ±1.0 of the L* a* b* and a maximum of 1.5 dE. For more than 10 years actual shipped products have been in the range of ±0.5 units on all colour scales establishing this ochre as the most uniform and high quality natural iron oxide in the market place. NRO is ISO 9002 certified. Products are not released for shipment unless certificates of analysis confirming quality specifications are satisfied. Ochres produced by New Riverside Ochre Company, Inc. are comparable to synthetic iron oxides in product consistency and are available at about 20% of the cost.

New Riverside Ochre Company, Inc.

NRO is the largest producer of premium grade NIO and chemical barite in the United States. The company is privately owned and has been operated by the same founding family since 1911. Through careful mineral exploration studies, attention to environmental impact, internal land development plans, and civic involvement, NRO has successfully conducted mine activities during the last 40 years within the city limits of Cartersville (population 20,000) and Emerson (population 4000), Georgia. Exhausted mines have been utilized as municipal sanitary land fills in the district for more than 40 years. NRO has received two environmental awards in recognition of the commercial development of 70 acres of land in Cartersville which have been mined and reclaimed. Shopping centres, banks, restaurants, automotive dealerships, and a US Post Office now exist on areas which were once mined to bedrock more than 40 m below original land surface.

References


New Riverside Ochre
The changing color of mineral production

Founded in 1911, New Riverside Ochre Co. is in the fourth generation of family ownership. Nestled on 1,000 acres of a wooded hillside in northern Georgia, near the growing town of Cartersville, it mines and produces ochre and barite products to customer specifications. Its mine reclamation programs have developed into a substantial property holding enterprise for the family holding company and have received several environmental awards. NAMN paid a visit to NRO in late September to learn more about the production and processing of ochre and barite, and discovered that everything is currently rosey in the pigments markets.

After the Cherokee Indians were expelled during the Trail of Tears in the 1830s, the north Georgia region was surveyed and divided into quarter mile lots (40 acres) if it was thought precious metals could be present or half mile lots (160 acres) otherwise. NRO's property was surveyed into sequentially numbered quarter mile lots.

Mining for ochre began in the 1877 and the grades derived were simply named after the lots from which they were extracted. The company's two ochre products are still named #404 and #548. Ochre is impure goethite, an inorganic, chemically inert, non-reactive and non-toxic natural earth pigment also called hydrated ferric oxide (FeOOH). It is used to obtain a range of colors from brown to buff, and as a base for producing a range of earth tone colors from red to dark brown in mortar, brick, roofing granules, paper, concrete, ceramic tiles, cosmetics, inks and paints.

Because ochre is an iron oxide it is a permanent color that will not fade or wash out. It has no fillers or extenders and has uniform consistency from bag to bag, assured with state-of-the-art color measuring and monitoring equipment. In August, the company achieved ISO9002 certification.

The ochre deposits are lenticular stratiform bodies which are conformably sandwiched between two distinct lithologic units of early Cambrian age. They overlie the Weisner formation of the Chilhowee Group and grade upward into the Shady Dolomite residuum. During exploration drilling on 15° centers, ore grade percentages are estimated. The currently active open-pit mine is on a deposit with a strike length of 1,000' with an average thickness of 30'. The district has not been fully evaluated but 30 years' of ore can be seen at current mining rates.

Ochre processing
Ochre is excavated from the chocolate and yellow marbled pit-face by the mining contractor who selects and classifies the ore by eye, segregating it into color stockpiles: #404, #548, #808, and umber. All four grades are similar in texture and color with #404 being the brightest yellow, to umber which is purplish brown. Color is governed by manganese oxide content which ranges from <0.5% MnO₂ in #404 to >3.0 MnO₂ in umber.

Ore is mixed from each stockpile in a bunker, in ratios according to the color grade required, where it is hydraulically slurried and gravity fed to a single log washer. Plus 50 mesh materials are rejected as waste by the log. The plus 325 mesh log overflow fraction is rejected as waste by a Dorr-Bowl rake classifier. The resulting ochre clay slurry gravity flows to one of two 80,000 gallon settling tanks where an ochre mud of 45-55% solids is produced. The clarifier overflow is recycled to the log washer.

The ochre mud is pumped to one of two 15,000 gallon slurry tanks which serve as capacitors to minimize variation in coloring characteristics. From the slurry tank, ochre is pumped to a Komline-Sanderson rotary vacuum filter where the slurry is concentrated to approximately 70% solids with an average particle size of 2 microns. A dispersant is added to the filter cake enabling the slurry to gravity feed a 500 gallon holding tank located inside the dry plant.

The dispersed slurry is dried indirectly at approximately 325°F on the
exterior of a rotary steam dryer as the color may be damaged if over heated. Dried pigment containing only 0.5% moisture is deagglomerated in a Raymond Imp mill and packed in one ton bulk bags (20%) or 50lb bags (80%).

With strong demand for ochre, NRO’s plant continues to work in excess of its planned capacity, averaging about 20% overtime during the last six months. The plant typically operates 4×10-hour shifts per week but has been running at 5×10-hour shifts.

**Barite processing**

Barite deposits occur stratigraphically above the ochre deposits. The barite occurs as structurally deformed Mississippi Valley Type deposits hosted by the early Cambrian Shady Dolomite. Barium enriched thermal waters migrating along structural avenues invaded the carbonate although barite replacement of the carbonate was minor.

Most of the ore was deposited in solution cavities and open spaces in shattered fault zones. Soluble components of the host rock were removed by ground water leaching, with barite—being highly insoluble—concentrated in the clay residuum. In 1924, NRO began to recover the barite that occurred in the overburden of the ochre.

Barite ore, 8-30% BaSO₄, by weight with a 10-15% average, mined by a dragline scooping 15 tons per bucket. Wheel loaders charge 35 ton trucks which transport the crude ore to the stockpile or washer plant. An average of three acres per year are excavated.

The washer plant—consisting of a four log washer in closed circuit with screens and crushers—produces a slurry from the crude ore. The plant delivers wet classified sands and gravels to a series of jigs. A 94-97% BaSO₄, by weight jig ore is produced ranging in size from 3/16” to 1”. Scavenger jig ore is recycled into the crude ore stockpile with a BaSO₄ content of 40-70%.

An Aitken classifier removes the plus 50 mesh fraction for the low overflow stream and Hutch and Aitken classifier sands and gravel are produced as a byproduct. Aitken classifier overflow is pumped to a bank of six inch hydrocyclones which reject the minus 10 micron solids. The plus 10 micron fraction reports to chemical conditioning prior to floatation recovery.

Sodium silicate, caustic soda and a petroleum sulfonate-based collector are added prior to froth floatation. Final concentrate at 6% moisture and 98% minimum BaSO₄, is belt conveyed to enclosed storage prior to transport to the magnetic separator.

After magnetic separation the non-magnetic concentrate is blended with dried float ore at predetermined ratios from which six products are derived. These are NRO CPC concentrate, NRO 80, NRO ATC 100, NRO 5010, NRO RAD BAN™, and feedstock for the dry grind plant. The dry grind feedstock is ground in a Raymond roller mill to produce NRO 8000, NRO 9000 and NRO 10000.

NRO’s barite is principally sold into extender and filler, chemical products of which there are over 2,000 applications, and high density markets although it also has applications in hydrocarbon drilling fluid markets.

A company called Chemical Products Corp. was established in 1935 as an outlet for the barite produced by NRO and is now the only company in the US to produce barium chemicals on a commodity basis.
Company focus

One of the main products produced by CPC is barium carbonate (BaCO₃) which is used in brick and tile manufacturing to control scum due to soluble sulfate salts contained in clay and to diminish porosity and prevent discoloration.

In optical glass, barium lowers viscosity and improves the refractive index. It is used in TV glass picture tubes where it helps contain high intensity radiation, and to provide the flat white effect in photographic paper and tire sidewalls.

Filler and extender applications for barite include paint, latex, and polyurethane foam manufacturing where it increases density and improves processing qualities e.g. carpet backing. NRO produces RAD BAN™, a heavy aggregate designed for radiation shielding concrete for use in hospital construction, radiation therapy units, nuclear research facilities, and commercial nuclear power plants.

Profiting from reclamation
NRO's 1,000 acre site is bordered by several road and property developments. Consequently, land reclamation has been a prime consideration for the company due to the potential value of its reclaimed real estate and property developers that want to take advantage of it. For this reason the company mines around the perimeter of its site in order to speedily provide fresh land for development.

The parent company created a property holding division to administer its reclaimed land—amounting to 50 acres—which is now home to three shopping centers, three car dealerships, two banks and a post office. New Riverside Ochre has won several reclamation awards for its successful reclamation. With further road development planned, the company will mine out resources from affected areas of its property as quickly as possible.

New Riverside Ochre - Basic process flow diagrams for barite (left) and ochre (right)
Barite: World sources and the US market

**Introduction**

Barite is an important industrial mineral with the following properties: high density (4.5 sp gr), low hardness (2.5 to 3.5 on the Mohs scale), low oil absorption and good thermal stability (1,580°C or 2,876°F). Barite is also virtually inert. The value of barite varies with purity, particle size, the character of impurities and color. Prices of barite concentrate range from about $30/t ($27/st) to more than $300/t ($270/st). End-use applications of barite can be grouped into the following categories:

- hydrocarbon drilling fluids,
- extenders and fillers and
- chemical products.

It is unlikely that other materials will replace barite in any of these categories.

Barium sulfate was deleted from the US Environmental Protection Agency’s (EPA) list of toxic barium compounds. This should eliminate any environmental concerns regarding the use of this mineral (Federal Register, Vol. 59, No. 123, June 28, 1994).

**End-use applications**

Because about 85% of the production is consumed as a drilling-fluid additive in hydrocarbon well installations, barite production is dictated by the world oil market. In this application, the barite mainly functions as a weighting agent that increases the specific gravity of the drilling fluid for the purpose of suppressing high formation pressures and preventing blowouts. Barite is also an important component in the filler-extender markets for paint, latex, plastics and urethane-foam manufacturing. In automobile painting, barite is used in the primer coat to retard rusting, and, in this application, it also contributes to the gloss of the top coat. Processors of polyurethane foam and plastics use barite to increase density, enhance resiliency and improve processing qualities in products such as floor mats, carpet backings and tennis balls. Other important applications include mold-release compounds in metals casting, brake systems and other frictional materials, acoustical compounds and high-density concrete. Barium chemicals have more than 2,000 specific industrial applications.

The major barium chemicals are carbonate and chloride. Barium carbonate is a raw material for the production of many other barium compounds. It is also used in brick and tile manufacturing to control scum caused by gypsum or magnesium sulfate in the

**Abstract**

The world’s barite reserve base is adequate for at least 100 years at the current consumption rate. China, India and the United States are expected to remain the leading producing countries, and the United States will continue to be the largest consumer. None of the known substitutes for barium sulfate are expected to impact existing applications. World production in 1995 was 4.41 Mt (4.86 million st), which is about 50% of capacity. Consumption is directly proportional to hydrocarbon well installation activity. Imports are expected to continue to supply more than half of the US requirements.

**TABLE 1**

<table>
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<td>1976</td>
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**TABLE 2**

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<tbody>
<tr>
<td>China</td>
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<tr>
<td>India</td>
<td>576</td>
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<td>USA</td>
<td>543</td>
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<tr>
<td>Morocco</td>
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<td>Mexico</td>
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clay and also to diminish porosity and prevent discoloration. In optical glass, barium carbonate lowers the viscosity and improves the refractive index. Barium carbonate helps contain high-intensity radiation in television glass picture tubes and face plates. It also provides the flat white effect in photographic paper. Other uses include serving as a flux for ceramics and in the production of barium ferrites (flexible magnets). These flexible magnets are used extensively in the small direct-current motors found in automobile windshield wipers, loudspeakers, electronic equipment, toys and magnetically attached decorative items. Barium chloride is used in the manufacturing of steel, leather and cloth.

World production and reserves

Barite is mined in more than 40 countries. World production of barite increased from about 3 to 4 Mt/y (3.3 to 4.4 million stpy) during the 1960s and then almost doubled during the 1970s. Production peaked in 1981 but has since declined. China became the world's largest producer of barite in the mid-1980s. Table 1 shows world barite production for the 20-year period from 1975 through 1995 (Searls, 1996).

Table 2 lists 1995 production by country (Searls, 1996). World mine production for 1995 totaled 4.4 Mt (4.9 million st), with the following top five producing countries accounting for over 70% of the world total: China, 34%; India, 13%; United States, 12%; Morocco, 6%; and Mexico, 6%.

It was estimated that in 1996 these contributing percentages would increase for China, India and the United States and decrease for Morocco. It was also anticipated that Mexico would remain unchanged.

The total world “reserves” are that part of all identified resources that are now economic. The “reserve base” includes reserves plus all other identified resources that are marginally economic or subeconomic. Table 3 is a compilation of US Geological Survey estimates of reserve and reserve-based tonnages for the world.

**References**


Family Room or Oil Field, Barite is Equally at Home

By Stan Bearden

What do tennis balls, carpet, television sets, cars and refrigerators have in common? They all contain barite.

Barite is an important industrial mineral with unique properties of high density (4.5 specific gravity) and low hardness (2.5-3.5 Mohs scale in which the hardness of a fingernail is about 2). And because it is relatively insoluble in water and acid, it can be used as a chemically inert material.

World production is between 4 and 6 million tons per year. World reserves should be adequate for about 100 years. The United States is the world's largest consumer of barite.

The leading world producers of barite are: China (30 percent), India (10 percent), United States (8 percent) and Morocco (6 percent). Other significant producing countries are Turkey, Mexico and Iran. The principal producing states in the United States are Nevada, Georgia and Missouri. Important historic production has come from other states such as Arkansas, Tennessee, Illinois and Montana.

Applications of barite generally can be grouped as follows: (1) hydrocarbon drilling; (2) extenders and fillers; (3) glass and fiberglass; (4) paint; and (5) chemical products.

About 90 percent of the barite consumed is used as a drilling fluid additive in hydrocarbon well installations. Twenty to fifty tons of barite are used per well. The principal function of the barite constituent is as a weighing agent to suppress high formation pressures and prevent blowouts. A secondary function is to increase the specific gravity of the drilling fluid in order to transport drill cuttings to the surface. The deeper the hole, the more barite is needed as a percentage of the total mud mix.

Barite is an important mineral in the filler extender markets of paint, latex and urethane foam manufacturing. In painting automobiles, barite is used in the primer coats to retard rusting. It also contributes to the gloss of the top coat.

Processors of polyurethane foam use barite in manufacturing such products as floor mats and carpet backings and tennis balls to increase density and improve processing qualities. Other important applications include mold-release compounds in metals casting, brake systems and other frictional materials, acoustical compounds and in high-density concrete.

The major barium chemicals are carbonate and chloride. Barium carbonate is a raw material for production of many other barium compounds. It is also used in brick and tile manufacturing to control scum due to gypsum or magnesium sulfate bricks.

Barium chemicals have more than 2,000 specific industrial applications in 17 major classifications. In optical glass, barium carbonate lowers the viscosity and improves the refractive index. Barium carbonate helps contain high intensity radiation in TV glass picture tubes, and provides the flat white effect in photographic paper. Other uses include serving as a flux for ceramics and in the production of ferrites (flexible magnets). Barium chloride is used in the manufacturing of steel, leather and cloth.

The value of barite varies as a function of purity, particle size, color, character of impurities, and mining and processing methods and location. Prices range from about $35 per ton to $200 per ton.

All of the principal barite mines in the United States are operated as open pit or surface mines. Many deposits of barite are inactive due to cost competition from imported sources.

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