EPI-SYNGENETIC MINERALIZATION IN THE ENGLISH MIDLANDS

by

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Summary

The geological concepts Plutonism and Neptunism are examined and applied to mineralogical environments. A modification of the Neptunian concept is considered and its products described under the title Neo-neptunian dykes. The occurrence and development of this form of ore body in the South Pennines is examined and an attempt made to provide a means for its identification in the field.

... a perfect battlefield in which Neptune and Pluto still dispute the empire of the world.

Jules Verne... "Twenty Thousand Leagues under the Sea" Chapter VII.

Introduction

The geological concepts Plutonism and Neptunism have, until recently, been thought to belong more properly to the igneous and sedimentary environments respectively, or to the history of geology, that is, the Huttonian-Wernerian controversy. In this sense they are both of long standing and acceptance.

The suggestion that they may be applied to mineralogical environments has met with considerable opposition, particularly in the case of Neptunism (Davidson, 1962), even though their original conception was in part founded on mineralogical investigation.

In this mineralogical application, the Plutonian concept invokes a process of ore deposition from hydrothermal solutions originating at depth from an igneous magmatic source. Neptunism, on the other hand, is generally defined as the mechanism of deposition of syngenetic and diagenetic concentrations of sulphides in sediments. The latter concept had its birth in the classical teachings of Werner in Freiberg in the latter half of the 18th century, and was based largely on his observations on the Kupferschiefer of the Thuringian basin of Germany (Adams, 1938). It was not until the middle of this century, however, that Werner's ideas were considered applicable to problems of ore genesis, and the Kupferschiefer is now almost universally accepted as being of syngenetic or Neptunian origin.

Though this deposit is the most obvious and widely quoted example of its type, there are many ore deposits throughout the world which are of a similar character. Such deposits include the Zambian Copperbelt (Mendelsohn, 1961); the Keweenawan deposits in the Nonesuch Shales of Michigan (White and Wright, 1954); Broken Hill, New South Wales (King and Thomson, 1953); and the pyrite-blende-baryte deposit of Meggen in Westphalia (Schmidt, 1918). Although the published literature on the origin of these deposits remains controversial, there is a rapidly growing body of geological opinion which favours the Neptunian, rather than the Plutonic form of genesis.

The Geological Environment

A number of mineral deposits in this country, which are similar in character to the examples quoted above, are also becoming accepted as being Neptunian in origin; the most quoted example is the Marl Slate of Lower Upper Permian age, which has been shown to be the English equivalent of the Kupferschiefer (Deans, 1950). These deposits are interbedded within the enclosing sediments, and may be of contemporaneous deposition with them. They are therefore the more readily accepted as having no obvious plutonic affinities. In the South Pennine area, deposits of undoubted syngenetic origin are almost entirely restricted to Upper Permian and Triassic deposits. They include:

(a) deposits of galena with associated uraniferous hydrocarbons, in the Magnesian Limestone (Deans, 1961);

(b) galena, associated with hydrocarbons and baryte cement in the Bunter Pebble Beds (reminiscent of the Rotliegènde "red beds" mineralization of Germany [Schüller, 1958]);

(c) copper mineralization, in many associations of minerals, in a wide distribution in Keuper deposits; and

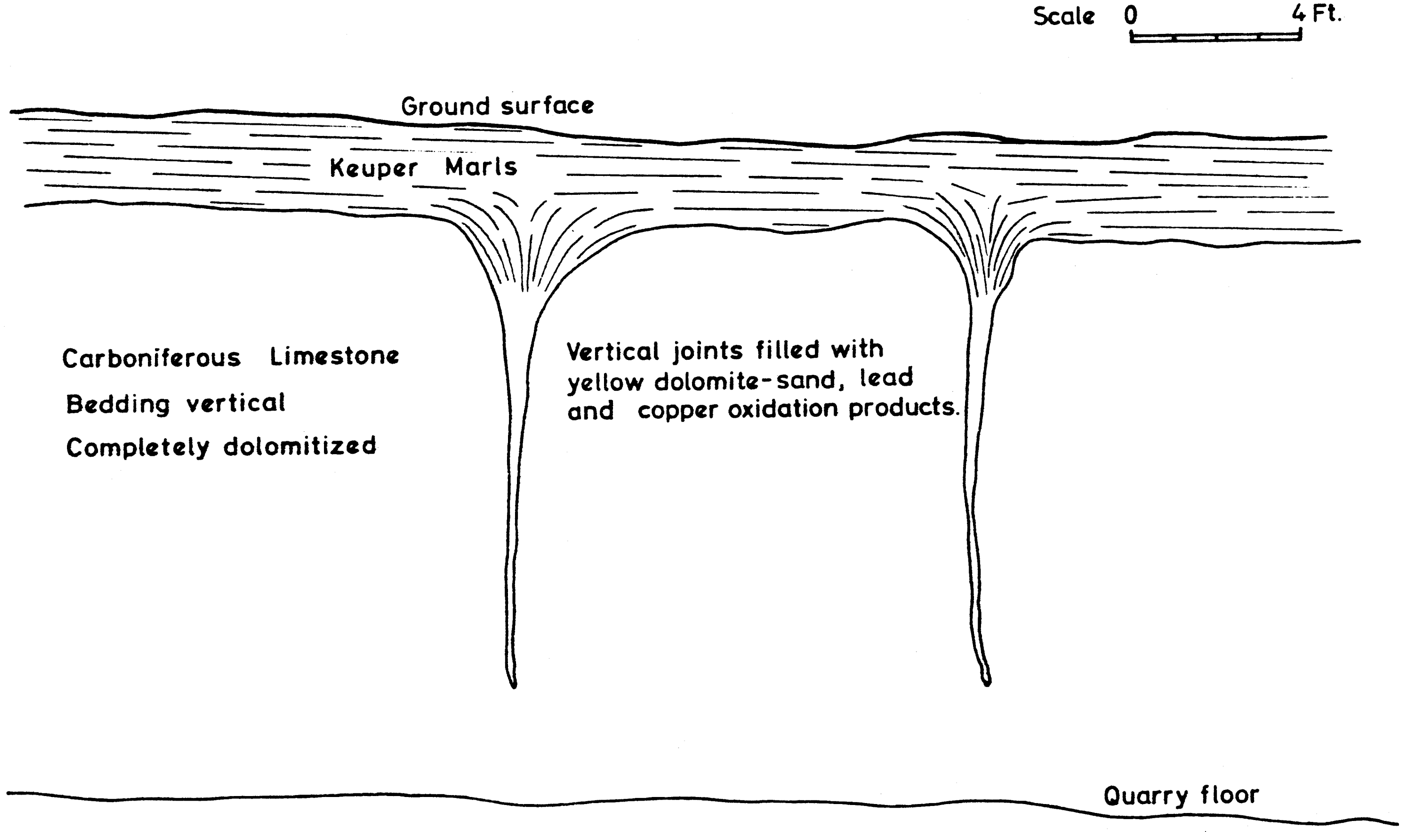
(d) segregations of nickel, cobalt, uranium and vanadium in the Keuper, especially in the Gypsiferous Marls of the Upper Keuper.

With some modification, this tentative acceptance of a Neptunian genesis for certain types of mineral deposit may be extended to include certain more or less vertical vein-like mineral deposits. Hitherto it has been a geological idée fixe to label every vein-like ore body as hydrothermal in origin. In the case of many such bodies in the British Isles, this theory of origin may be the right one. There are igneous relationships which would appear to preclude any other way of thinking. In other cases, however, the compatibility of the observed nature of the body with a conventional hydrothermal origin is hard to accept.

It has already been stated that the Neptunian concept implies ore genesis by the syngenetic or diagenetic concentration of sulphides in sediments. Dunham (1964) has agreed that this concept may, in certain cases, be extended to embrace vein-like deposits. If this is interpreted correctly, the definition of the Neptunian concept may be modified by adding: <u>Certain mineral deposits of an epigenetic character may also be Neptunian in origin.</u>

The term Neptunian Dyke is of common usage, especially amongst sedimentologists and stratigraphers. It was probably coined by Lapworth in the early 1900's (Hazler Hill, near Church Stretton,

Fig. 1 E. Face of Cloud Hill Quarry
Breedon-on-the-Hill. Leicestershire.



where Ordovician sediments occupy fissures in the Precambrian, being the type locality.) In the Midlands there is evidence available to suggest that many mineral bodies, hitherto considered to be of hydrothermal origin, are in fact pseudo- Neptunian or Neo-neptunian "dykes" filled with deposits of epigenetic mineral matter derived from a remobilized earlier syngenetic deposit. In the South Pennines such "dykes" are displayed to perfection, and examples illustrating the development of the "dyke" system in all its several stages are visible.

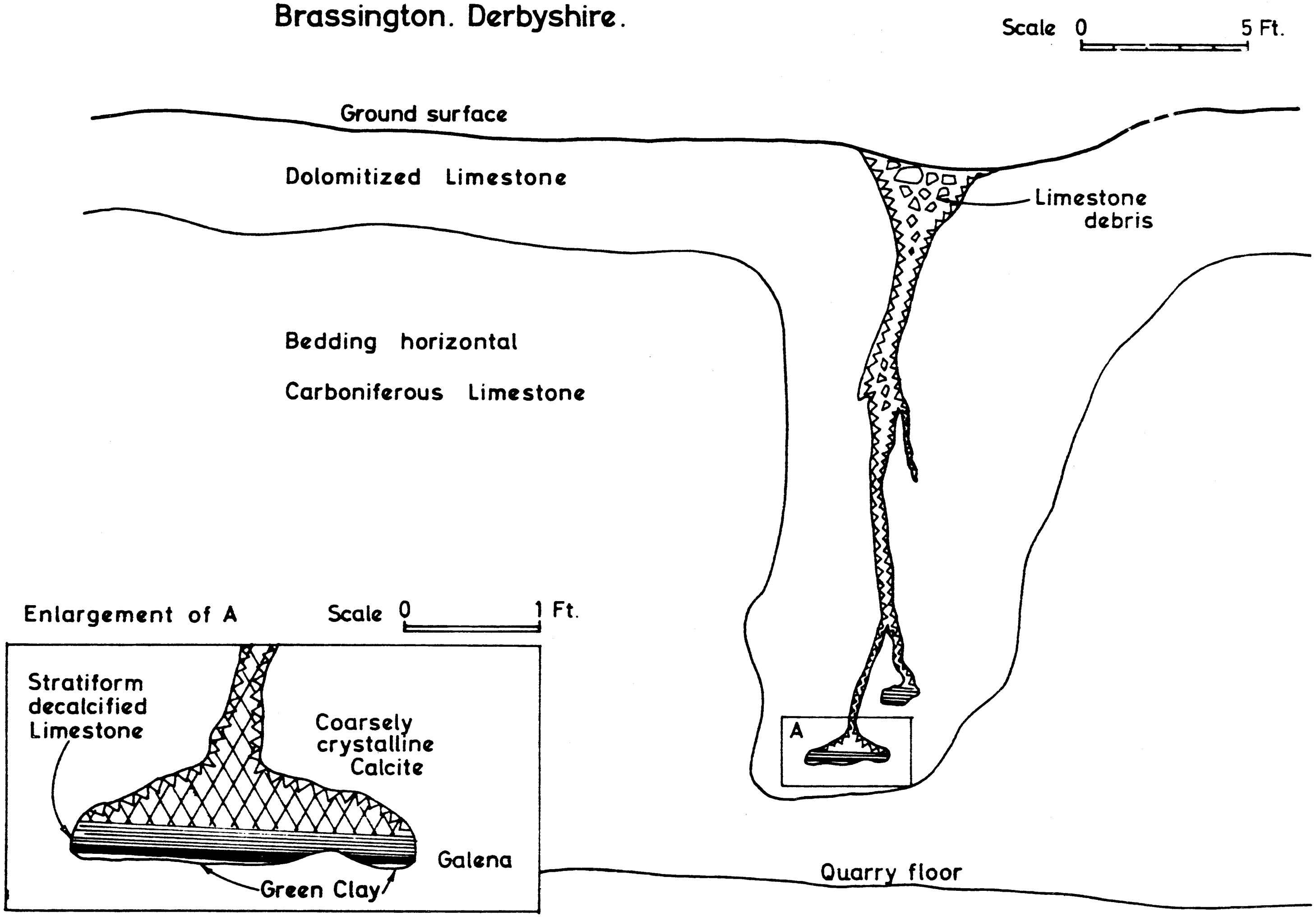
As far as these occurrences are concerned, the mechanism of deposition would appear to be related to the Carboniferous Limestone-Triassic unconformity, connected with cavernization of the limestone before, during and after the Triassic period. It should be be noted that this type of mineralization is by no means restricted to the Carboniferous Limestone-Permo-Triassic unconformities, but occurs in pre-Permian formations wherever there is, or has been, Permo-Triassic transgression. In each case,however, a separate characteristic mineral assemblage is produced. These include, for example, the palygorskite-baryte-chalcocite mineralization in the Precambrian of Charnwood Forest (Evans and King, 1962), and the galena-baryte and chalcopyrite association in the Coal Measures, particularly in the Leicestershire and South Derbyshire Coalfield (Binns and Harrow, 1897). There is,however, the possibility of pene-contemporaneous deposition of galena within the Coal Measures, as may be seen lying immediately above the Marine Band at Overseal in South Derbyshire. It is in the Carboniferous Limestone, however, that these deposits assume economic importance.

Careful study of individual occurrences shows that, in each, there is a characteristic pattern of mineral deposition and associations,which enables one to recognize this type of deposition even where the unconformity has been removed by erosion. There is no direct evidence that the Zechstein seas covered the South Pennine area, though Kent (1957), in his paper on Triassic relics in the South Pennines, has suggested such a transgression. Certainly we see Permian deposits of Marl Slate age on the western side of the North Pennines, but it is much more likely that some of the Carboniferous Limestone was exposed in pre-Triassic times, and that it was in fact covered by at least Lower Triassic sandstones and marls. There are Bunter beds due west of the South Pennines in the neighbourhood of Leek; and the controversial sand and clay pits described by Yorke (1961), which lie in the Brassington and Friden districts of Derbyshire, are rich in pebbles identical in their many lithologies to Bunter pebbles. Whether these pocket deposits of sands, clays, and pebbles are in fact in situ Triassic deposits, or whether they are composed of re-worked Triassic material is not yet known (Ford, in press). The presence of this supposed Triassic material, derived or otherwise, further promotes, however, the possibility of a Triassic transgression.

Additional evidence is probably provided by the patchy dolomitization of the Carboniferous Limestone. Some of these patches may be measured in square metres, while others (for example, that which includes Harborough Rocks near Brassington) may be as much as 16 square kilometres in extent. The process of dolomitization clearly took place subsequent to sedimentation (Parsons, 1922), although exactly when it occurred is not certain. Dunham (1952) has suggested that the dolomite originated by downward infiltration of waters from the Zechstein sea, a hypothesis which would answer many of the problems with which we are confronted in the South Pennines. The zone of dolomitization clearly transgresses the stratigraphic zones and bears no direct relationship to the present surface topography. It is patchy in itself, limestone relics being common. The resultant dolomite is frequently cavernized, producing openings which are often sand-filled (Ford and King, 1965).

If the Carboniferous Limestone-Triassic unconformity is of such importance in the study of Neo-neptunism in the South Pennines, then the most obvious place to look for evidence of the process is in the outliers of Carboniferous Limestone south of the main mass of the Pennines, where they are surrounded and overlapped by Triassic deposits. A number of such localities (Breedon in Leicestershire; Snelston, south of Ashbourne, Derbyshire; Stanton, west of Ashbourne; Kniveton, Derbyshire etc.) show evidence of what may be termed epi-syngenesis to perfection. In the first three of these localities, the Carboniferous Limestone-Triassic unconformity is exposed and it is seen that the limestone is in fact strongly cavernized below the unconformity. The mineralization is characterized by sand-filled pipe-like bodies, which have an average depth of 3.5 metres, and have been lined with calcite, baryte (ranging in habit from a coarse

Fig. 2 S.E. Corner of Manystones Quarry
Brassington. Derbyshire.



pink platey type to the variety "caulk"), galena, chalcocite, copper carbonates and marcasite Text-Fig. 1 G.R. SK413216. The additional presence of manganese salts may have special depositional significance, as has been pointed out by Burrell (Gustavson, Burrell and Garretty, 1950) and Dunham (1964). The presence of hydrocarbon compounds may have similarly important genetical significance (Evans, 1963).

As one moves north onto the main mass of the Carboniferous Limestone, the Triassic deposits disappear. However, the pattern is preserved, except that the Neo-neptunian "dyke" systems become more complex and, for the first time, stratiform deposits develop. These may be seen either where the cavernization has been bottomed or where it provides a sedimentary trap. A typical example of this may be seen in Manystones Quarry near Brassington (G.R. SK237552; Text-fig. 2).

A further example from the same locality shows the sand, which fills the centre of a pipe, surrounded by calcite and baryte.

Perhaps the most striking example of Neo-neptunism to be seen is in Golconda mine (G.R. SK249552) 1.6 kms. east of Manystones Quarry, at the eastern end of the Harborough Rocks ridge (Ford and King, 1965). Here the ore bodies show maturity and complexity. The various types may be listed as follows:

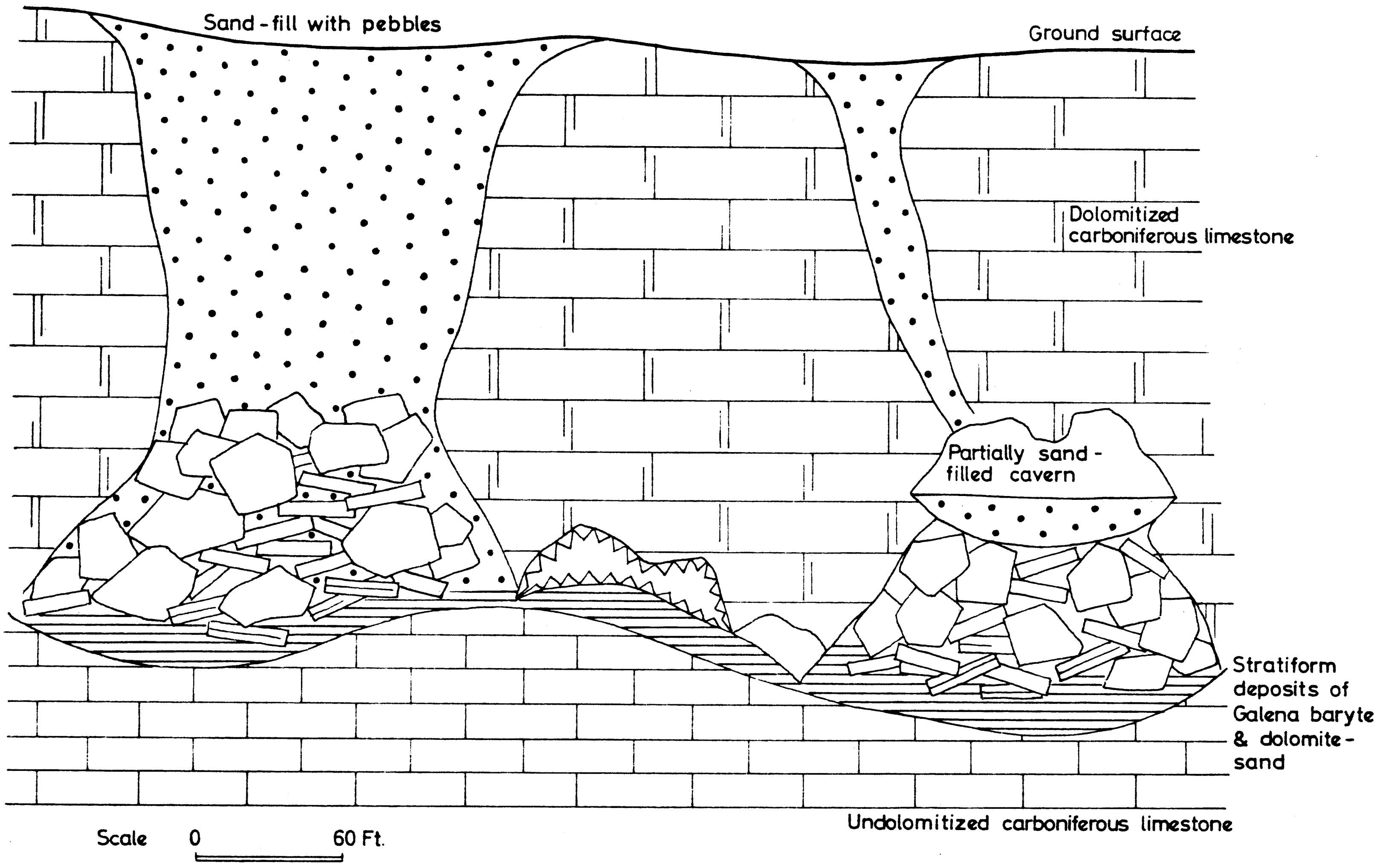
1. Undisturbed stratiform ores.
2. Cavity linings.
3. Collapsed bedded ores and cavity linings.
4. Vertical scrins.
5. Metasomatic replacements.
6. Placer deposits in post-mineralization solution cavities.

The history of origin of these ore bodies is obviously complex, but they are, in fact, complications of the more simple genetical story seen in the ore bodies further south, for example at Snelston in Derbyshire. In contrast to the rest of the mining field, the dominant vertical rake-veins, of undoubtedly hydrothermal origin, are absent and the larger portion of the Golconda ore bodies are shown to be more or less horizontally disposed at the gently undulating contact between an incompletely dolomitized zone of the Carboniferous Limestone above, and an unaltered zone of the limestone beneath. There is abundant evidence that the mineralizing solutions travelled both downwards and laterally. Lateral movement has been controlled to an important degree by the presence of clay beds, although it is not certain at present how these clay beds originated. In some cases they are of contemporaneous deposition with the limestone and may then represent tuff bands. Others, which do not persist laterally beyond 20 metres and are transgressive, may well be deposits of "vitriolic" clay produced by exclusion from the dolomitized zone (Zwierzycki, 1950). They are usually well developed at the dolomite-limestone junction. It is certain that these clays, whatever their origin, played an important part in "ponding" solutions. It is also probable that they played an important part in the precipitation of the ore minerals by a process of adsorption.

Early phases of mineralization resulted in the development of solution cavities at the base of the dolomite, in which a stratiform deposit was accumulated, consisting of baryte and galena as gravitational layers interstratified with derived dolomite sand. Repeated phases of solution gave rise to further cavities, partly or completely filled with breccias of collapsed blocks of bedded baryte, galena and dolomite, some of which were cemented by calcite. (Fig. 3)

There has been, as a final phase, a most interesting and widespread development of hemimorphite and aurichalcite. It has always been assumed that these oxidation products result from the breakdown of blende and copper sulphides. In Golconda, however, it is doubtful if primary blende ever existed. The presence of silica in these minerals is no problem, as silica sand is ubiquitous.

Fig. 3 Galconda Mine
Brassington. Derbyshire.



Origin of the Ores

The origin of the mineralizing solutions is problematical and under examination. The probable influence of a postulated Triassic unconformity has been mentioned already, and it is possible that the dolomitization was produced by the penetration of Triassic ground waters into the limestone. Since the mineral deposits fill cavities in the dolomite, the dolomitization appears to have preceded the mineralization, (as was pointed out originally by Dunham, 1952), though a zone of dolomitization does not of necessity imply an ore body. Thus the most frequent occurrence of Neo-neptunic mineral deposition in the dolomite may be purely a matter of selection through greater porosity.

In 1934, Dunham suggested that the epigenetic Hercynian mineralization of the English Pennines was still in progress when the Zechstein seas advanced over the area, and that hydrothermal fluids continued to pour into the lagoon long after the encroachment, thus providing a build-up of metal concentrations in an environment of foul-bottom conditions. If this mineralization continued into Magnesian Limestone times, Dunham suggested that the effect would be to scatter the metals over a wide area, as has been confirmed by Deans' valuable work in Nottinghamshire and further north (Deans, 1961).

In the Midlands, during Zechstein and post-Zechstein times, not only lagoonal sediments, but also "red beds" were deposited. In this area, the latter constitute a continental phase continuing virtually unbroken, not only throughout the Zechstein and later, but also from the Upper Carboniferous to the Rhaetic marine incursion. Neither was there any serious break in the gradient of increasing aridity in this long period, the only breaks being localized, as in Bunter times when invasions of piedmont fans of pebbles occurred from the Mercian Highlands.

"Red beds" lithologies have long been of interest to the geologist whatever his specialization, and are becoming increasingly so. The problems they present are pertinent to the subject matter of this paper. In the Midlands we may have the answers to many of the outstanding problems. A paper by Finch (1933) described "red beds" copper deposits in the Western States of America. He ascribed the genesis of these deposits to a syngenetic mechanism which was later converted into an epigenetic system by sulphidization. In these deposits there are many similarities to the deposits under discussion in this paper. Popov (1959), when describing a multi-metallic ore suite in the "red beds" of Central Kazakhstan in Russia, ascribed the genesis to syngenetic processes, noting in particular the affinities of lead sulphide for carbonate horizons in the ore-grade sediments, and the deposition of galena in deltaic fans of pebble beds. Both of these workers describe the genesis of syngenetic ores in a sedimentary succession in tectonic basins, under terrestrial environments similar in many aspects to that of the South Pennine area. Perhaps the most important recent contribution in this field is the valuable work done by Mohr (1964), in his comparison of "red beds" in Ethiopia and Alderley Edge in Cheshire. This provides additional evidence to support the Neo-neptunian hypothesis. His suggestion that hot alkaline mineralized solutions may have been pouring out at surface, during the formation of the Triassic basins, agrees with Dunham's suggestion of hot-spring activity post the main Hercynian mineralization (1934). It also provides a mechanism capable of emplacing metallic ions in the more porous aquifer-type members of the Permo-Triassic formations.

A comparative study of the South Pennines and Alderley Edge suggests that the genetical problems of each mineralized area are remarkably similar. The close connection of the ore-bodies to structural imperfections, either faults or swallets, raises again the basic problem of epigenesis and syngenesis, which is best answered by Neo-neptunism.

In an interesting paper, Warrington (1965) has set out to establish that the multi-metallic ores of Alderley Edge were emplaced by a "simple" epigenetic process from an acid igneous source. The evidence set out for this case, though of value, would not appear to be conclusive. For example, the use of the cobalt: nickel ratio in the determination of the genesis of ore deposits (Davidson, 1962) is by no means an accepted fact, as was ably shown by Mohr (1960).

The migration of mineralizing solutions within Permo-Triassic sediments, derived originally from a hydrothermal epigenetic source, is a study as yet not very far advanced. A better understanding of its processes will ultimately provide the answer to many problems of ore genesis, particularly in the English Midlands.

As far as the South Pennine area is concerned it is suggested that, by natural processes of terrestrial weathering, solutions of metallic salts, richer than average due to the close proximity of the mineral enriched Zechstein deposits and Magnesian Limestone, and possibly minor local playa lake deposits, were mobilized in Triassic times, as in the Rotliegende of Germany, and, to varying degrees, concentrated within the Triassic ground water circulation. The mineral-rich solutions thus produced were concentrated below the drought water table, the depth of which may have been great. This may be seen at Golconda mine, where it stood at least 450 feet from the present ground surface, as is shown by the complete oxidation of zinc and copper, and partial oxidation of galena, right to the mine bottom, by way of the cavernization. The latter is an undoubted water system, showing water-worn walls and residual clays. This is not restricted to Golconda but is true of all pipe-like mineral bodies so far examined in the South Derbyshire area. By processes of either catalytic precipitation, adsorption or the influence of hydrocarbon solubilization or all of them, the ore bodies were developed in the characteristic pattern described.

Identification of a Neo-Neptunian Dyke

Finally we need a means of identification for the Neo-Neptunian mineral body. In Derbyshire there are three terms used to describe the principal ore bodies: Rake veins, scrin veins and pipes. These, in the "Derbyshire Lead Mining glossary" (Kirkham, 1949), are described as follows: "a scrin is a narrow cleft in the rock or hillside wherein lead ore is sometimes found. A pipe is distinguished from a vein by its irregularity in width. In the widest parts, a pipe is usually filled with soft clays or loose loamy soil in which the ore lays in loose lumps. A pipe generally runs in a contrary direction to the veins nearby. A rake is so called by its being wider or stronger than scrins. It is distinguished from a pipe by the regularity of its sides, also by the ore being in an upright position instead of a casual condition as in a pipe."

Apart from the stratiform deposits, which are in themselves obvious, do we in fact have the ready means of identification of a Neo-neptunian ore body? It is difficult to assign any ore body to a Plutonic or Neptunian genesis until it has been carefully examined, but I feel certain that we shall ultimately consider the term "rake-vein" to imply a plutonic hydrothermal origin, and that "pipes" imply Neo-neptunism, with scrins probably originating by either means and identified only by their field relationships.

Acknowledgements

The writer wishes to acknowledge with gratitude the help he has received from many people. These include the management of the several mining and quarrying properties visited many times, and in particular Dr. T.D. Ford and Dr. C.H. James, whose interest, encouragement and healthy criticism have been vital to this work.

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Manuscript received 23rd April, 1966