

LAYERED EPIGENETIC GALENA-BARITE DEPOSITS  
IN THE GOLCONDA MINE, BRASSINGTON,  
DERBYSHIRE, ENGLAND

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ABSTRACT

Although worked since at least the eighteenth century the rich galena-barite ores of the Golconda Mine near Brassington on the southern flank of the Derbyshire lead-fluorite-barite field have not previously been described in detail. In contrast to the dominant vertical rake-veins of hydrothermal origin in the rest of the field, the Golconda ore-bodies are shown to be more or less horizontally disposed at the gently undulating contact of an incompletely dolomitized zone of the Carboniferous Limestone above, and an unaltered zone of the same limestone below. Early phases of mineralization resulted in the production of solution cavities at the base of the relatively porous dolomite in which crystals of galena and barite accumulated as gravitational layers interstratified with derived dolomite crystal sand layers. Repeated phases of solution gave rise to further cavities partly or completely filled with breccias of collapsed blocks of bedded barite, galena and dolomite, some of which were cemented by calcite. Remaining cavities were then lined with large calcite scalenohedra. A late oxidizing phase led to the development of widespread hemimorphite and aurichalcite. The lack of ore-bodies in the unaltered limestone below, suggests that the mineralizing fluids travelled either laterally or downwards, possibly being fed as mineral-rich deep groundwater brines by nearby uprising hydrothermal solutions. A late Triassic age for mineralization is suggested. Subsequent groundwater movements have led to further cavernization together with the inwash of sands of possible Tertiary age from large sink holes on the surface.

## INTRODUCTION

THE Derbyshire mining field is well-known for its long history of production of galena, fluorite and barite from rakes, scrins and flats in the Carboniferous Limestone. These three local terms, respectively, refer to large and small fissure veins with near vertical extent and to more or less horizontal metasomatic replacements, generally beneath an impervious layer such as basalt or shale. The distribution of ores has been summarized by various authors (1, 2, 4, 7, 13, 15) and in all these a traditional hypothesis of ore genesis by uprising hydrothermal solutions into tectonically opened fissures has been advocated. A zonal arrangement of gangue minerals in the rake veins showing dominantly calcite gangue on the west, barite gangue in the middle, and fluorite gangue in the east has been described. The other half of such a concentric zonal scheme has been assumed to be buried beneath the Coalfield to the east.

The Golconda Mine has provided rich galena-barite ore since at least the eighteenth century, from what has been assumed to be a metasomatic replacement associated with adjacent rakes. Owing to difficulties over access no detailed study has been made until now and the results of this work necessitate at least a partial revision of the method of ore-emplacment. It is here suggested that the basic method of ore-deposition has been by precipitation in open cavities, with crystals accumulating in quasisedimentary layers. Collapse structures are also present, having taken place both during and after ore deposition.

The authors are very grateful to the owners of the mine, the Hopton Mining Company, for their kindness in giving permission and providing facilities for repeated descents during 1964. The mine has now ceased production and the winding gear is about to be withdrawn.

## THE MINE AND ITS STRATIGRAPHICAL RELATIONSHIPS

Little is known of the early history of the mine but there are in the great cavern encountered in the workings a number of initials and dates going back to 1771. The name may be older as it is taken from the fabulously rich gem-cutting center of seventeenth century India. Some of the stopes show evidence of having been hand-worked, presumably in the days before explosives. Since the greater part of the ore body lies at a depth of 350 to 400 feet below the surface it may be assumed that it was found by chance following of scrins (small fissure fillings) down from the surface sometime in the seventeenth or eighteenth centuries. It is known to have been a rich lead mine in the mid-nineteenth century but no documents or production figures have been traced. Production was almost at a standstill when the Hopton Mining Company took possession in 1915. Improved haulage facilities were installed and many thousands of tons of barite were produced, galena being relegated to the status of by-product. Dunham and Dines (4, p. 91) estimate that the total production of barite was about 75,000 tons up to that date. The yield of galena averaged about 1 percent during the Hopton Mining Company's occupation.

During the Second World War it became evident that the easily accessible deposits were becoming exhausted and two exploration drives were made with little success and production ceased about 1950. No serious attempt was made to evaluate surrounding properties, though there are numerous old mine dumps. None of the remaining open shafts are deep enough to have reached the Golconda ore horizon.

The only existing mine plan was made by the late manager, E. Weightman, during his period at the mine from 1915 to 1945. It is reproduced as part of

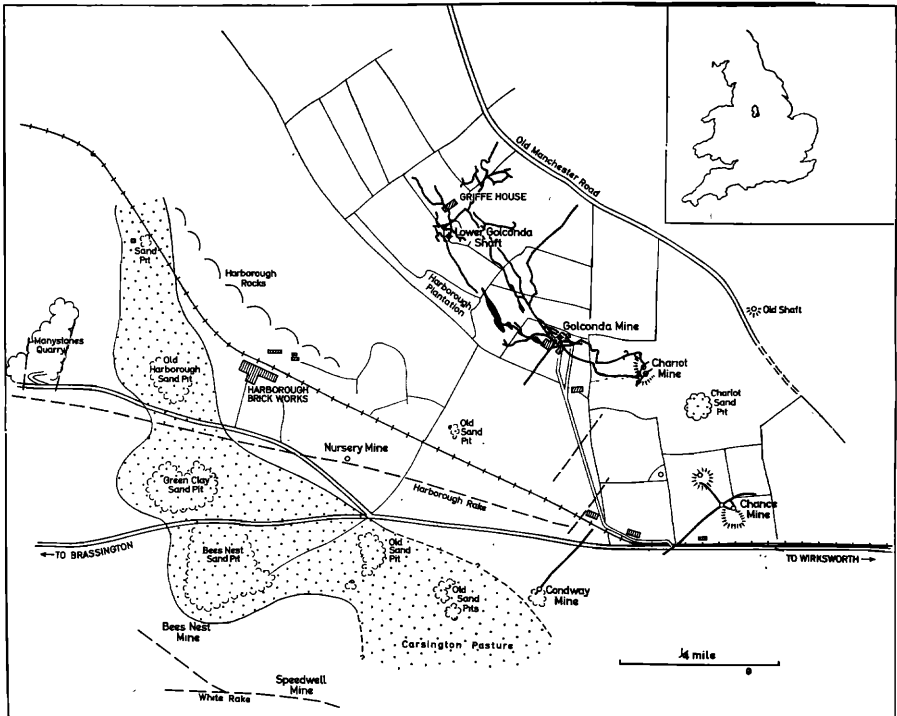


FIG. 1. Map to show the position of the Golconda Mine at the southern edge of the Derbyshire Carboniferous Limestone massif (inset) and to the silica sand infillings of Tertiary (?) sinkholes and solution cavities (stippled). The unshaded area is all dolomitized Carboniferous Limestone with a gentle northeasterly dip. The position of "rake" fissure veins is shown by broken lines.

Figure 1. Some three miles of roadways are shown within an area roughly half a mile NW-SE and a quarter of a mile SW-NE. Some of these were back-filled during or after Weightman's time and the authors estimate they have been able to examine rather less than half the roadways, plus the adjacent stopes, many of which are not shown on the plan.

Access to the mine was by two shafts, 1,250 feet apart. Of these the southern or Upper Golconda Shaft is the only one now in use. From this, levels radiate at 300, 360 and 420 feet depth, with interconnecting inclines.

The levels follow the ore-body at the junction of the dolomitized zone above and the unaltered Carboniferous Limestone below. The regional dip of the limestones and dolomites is less than 5° NE but the base of the dolomitized zone undulates by as much as 120 feet, giving ridges and hollows in the ore body (formerly known to the miners as "anticlines and synclines"). Locally the base of dolomitization rises at prominent joints, up to 100 feet in one case. As a result of these undulations the haulage roads meander following the strike of the base of dolomitization, particularly along the flanks of the north-westerly trending ridges.

The limestones are thick-bedded bioclastics of the lower part of the D<sub>1</sub> zone, lying about a mile to the north of a marginal reef belt through Brassington. In the dolomitized zone the beds are in places separated by green clay wayboards believed to represent contemporary volcanic dust horizons, though some may be equivalent of the "vitriolic clay" produced by exsolution from the dolomitized zone as described in Poland by Zwierzycki (18). These are rarely more than a few inches thick, but one bed over six feet thick is known. In places the clays form the floor to mineral accumulates, and indicate that they at least partly controlled the direction of flow of mineralizing fluids, but their small thickness meant that they could also be breached and thus have little control in other places. Stratigraphic correlation of the thin clays within the mine has not yet proved possible. None of the clays can be correlated with beds outside the mine, though some may represent tongues extending from the thick Hopton Agglomerate exposed in Stones Dale about a mile to the south-east.

The dolomitization of the limestone has been described as subsequent to sedimentation by Parsons (15) though the details of how and when are as yet unknown. The dolomitized zone clearly transgresses the stratigraphic zones and is patchy in occurrence though outcropping over some ten square miles. Its genesis has been variously regarded as related to a former Triassic cover, or as due to downward percolation of magnesian solutions from the Permian seas. The first of these alternatives is favored by the present authors but the evidence will be discussed elsewhere. Dolomitization is never complete and a residual calcite matrix and "ghost" fossils are generally present. Preferential solution of calcite may lead to disaggregation of the dolomite with resultant topographic effects such as residual "tors" of dolomite (9), and underground effects as discussed later.

Overlying the limestones and dolomites around the Golconda Mine are silica sands and clays of the Derbyshire pocket deposits (17). These are preserved largely in ancient solution hollows of unknown age as the sediments are unfossiliferous. Often regarded as Triassic relics (11) opinion (9, 10) is now that they are Tertiary in age though largely composed of material derived from a former Triassic cover. They are overlain in turn with thin glacial till, and patches of chert gravel.

#### THE ORE BODIES

The minerals present are dominantly galena and barite. A few traces of fluorite have been found. Sphalerite, chalcopyrite and chalcocite are present

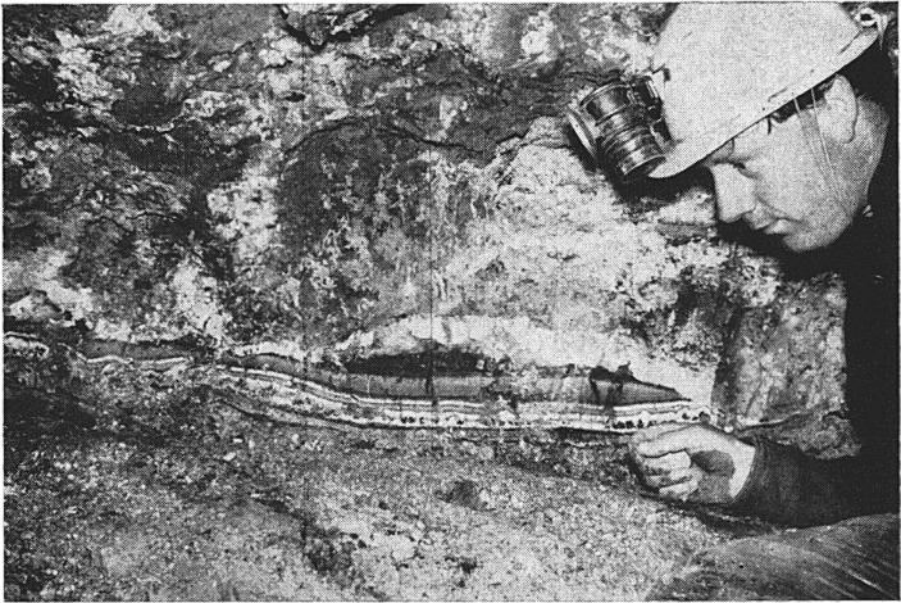


FIG. 2. Sedimentary layers of galena (black), barite (white), barite-dolomite mixture (light gray), and dolomite crystal sand (dark gray) on the floor of a solution cavity between limestone below and dolomite above.

as residual traces, having been largely oxidized to hemimorphite, aurichalcite, a little smithsonite and hydrozincite. Some cerussite is also present. Dolomite and calcite are ubiquitous, the latter in several forms as discussed below. Free hydrocarbons are locally present, but they are more common as inclu-

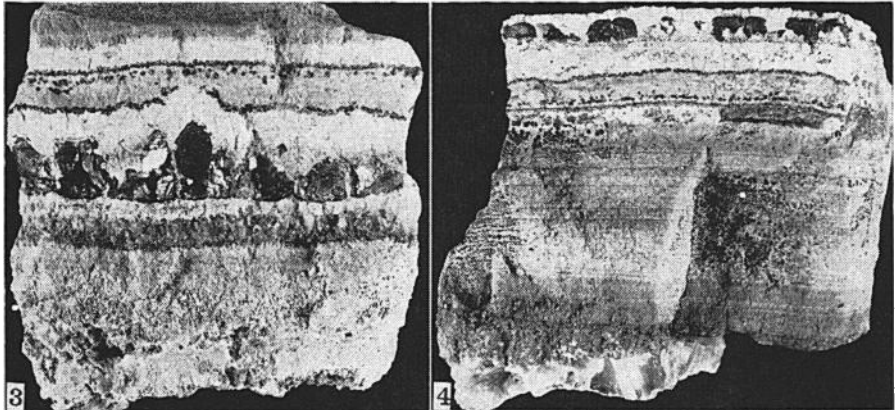


FIG. 3. Closeup of a specimen from the deposit seen in Fig. 2 ( $\frac{3}{8}$  natural size).

FIG. 4. Specimen of bedded ores and derived dolomite crystal sand from another cavity-filling. Note manganese spotting on joints ( $\frac{1}{2}$  natural size).

sions in calcite, some showing zoning. Rare marcasite is present as dendritic growths in cracks in the oxidized minerals.

The mineral associations present may be divided into several categories:

1. Undisturbed layered ores.
2. Cavity linings.
3. Collapsed layered ores and cavity linings.
4. Late cavity linings in collapsed ore-bodies.
5. Vertical screens.
6. Metasomatic replacements.
7. Secondary oxidation products.
8. Placer deposits in post-mineralization solution cavities.

*Undisturbed Layered Ores.*—A typical example of one of these is visible in the eastern drive, and shows a section (Figs. 2, 3, 4):

	Inches
14. Dolomite roof	
13. Crystalline barite forming floor and roof of small vugs	8
12. Laminated dolomite crystal "sand" passing down into	2
11. Finely granular barite	$\frac{1}{4}$
10. Small galena crystals	$\frac{1}{10}$
9. Finely granular dolomite with scattered small galena crystals towards the top	$\frac{1}{4}$
8. Small galena crystals showing similar catenary bedding	$\frac{1}{10}$
7. Finely granular barite showing catenary bedding over galena aggregates	up to $\frac{1}{2}$
6. Layer of large (up to $\frac{1}{2}$ inch) galena crystals showing upward growth of aggregates of cubes	up to $\frac{3}{4}$
5. Finely granular barite with a few small galena crystals	less than $\frac{3}{4}$
4. Crystalline calcite, with a little hydrocarbon at the base	$\frac{1}{4}$
3. Aggregate of dolomite and barite crystals becoming more baritic towards the top	$1\frac{1}{4}$
2. Green clay "wayboard"	2
1. Floor of unaltered limestone	

Traced laterally this sequence shows certain variations within a few feet. Beds 3, 7 and 9 to 12 show variations in thickness and composition, in particular developing lamination of barite grains and dolomite crystal "sand-grains" closely similar to small scale current bedding. The base of bed 2 in places includes detached pieces of green clay, and has a few calcite-filled contraction cracks, both normal and parallel to the bedding. The lateral termination of this deposit could be seen on one side where dolomite roof closed to meet the limestone floor. Here the lowest beds of the above sequence were overlapped by the middle beds, but the highest beds show regression offlap. About one inch of gray-green clay formed the base of the bedded ores, and rested on unaltered limestone. Although closely similar in appearance to the clay wayboards generally considered to be volcanic tuff horizons elsewhere in Derby-

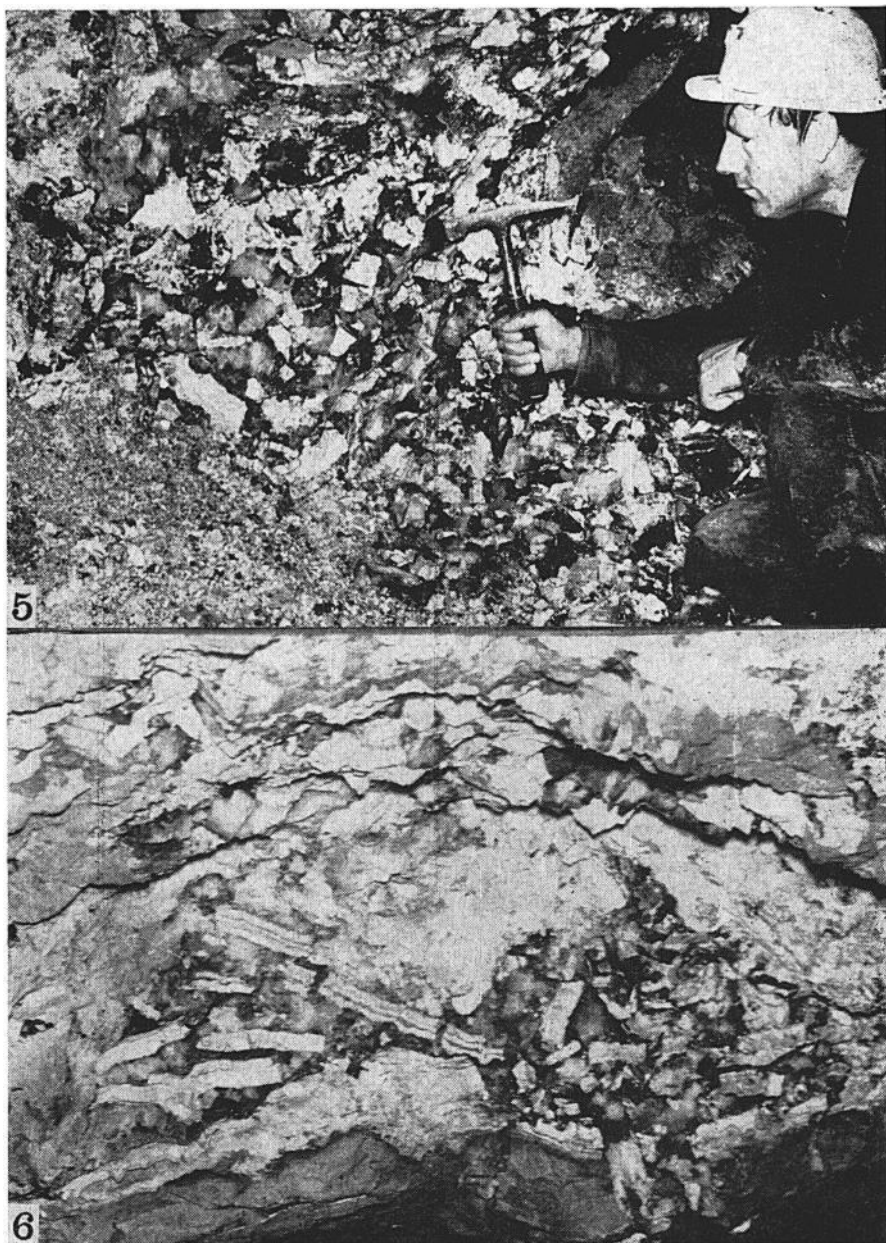


FIG. 5. Collapse-breccia of barite blocks (light) in calcite (gray). Note that some calcites show a dark rim owing to hydrocarbon inclusions.

FIG. 6. Collapse breccia of barite-galena-dolomite-crystal-sand blocks in calcite in the roof of a stope. The slabs are about two inches thick.

shire, this clay may be the argillaceous residual from the dolomitization of the overlying limestone as in Poland (18).

Elsewhere in the mine similar sequences could be seen with the main components still being aggregates of galena crystals clearly showing upward growth, or barite linings of vugs either all around the bedded ores or at the top only of the sequence; also stratiform granular accumulations of barite and dolomite crystals. The latter in some cases showed sedimentary structures such as small scale current bedding, infillings of small cavities, wedging out and catenary bedding, indicating at least limited transport of the dolomite crystals. In one case the base of a bedded sequence was a breccia of small chips of dolomite each surrounded by a coating of barite. The scale varied and individual layers comparable to units in the above sequence could be as much as six inches thick. No cyclic rhythm could be made out, the position and thickness of the dolomite crystal sand layers being fortuitous within the barite-galena alternation. In a few cases the proximity of two or more clay wayboards was associated with separate sequences one above the other.

The dolomite crystal sands in the bedded ores were often distinguished by light and dark laminae, the latter showing manganese dendrites between the crystals, which were generally larger than in the light bands.

*Cavity Linings.*—These were common throughout the mine and consisted almost entirely of barite of the typical Derbyshire "Caulk" variety with a few galena octahedra. The linings were commonly about two inches thick and were often easily detachable from the dolomite host by hand pressure alone. This sometimes revealed scattered galena crystals beneath the barite. They were also seen but less commonly within or on the barite. In a few places barite and calcite were found to have grown together as linings, the calcite then being in scalenohedra up to one inch above the barite surface.

*Collapsed Layered Ores and Cavity Linings.*—These were by far the most common ores and many stopes showed faces of up to eight feet of a breccia of barite slabs from cavity linings in a coarsely crystalline calcite matrix. Composite slabs of bedded ores were included in places but seemed to have been more likely to break up. It was obvious in some cases that the barite linings had become too heavy for adherence to the dolomite wall and had fallen off to accumulate like an irregular heap of roofing slates. In some places slabs of dolomite and barite peeled off together to accumulate in a breccia. In some cases this appeared to have happened repeatedly while calcite crystals were growing in the cavity below, so that slabs came to rest on calcite. Indeed one example showed a slab of barite resting on the tips of several calcite scalenohedra. Calcite in such deposits generally had hydrocarbon inclusions, particularly in the outer zones of growth. Blocks of dolomite were present in most such breccias, and in some there were lenses of dolomite crystal "sand." In a few cases these in turn had been broken after being lightly cemented with calcite, to form second generation breccias. A few collapses had brought down parts of the green clay beds so that these too were incorporated.

*Late Cavity Linings in Collapsed Ore-Bodies.*—At the completion of collapses described above there remained open cavities, which were lined by

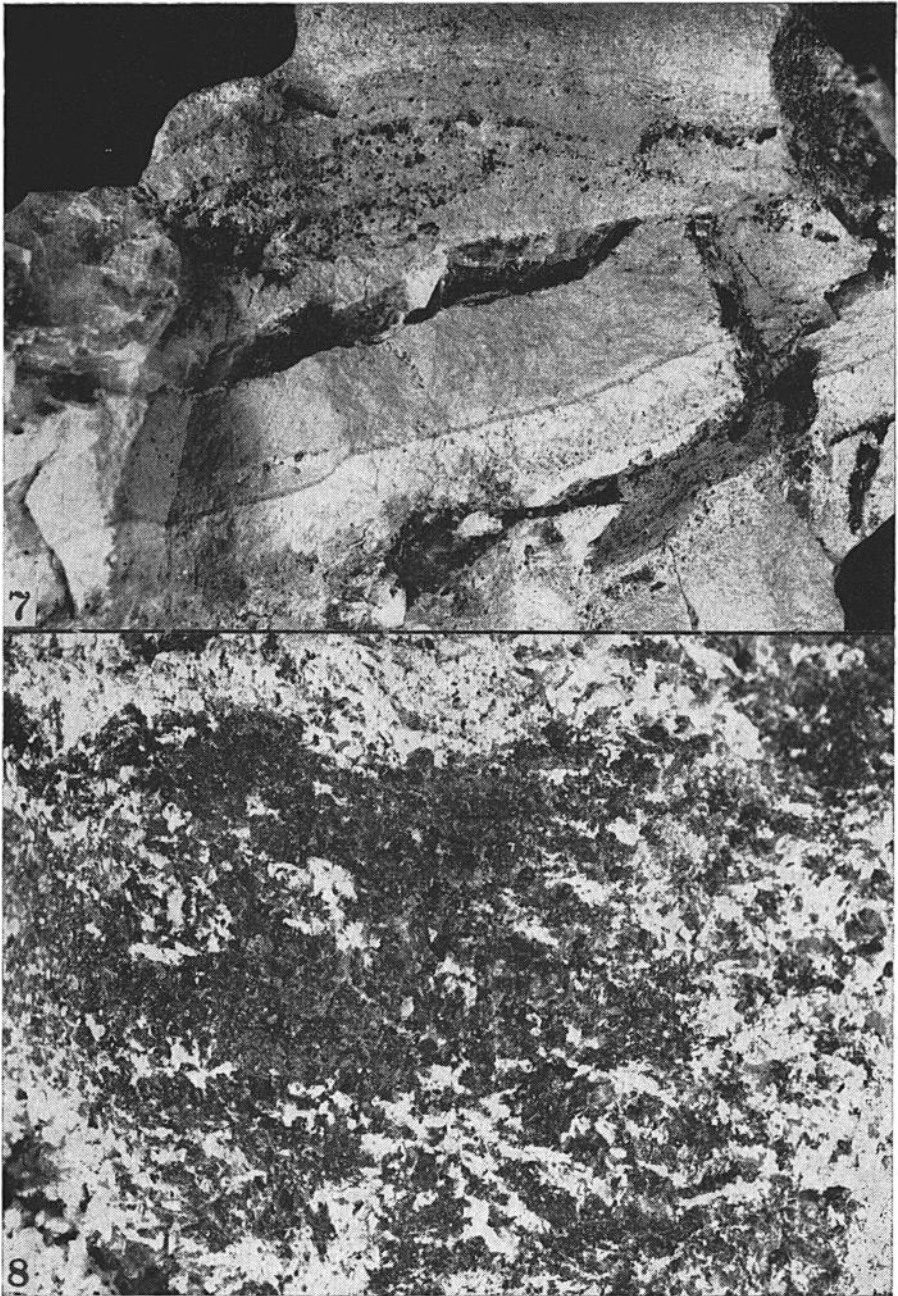


FIG. 7. Breccia of barite (light gray) adhering to dolomite (dark gray) showing decalcification pores. Some late calcite cement is visible between the slabs (natural size).

FIG. 8. Metasomatic replacement of dolomitized limestone (dark) by barite (light) at contact of dolomitized and unaltered limestones (slightly enlarged).

mineral deposition from the late phases of the original solutions. These linings were at first of a limited amount of barite and then entirely calcite in large slightly turbid scalenohedra, some up to a foot in length. In some cases growth was sufficient to fill the cavities completely whereas elsewhere these calcite lined vugs remained open and in some cases were unaffected by later stages.

*Vertical Scrins.*—It is unfortunate that nowhere in the mine or the immediately surrounding area can the relationship to a major rake vein be seen, though several are known to have been worked nearby, e.g., Harborough Rake (Fig. 1). The rake veins are the infillings of large nearly vertical fractures, and are commonly associated with stringers of ore going off into adjacent joints. These are usually known as scrins in Derbyshire. What are termed "scrins" are infrequently seen in the mine as joints with mineral linings generally less than two inches wide. Such as have been examined show symmetrical barite linings on each side with calcite in the middle, with only a few small crystals of galena. Although several of the scrins can be seen to extend upwards into the dolomite forming the roof of the ore-bodies, none have been seen to extend downwards into the unaltered limestone, though it must be admitted that suitable exposures are few. The west drive is largely in unaltered limestone below the deepest workings and it crosses the strike of scrins in the dolomite above, but only thin traces of mineralization were found in the limestone associated with dolomitized joints. In one section a scrin can be seen to have been involved in a collapse, and in another the scrin has remained firm and now forms one wall of a late calcite-lined vug.

*Metasomatic Replacements.*—Evidence of in situ replacement is uncertain, and only in a few places have apparent examples been found. These take the form of barite replacing dolomite in an irregular patchy manner (Fig. 8). Close examination has failed to reveal barite pseudo-morphing dolomite and it is possible that the correct interpretation should be of barite filling the cavities in cavernous dolomite. This suggestion appears to be confirmed by their occurrence close to places where dolomite crystal "sand" lies in cavities, indicating the dolomite crystals in the dolomitized limestone were in places sufficiently disaggregated to be transported and redeposited as sediment, leaving a spongy mass with pores to be infilled with barite.

The host dolomite is, of course, a metasomatic replacement of limestone, but it is not necessarily part of the mineralization and will be discussed elsewhere.

*Secondary Oxidation Products.*—Most of the galena crystals exposed in vugs have a coating of cerussite, and it has also been found in partly sand- or gravel-filled cracks formed by late collapse, and in a few places as pseudo-morphs in small cavities in barite from which galena had been dissolved out. Here it occurs in an acicular habit with crystals up to  $\frac{1}{4}$  inch in length. By far the most common secondary mineral is hemimorphite, which occurs as encrustations or rosettes of small tabular crystals showing a high luster and colors varying from pale yellow-green to dark brown. It occurs chiefly in cracks in barite but also coats calcite. The barite is generally cavernous owing to the removal of sphalerite, of which only a few residual traces have

been seen, but the source of the silica was something of a mystery at first. The discovery in one section of a thin layer of sand cemented with hemimorphite at the base of a sand filled cavern, resting on barite, indicates that the source of the silica is probably in ground water in the sands. Indeed one of us (10) has already described halloysite nodules formed by leaching of kaolinite in nearby sand pits.

Aurichalcite is a less common oxidation product of sphalerite, chalcopyrite and chalcocite as these apparently occurred in close proximity only in some restricted parts of the mine, chiefly in the hollows of the base of dolomitization. This may indicate an original depth zoning of copper and zinc below lead in the ore-bodies as a whole but the occurrences are too sporadic to be sure. Rare dark green smears have been seen in one locality which may be chrysocola, formed in an analogous way to the hemimorphite.

Smithsonite has been seen only in a few late cavities where sand was apparently absent at the time of deposition. In one case it formed a stalagmitic layer on the floor of a vug.

Hydrozincite is still forming late stalagmitic deposits indicating continuing oxidation of zinc minerals in the overlying rock. It occurs as ribbons down the wall, as floor encrustations, and as "cave pearls" or pisoliths coating sand grains.

Except for the last, the secondary minerals are commonly associated with a late generation of small calcite crystals, occurring as clusters of minute modified scalenohedra. Joints and cracks in any of the above categories of deposit are commonly covered with manganese dendrites, and marcasite dendrites (mostly pseudomorphed in limonite) have been seen in a few places.

Fluorite has only been seen as pale purple coatings of saccharoidal texture on joints in areas of secondary oxidation products, and it would appear that it also is a secondary product, perhaps resulting from solution of fluorite from nearby earlier phases.

*Placer Deposits in Post-Mineralization Solution Cavities.*—Parsons (15) considered the porosity of the dolomitized limestone to average five percent in contrast to negligible porosity in the unaltered limestone. Thus the basal part of the porous dolomitized zone, together with the numerous vugs, has both throughout mineralization and since, been a preferential zone for ground-water solution. The intermittent collapses during mineralization were brought about by solution disaggregation of the host dolomite yielding bedded dolomite crystal sand. Since mineralization, solution has continued to disaggregate dolomite and thus to free blocks and smaller pieces of ore. Continued collapse of solution caves has allowed sand and gravel to be washed in through the roof, so that many of the solution caverns now have a partial sand fill with or without derived dolomite crystal sand and blocks. Mining cuts through the fill have revealed that most have a placer breccia of barite at the base, with some lenses of small barite gravels within the sands. These placers have been rich enough for mining at times, being particularly easy to extract. In a few cases blocks of galena have been found in the placers; one seen was over 150 pounds in weight. Pea size galena gravel has been seen in one case. It is clear that both galena and barite breccias

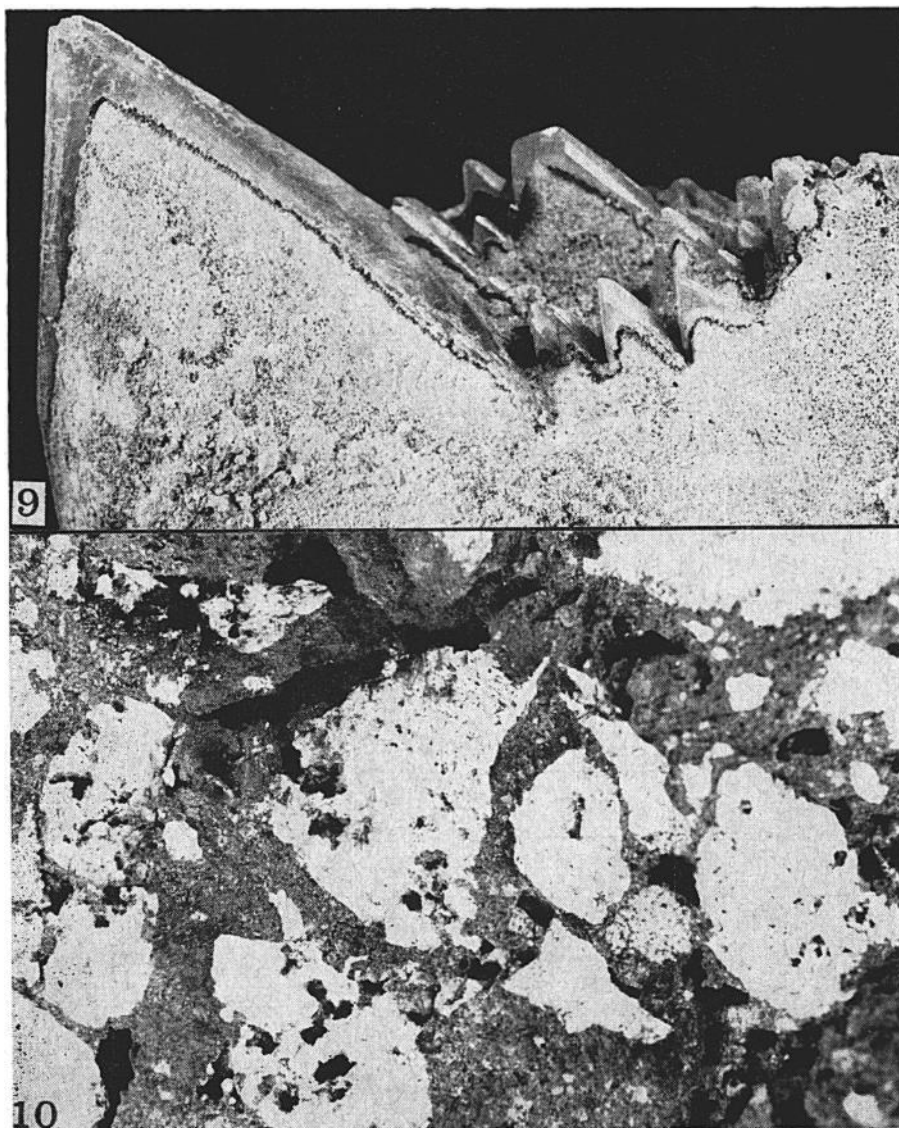


FIG. 9. Calcite scalenohedra showing sand-covered "ghosts" inside. The late growth was on one side only (natural size).

FIG. 10. Detrital barite fragments in limonite-cemented sand from an alluvial layer in a late solution cavern (twice natural size).

are essentially placers in which the fragments have been transported only a few feet at most. The sandy matrix is locally loosely cemented with iron and manganese oxides derived by leaching of sands nearer the surface. Some sand was washed into at least one cavity before calcite crystal growth had

finished and scalenohedra have been found containing a sand covered "ghost" inside (Fig. 9).

Specimens that suggest a similar series of phases of mineral deposition in cavities at the base of dolomitization have been found on the tips of Nursery Mine, Chariot Mine, Condway Mine, Chance Mine and in Many-stones Quarry (Fig. 1).

#### MEANS OF ORE EMPLACEMENT

It will have been evident from the occurrence of layered ores in solution cavities that the ore-bodies were formed as "meat in a sandwich" between the dolomitized limestone above and the unaltered limestone below, and the question arises—were the ores deposited from rising solutions prevented from rising further by relatively impervious beds as in the traditional manner, or were they deposited at the base of penetration by mineralizing brines? Dunham (2, p. 415) claimed that the ore-bodies were ponded beneath a roof of secondary dolomite. By contrast the authors regard the bedded ores and their relationships as evidence that deposition here was at the *base* of penetration of mineralizing solutions or brines with the unaltered limestone as a *floor* beneath. The reasons are that the unaltered limestones show little sign of mineralization whereas the dolomite is heavily affected, that the dolomite has been disaggregated by pre- or early mineralizing solutions leaving open solution cavities, and that the relatively impervious green clay wayboards form the floor to bedded deposits. The authors visualize a process of crystallization of the various mineral phases (with alternation and repetition) in open cavities so that gravitational accumulation could take place. Crystals that settled could continue to grow upwards, whereas granular aggregates of both precipitated minerals and derived dolomite crystals could accumulate as sediment around and over them. Linings of vugs could be formed as a later stage and still later breccias could be formed by collapse.

The occurrence of smaller ore-bodies lying on higher green clay wayboards supports the concept of downward or lateral migration of ore fluids.

The vertical scrins would have been taken in the traditional view as evidence of vertically rising small fissure veins, but here, although the lack of exposure makes the evidence uncertain, the scrins appear to die out downwards. Since some at least of the scrins have contributed material to collapse breccias and perhaps also to bedded ores, it seems clear that they are an early phase of mineralization, but their mineral filling could just as easily have come downwards as upwards.

Thus the authors have no doubt that the means of emplacement is by precipitation (and subsequent sedimentation, collapse and brecciation) from downward or laterally migrating solutions. The presence of hydrocarbons both as inclusions and blocks of bitumen suggests that they may have had a catalytic effect in mineral transport and precipitation in the manner hinted at by Evans (6).

It is also clear from the phases of mineralization that the physical and chemical characters of the fluids changed with time. Early decalcification of the dolomitized zone and precipitation of sulfides implies a reducing environ-

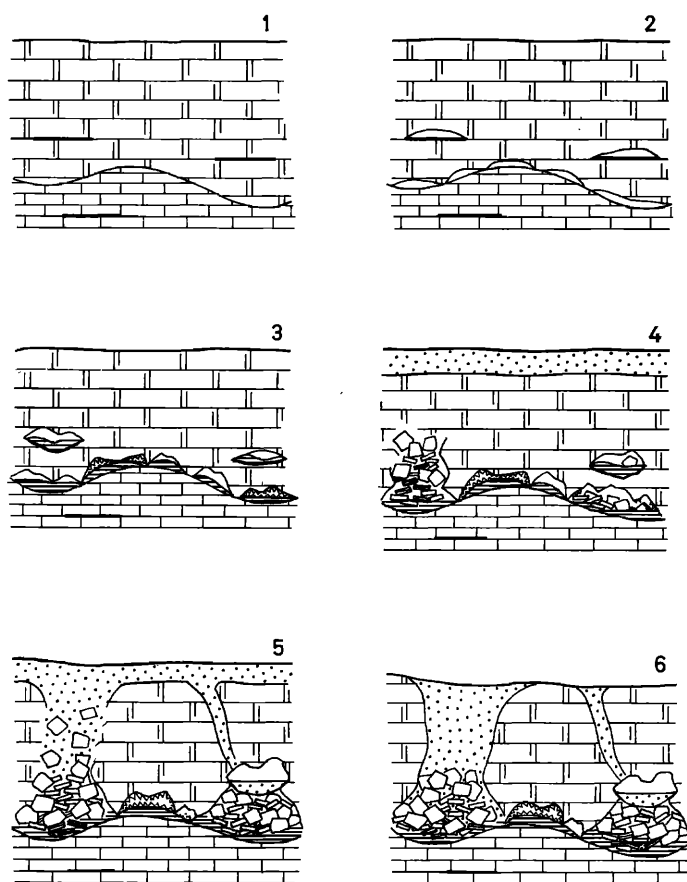


FIG. 11. Diagrams to illustrate the evolution of the Golconda ore deposits.

1. The dolomitized limestone rests with an undulating boundary on unaltered limestone, both with scattered clay beds.

2. Early solution cavities develop at the base of the dolomitized limestone and above some clay beds.

3. The solution cavities are partly filled with bedded ores composed of precipitated galena and barite interbedded with derived dolomite crystal sand. Barite, or later calcite, lines some of the resulting cavities.

4. Repeated phases of solution lead to intermittent collapse of parts of the bedded ores and the dolomite roofs. The Tertiary sand cover may have been deposited during this stage.

5. Further solution leads to the collapse of more dolomite and allows the sand cover to subside, with some washed into both solution cavities and collapse caverns.

6. While solution and collapse continue, surface erosion, probably glacial, removes all the sand cover except that preserved in the solution-collapse pits.

ment but only sufficiently acidic to attack residual calcite in the porous dolomite. Later this slight acidity seems to have been even more restricted in distribution with disaggregation of the dolomite proceeding only a foot or so above growing calcite scalenohedra. Differential distribution of as yet unknown (perhaps organic) catalysts may have been a critical factor. The incoming of the secondary minerals indicates a later change to oxidizing conditions.

Nothing is as yet known of the temperature regimes, but all the minerals present suggest at the highest a low-temperature hydrothermal regime, and they are all well-known from supergene deposits also. The sedimentary layering of phase 1 suggests conditions of temperature (and thus pressure) below the boiling point of water, probably well within the normal range of groundwater temperatures.

The question arises as to whether the Golconda ores should be regarded as syngenetic or epigenetic. The sulfides are syngenetic in the sense that they were deposited within contemporary sediments laid down in pre-existing cavities, but since these sediments are in a sense fortuitous contaminations of precipitates from introduced fluids in a much older country rock, the ores are better classified as epigenetic.

#### REGIONAL SIGNIFICANCE

The concept outlined above of apparently Neptunist deposition of a major ore-body in Derbyshire is completely new. Traditionally, as outlined by Ford (8) uprising hydrothermal solutions have been responsible for all mineralization in Derbyshire, and the evidence of the spreading out of metasomatic replacements under the shale cover or under the main lava horizons indicates that this is probably correct for most of the veins. Regional zoning of gangue minerals similarly suggests a telemagmatic source such as a buried granite, though no parent granite is known. However, when the geochronological history of Derbyshire is considered various problems arise. Moorbath's dating (13, p. 335) of the lead ores as late Triassic or early Jurassic appears at first to conflict with the uprising hydrothermal hypothesis which requires an impervious cover over the whole area though the limits of accuracy ( $180 \pm 40$  m.y.) would cover the whole Triassic period (13, p. 319). From the occurrence of derived chert from the limestones in the Bunter Pebble Beds (early Triassic) only a few miles to the south and from the fact that if the sub-Triassic surface is projected northwards it only just clears the present limestone surface, it seems highly likely that at least some of the limestone was exposed in Triassic times. If this were so, hydrothermal solutions could have emerged as hot springs, in the manner described by Dunham and Hirst (5) for the Kupferschiefer. Moorbath's late Triassic date also conflicts with the assignation of the primary Variscan mineralization of the South Pennines to the Permo-Triassic boundary by Fitch and Miller (7). This latter, however, is really the date of hydration of basalt and is not necessarily the age of mineralization. At this stage the authors regard the Golconda mineralization as of Triassic age.

In view of this the authors suggest that the relationship of the Golconda ore-bodies is that uprising hydrothermal solutions could have come up some nearby fissure to form a rake-vein, and then spread out through the porous dolomite mingling with meteoric ground-waters to sink as "pseudo-Neptunist" brines. This may also explain the apparently anomalous Masson deposits at Matlock, Derbyshire, where rake-veins appear to be associated with metasomatic replacements and solution cavity linings resting *on* impervious lavas in partly dolomitized limestone (2, p. 98).

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