Bulletin Peak District Mines Historical Society Vol. 9, no. 2 Winter, 1984

II Mineral Associations

Mohammad A. Mostaghel

ABSTRACT

The result of a preliminary study of mineral associations of galena, sphalerite and pyrite with the major non-metallic minerals (calcite, fluorite and baryte) in 138 selected ore deposits from the south Pennine orefield shows that the three sulphides have strong preference for precipitation with calcite. Galena + calcite is the dominant mineral association of 55 of the 134 ore deposits containing PbS and sphalerite + calcite is the main mineral association of zinc sulphide in 13 of the 25 ore deposits which contain ZnS. Pyrite and calcite form the main mineral assemblage of iron sulphide in 10 of the 23 ore deposits where megascopic pyrite is found. Galena, sphalerite and pyrite have slightly different behaviour patterns in respect to the association with fluorite and mixtures of different non-metallic minerals.

INTRODUCTION

Although study of mineral associations in carbonate-hosted base metal sulphide deposits is often overlooked, it is important for three reasons. Firstly, it is a guide to the chemistry of the ore-forming solutions because it is probable that the minerals approached equilibrium with the ore fluids at the time of deposition. Secondly, the differentiation of different mineral associations can be used to delimit the relative depositional sequences of the minerals within each specific association which is essential in finding the paragenetic sequences during each phase, or entire history, of ore mineralisation in every ore deposit. Thirdly, the recognition of mineral assemblages is important in establishing preferential deposition of sulphide minerals with each non-metallic mineral which could provide an additional tool in future exploration in the same orefield or in other geologically similar environments.

The South Pennine orefield is considered to be one of the four carbonate-hosted Mississippi Valley-type orefields in Britain (Ford, 1976). It lies at the southern end of the north-south trending Pennine Hills in central northern England. The orefield consists of hundreds of veins (locally known as rakes and scrins) and replacement-stratiform ore bodies (known as pipes and flats) in an uplifted plateau of Lower Carboniferous (Dinantian) limestone. The principal sulphide minerals are galena and, less abundantly, sphalerite and pyrite which often constitute less than 10 percent of the ore bodies and were regarded as the only useful minerals in the early periods of mining development in the ore-field. More than 90 percent of the ore bodies are made up of different proportions of calcite, fluorite and baryte which are the principal ore minerals in the present-day exploration in the orefield.

Although mineral associations in the south Pennine orefield have not been previously studied, the impression that the base metal sulphides are mainly found in association with calcite has generally been perceived by those who have studied other aspects of ore mineralisation in the orefield. For example, in a recent review of ore genesis in the English Pennines, Dunham (1983) stated that "sulphides, particularly galena, were certainly deposited with calcite". As part of a research project on the genesis of sulphide mineralisation in the South Pennine orefield (Mostaghel, 1984) an attempt was made to study the association of the principal sulphide minerals with the major non-metallic minerals (calcite, fluorite and baryte). The results of this preliminary study are discussed here.

COLLECTION OF DATA

In order to investigate the types of mineral association in the orefield, 138 ore bodies were selected for sampling and field observation (Fig. 1). The ore bodies were chosen on the basis of: (a) their geographical distribution in the orefield, and (b) availability of sufficient mineralised samples. Most of the samples used in this study were collected from the "waste dumps" of past mining developments in the orefield. In situ samples were collected from a few ore bodies where minerals are being mined at the present or where access to old workings is still available.

The different megascopic mineral assemblages in the samples of each ore deposit were noted in the field and over 4000 fist-size representative samples were collected from the ore bodies for laboratory studies. In addition, the main mineral associations of PbS, ZnS and FeS_2 were determined in each of the 138 ore deposits on the basis of the relative abundances of the mineral assemblages in the samples studied.

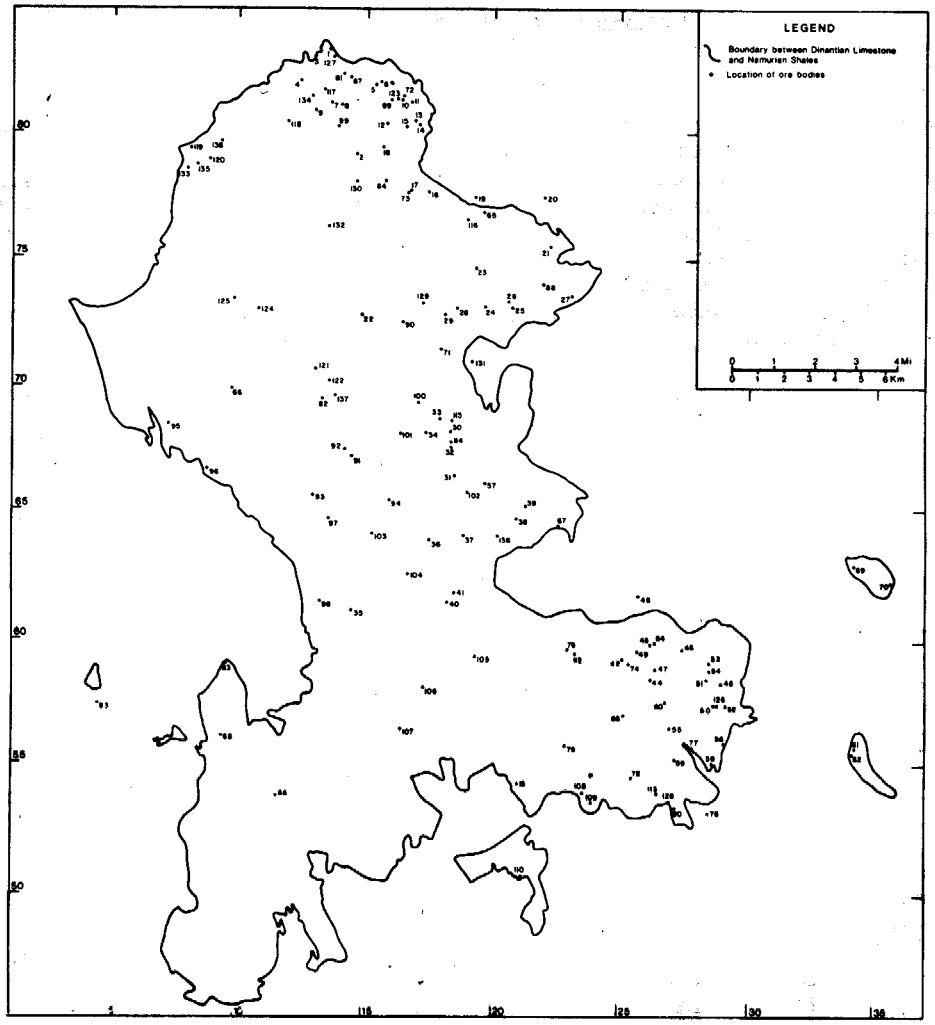

Fig. 1. Location of the ore deposits studied.

It should be pointed out that due to extensive mineral exploitation during centuries of mining in the orefield and lack of access to many old subsurface workings, the only minerals left from a great number of ore bodies are now found in the "waste dumps" which constitute a prominent feature of the landscape in the orefield. Although studies which are based on samples collected from these dumps may not provide a complete picture, it is, in many cases, the only avenue for research on sulphide mineralisation in the orefield.

RESULTS

On the basis of laboratory studies of collected samples and field observations, 60 different mineral assemblages of base metal sulphides were recognised in the South Pennine orefield. Some of these assemblages contain secondary alteration minerals and are, therefore, omitted from Table 1 which shows the distribution of 35 common primary mineral associations in the 138 ore deposits. Table 1 also shows that out of 138 ore deposits 134 contain different assemblages of galena, 25 contain assemblages of sphalerite and pyrite is found in 23 ore deposits. Assemblages containing primary Cu minerals are rare in the orefield and association of galena and chalcopyrite is found only at Ecton Mines (site 63 in Fig. 1 and Table 1).

Of the principal sulphide minerals, only sphalerite has a restricted occurrence and is found near the eastern margin of the orefield and the eastern inliers (Fig. 1, Table 1). Galena, on the other hand, can be found almost anywhere in the orefield and, although it changes from one deposit to another, the ratio of galena to sphalerite is probably near 10 to 1 for the whole orefield. Because of abundance of galena, the assemblages of this sulphide are by far the dominant base metal mineral association in the majority of the ore

Table 1. Primary mineral assemblages in the South Pennine orefield.

MINERAL ASSEMBLAGES / LOCATION	1- Odin Mine	2- Scrin Rake	3- Windy Knoll	4- Mashhill Mine	5- Dirtlow Rake	6- Dirtlow Rake	7- Hazard Mine	8- Hollandtwine Mine	9- Portway Gravel Pit	10- Upper Small Dale Pipe	11- Lower Small Dale Pipe	12- Moss Rake	13- Outlands Head Quarry	14- Rowall Nook Mine	15- Earl Rake	16- High Rake	17- High Rake	18- Shuttle Rake	19- Shepherd's Flat	20- Ladywash Mine	21- Main Rake	22- Moury Mine	23- White Rake	24- Watersaw Rake	25- High Rake	26- High Rake	27- Deep Rake	28- High Rake	29- Crossdale Head Mine	30- Mogshaw Rake	31- Mondale Rake	32- Bole Hill Mine	33- Sheldon Mine	34- Magpie Mine	35- Hartington Iron Mine	36- Long Rake	37- Long Rake	38- Raper Mine	39- Conksbury Quarry	40- Kenslow Pit	41- Kenslow Mine	42- Bonsall Moor	43- Tearsall Quarry	44- Blake Mere Quarry	45- Oxclose Mine	46- Devonshire Mine
Galena + Calcite	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●			●	●	●				●	●					●	●				●	●	●	●	●	●	●
Galena + Baryte		●																								●												●			●			
Galena + Fluorite		●																								●			●		●							●			●	●	●	●
Galena + Baryte + Calcite		●		●	●	●	●	●		●			●			●		●	●				●	●			●		●	●		●									●	●	●
Galena + Fluorite + Calcite	●				●					●	●			●	●				●	●				●	●		●		●	●	●						●	●	●			●	●	●
Galena + Fluorite + Baryte		●									●										●					●	●			●	●							●	●			●	●	●
Galena + Fluorite + Baryte + Calcite		●		●	●																			●		●				●	●	●						●	●			●		
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Chalcopyrite + Galena + Calcite																																												

Table 1 continued

MINERAL ASSEMBLAGES / LOCATION	47- Moorland Lane	48- Millclose Mine	49- Slack Mine	50- Ball Eye Mine	51- Low Mine	52- Old Gange Vein	53- Masson Pit	54- Beck Mine	55- Goodluck Mine	56- Dovegang Mines	57- Mandale Mine	58- Shaw's Quarry	59- Intake Quarry	60- Slaley	61- Glory Mine	62- Crich Quarry	63- Ecton Mine	64- Tideslow Rake	65- Crosslow Vein	66- Grove Rake Vein	67- Blythe Mine	68- Manifold Valley	69- Butts Quarry	70- Fall Gate Quarry	71- Putwell Hill Mine	72- Moorfurlong Pipe	73- High Rake Mine	74- Beans and Bacon Mine	75- Exlow Mere Lane	76- Lady Flats Mine	77- Middleton Mine	78- Bone Mill Quarry	79- Golconda Mine	80- Round Flat Vein	81- Pipe Vein	82- Hubberdale	83- Mixon Mine	84- Tearsall Farm	85- Ible Mine	86- Bincliffe Mine	87- Cowlow Nick	88- Sallet Mine	89- Hope Quarry	90- Burfoot Mine	91- Whalf Pipe	92- Knotlow Mine
Galena + Calcite			●	●	●	●	●		●	●		●		●	●	●	●	●	●	●	●		●		●		●		●	●		●	●		●	●		●			●	●
Galena + Baryte				●		●	●		●	●	●	●			●	●	●		●		●	●	●		●	●	●	●		●	●	●	●	●	●	●	●		●	●		●	●
Galena + Fluorite			●	●		●	●	●								●			●				●	●			●	●		●		●		●			●	●		●			
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Table 1 continued

MINERAL ASSEMBLAGES \ LOCATION	93- Hurdlow Station	94- Fern Dale	95- Greensides Mines	96- Hitter Hill	97- High Rake	98- Carder Low	99- Bradwell Moor	100- Field Grove Mine	101- Hard Rake	102- Lathkildale Mine	103- Prospect Mine	104- Green Lane Pit	105- Mouldridge Mine	106- Green Rake	107- Hindlip Quarry	108- Nickalum Pipe	109- Great Rake Vein	110- Standlow Quarry	111- Hipley Dale	112- Moss Venture Vein	113- Yoke Cliffe Mines	114- Hard Rake	115- Dirtlow Rake	116- Foolow	117- New Rake	118- Watts Grove Rake	119- Barmoor	120- Bee Low	121- Whas Rake	122- Moor Lane	123- Pindale Quarry	124- I.C.I. Quarry, South Fault	125- I.C.I. Quarry, Meerhead Fault	126- Ball Eye Quarry	127- Treak Cliff Cavern	128- Gells Mine	129- Cressbrook Mine	130- White Rake	131- Headstone Cutting	132- Edge Rake	133- Ridgeclose Quarry	134- Linicar Rake	135- South of Bennetston Hall Quarry	136- East of Bennetston Hall Quarry	137- Hubbadale Mine	138- East of Lomber Dale
Galena + Calcite	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●		●	●	●			●	●		●		●		●	●	●	●		●		●					
Galena + Baryte			●	●	●		●		●		●			●			●	●	●	●	●	●	●	●	●	●			●	●	●	●	●						●		●	●	
Galena + Fluorite							●																	●	●	●					●	●	●	●								●	
Galena + Baryte + Calcite			●	●	●				●			●		●		●		●	●	●			●	●		●		●			●	●		●		●	●			●		
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deposits. Where galena and sphalerite are both present in an ore bodies, most of sphalerite preferentially forms its own assemblages rather than being intimately associated with galena (Table 1). Pyrite also forms its own assemblages in preference to association with galena and/or sphalerite although, on microscopic scale, it is frequently associated with sphalerite (Mostaghel, 1984).

Table 2 summarises the distribution of the ore deposits in terms of their dominant mineral association of the three base metal sulphides. Galena + calcite is the dominant mineral assemblage of PbS in 55 ore deposits indicating that galena has a strong preference for precipitation with calcite (Table 2). The second most common association of PbS is galena + baryte which is the dominant mineral assemblage in 36 ore deposits (Table 2). The other mineral associations of galena, in their decreasing occurrence, are: galena + baryte + fluorite, galena + baryte + calcite, galena + fluorite, galena + fluorite + calcite and galena + calcite + baryte + fluorite (Table 2). The same preference of association is shown by both sphalerite and pyrite with some minor differences. These differences are (1) neither sphalerite nor pyrite form a dominant association with the three non-metallic minerals as does galena, and (2) both sulphides have slightly different behaviour patterns from galena in respect to association with fluorite and different assemblages of calcite, baryte and fluorite (Table 2).

Table 2 DOMINANT MINERAL ASSOCIATIONS OF GALENA, SPHALERITE & PYRITE

Sulphides	Calcite	Baryte	Baryte + Fluorite	Baryte + Calcite	Fluorite	Fluorite + Calcite	Calcite + Baryte + Fluorite	Total No. of Ore Deposits
Galena	55	36	15	12	7	6	3	134
Sphalerite	13	3	3	1	2	3	0	25
Pyrite	10	4	2	3	3	1	0	23

It is also evident from Table 2 that in 77 percent of the ore bodies containing galena the sulphide has dominant association with calcite, baryte or mixture of the two minerals. This percentage is 68 and 74 for sphalerite and pyrite, respectively.

CONCLUSIONS

Although the results presented here are preliminary, a number of conclusions can be drawn from them regarding the mineral association in the south Pennine orefield:

1. The three principal sulphides show strong preference to be associated with calcite. This is due to the fact that calcite is by far the most common mineral in the orefield and is the dominant mineral in 60 of the 138 ore deposits studied (Mostaghel, 1983).
2. Of the three major non-metallic minerals, fluorite shows the least preference for association with the base metal sulphides indicating that the ore fluids which were responsible for fluorite mineralisation in the orefield did not contain sufficient amounts of lead, zinc and iron for large volume deposition of galena, sphalerite and pyrite with fluorite.
3. The diversity of the mineral assemblages in the orefield coupled with the realisation that ore deposition in the South Pennine orefield occurred over a long period of time as the result of separate pulsations of ore fluids which produced multi-phase mineralization phenomena in the area (e.g. Ineson and Al-Kufaishi, 1970; Mostaghel, 1984) indicate that the mineralising fluids did not have a uniform chemistry during the course of ore deposition in the orefield. As pointed out by Schnellmann and Wilson (1947), in any particular ore deposit in the orefield "there may have been more than one mineralizing stream, each following an independent course" and therefore it is conceivable that these ore-forming streams had different compositions and chemistry or as they moved from the east (where it is postulated that they first entered the orefield) to the west of the orefield, their composition changed as the result of mineral precipitation and/or interaction with the host rocks.
4. There are no major differences in mineral association between the vein deposits and the replacement-stratiform ore bodies.

ACKNOWLEDGEMENTS

This paper forms part of a Ph.D. thesis submitted to the University of Leicester. I am indebted to Dr. T.D. Ford who supervised the work and commented on the manuscript. Thanks are also due to my wife, Elisabeth, for preparation of the tables and the manuscript. The author remains solely responsible for the views expressed here.

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M.S. Received August 1984.