GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL 14, NO. 2, 2008: 197 - 201
 ISSN 1118-0579

MINERALOGY AND GENESIS OF THE LALAMILA IRON DEPOSIT, CENTRAL REGION, TOGO

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(Received 5, July 2006; Revision Accepted 1, February 2008)

ABSTRACT

The Lalamila iron deposit is made up essentially of coarse steel grey hematite and accessory magnetite, gahnite and plumbogummite. This peculiar mineralogy is an evidence of transformation occurred during the Pan African event of a primary association of magnetite, galena and sphalerite.

KEYWORDS: Grey crystalline hematite, Magnetite, Gahnite, Plumbogummite, Transformation.

INTRODUCTION

In Togo, several iron deposits recognized as itabirite have been discovered in many localities in Atacora range of Kara and Central regions (Katchinsky, 1935; Dempster, 1965, 1966; Kpalimé, 1977, Kpalma and Seddoh, 1983). These iron formations are formed by banded alternating iron-rich and silica-rich layers. The iron – rich layers are made up essentially of hematite and minor magnetite (Kpalma and Seddoh, 1983).

In the south western part of the district of Blitta, an iron deposit was discovered east of the village of Lalamila (Fig 1). It differs from the former ones by the absence of banding structure, and it is characterised by high contents of aluminium, phosphorus, zinc and lead. The area in which the deposit occurs is a slightly dissected plateau of moderate relief with external drainage. The climate is intermediate to subsudanean with annual rain fall of about 1300 m in some rainy years.

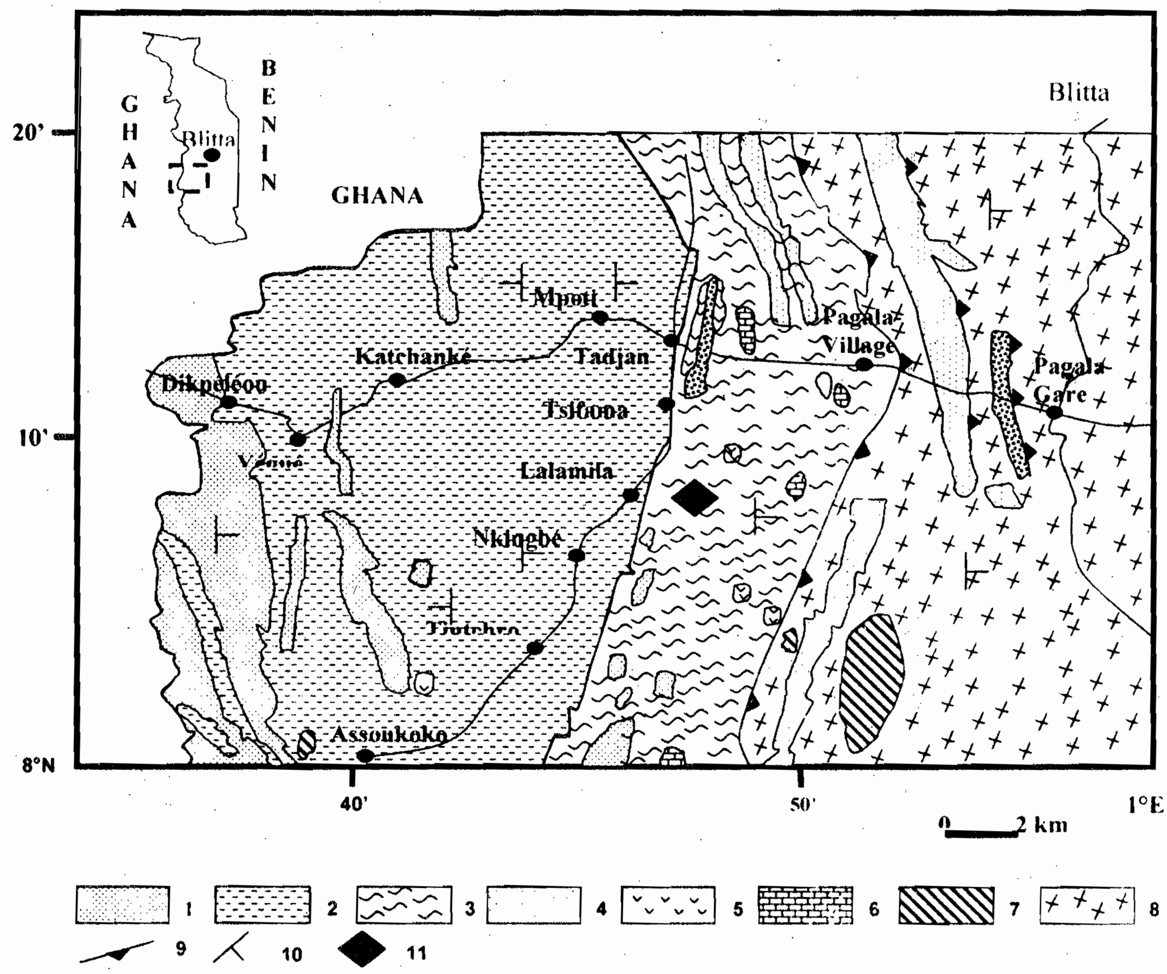

Fig. 1 : Sketch map of the geology of the South Western part of the District of Blitta and location of Lalamila deposit. 1 = quartzites with séricite and/or muscovite; 2 = sericitic and chloritic schists; 3 = micaschists, graphitic schists; 4 = feldspathic quartzites; 5 = metavolcanics; 6 = dolomitic rocks 7 = serpentine rocks; 8 = amphibolitic gneisses; 9 = thrusting; 10 = dip; 11 = Lalamila deposit

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Description of the regional geology has been provided by Magat and Blot (1984a ; 1984b), Godonou et al., (1986) and other workers. The deposit is an interbedded vein about 7 m thick and with unknown length. The vein is essentially made up of coarse crystals of hematite and with high lead and zinc values. It is hosted by old supracrustal rocks of upper Proterozoic age, which were deformed and metamorphosed during the pan African orogeny, c. 650 – 550 Ma, which imposed a general N-S foliation (S_1) with eastward dip. These supracrustal rocks are made up essentially of schists and quartzites with limestone intercalations and subordinate volcanics. Their mineralogy is dominated by the association of muscovite, quartz and accessory albite, apatite, ilmenite, sphene, etc. The objectives of this paper are to study the mineralogy and the chemistry of the peculiar Lalamila iron deposit and to discuss the conditions of its formation and its possible origin.

Methodology

Ten samples were collected from a pit for study. For mineralogical part of the investigations polished sections were prepared and examined by reflecting petrographic microscope. Mineral identification was supplemented by X-ray powder diffraction and electron microprobe. For chemical studies crushed samples were analyzed by multi-element ICP spectroscopy.

RESULTS

Mineralogy

The ore is coarse grained, massive and steel-grey in colour. It consists essentially of hematite with minor amounts of magnetite, gahnite and plumbogummite crystals. Under the microscope, its texture is coarse tabular to coarse granular with grain size > 100 µm. Hematite shows bladed, squared, or triangular euhedral sections. Magnetite grains occur as massive aggregates of subhedral to euhedral porphyroblasts. Gahnite occurs in idiomorphic well-formed crystals with grain size around 100 µm. It appears under unpolarized light in dark red colour. Magnetite and gahnite crystals are disseminated in the hematite mass. Plumbogummite forms fine granular crystals filling interstices between hematite minerals. It is transiucid with a weak optical relief.

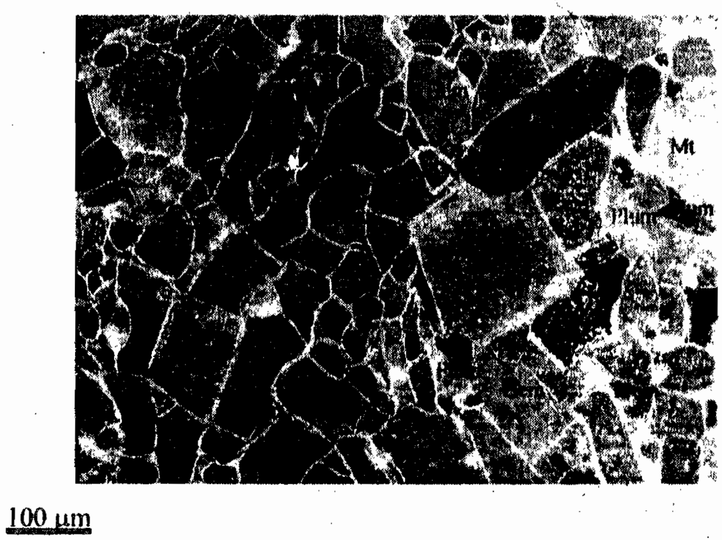

Fig. 2: Microphotograph showing the textural relations of minerals of the sample TOG 24, (x20)
Hem = hematite; Gah = gahnite: Mt = magnetite; Plum = plumbogummite.

CHEMISTRY

Geochemistry

The results of the ICP analyses carried out on five samples are presented in Table 1. Save the iron with 94.70 wt. % Fe_2O_3, the other major elements are aluminium (2.30 wt. % Al_2O_3) and phosphorus (1.33 wt.% P_2O_5). Titanium content is low. For minor elements, only lead and zinc show high values up to 15 000 ppm and 3 200 ppm, respectively. No trace of sulphur was detected.

Table 1: Mean chemical composition of ore sample (n = 5)

	SiO_2	Al_2O_3	Fe_2O_3	Mn_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
wt. %°	0.3	2.3	94.7	0.04	0	0	0	0.1	0.07	1.33	0.7	99.79
	Ce	Co	Cr	Cu	La	Ni	Pb	V	Y	Zn	Zr	
ppm	45	32	40	41	20	86	15.000	183	24	3 200	117	

Mineral chemistry

The results of microprobe analyses are summarized in Table 2 which shows also the crystal structural formulas calculated for each mineral species studied. Hematite is pure in composition with small amount of ZnO and Pb of 0.31 and 0.41 wt. % respectively. The gahnite has about 96 mole % $ZnAl_2O_4$ which corresponds to 51.45 wt Al_2O_4 and 43.13 wt % ZnO. Iron is the only other element present, but in minor amount (4.19 wt %). On the basis of 32 oxygens, the crystal structural formula can be written as: $(Zn_{1.008},Fe^{2+}_{0.112})_8(Al_{1.919}O_4)_8$. As observed in the formula iron substitutes principally for zinc. The plumbogummite presents the following composition: phosphorus 23.2 wt % P_2O_5, aluminium 25.7 wt Al_2O_3, lead 41 wt % PbO and iron 2.3 wt % FeO. Its formula expressed on the basis of two moles of (PO_4) per formula unit is: $Pb_{1.08}(Al_{2.98}Fe_{.16})(PO_4)_{1.85}(OH)_{5.56}.H_2O$.

Table 2: Microprobe analyses (wt. %) of hematite, gahnite and plumbogummite

Species	FeO*	ZnO	PbO	Al_2O_3	P_2O_5	Total	Locality	References
Hematite	99.54	0.37	0.14	-	-	100.25	Lalamila	1
Gahnite	4.19	43.13	-	51.45	-	98.77	Lalamila	1
Gahnite -	44.39	-	55.61	-	100.00			2
Gahnite	7.9	35.85	-	55.91	-	99.66	Chiapaval	3
Gahnite	5.29	40.89	-	53.71	-	99.89	Sterling Hills	-
Plumbogummite	2.31	-	41.00	25.71	23.21	92.23	Lalamila	1
Plumbogummite	-	-	38.41	26.32	24.42	89.15		2

* - Oxidation state of Fe undetermined; but certainly ferric in hematite and plumbogummite and ferrous in gahnite;
- =. Not determined or given;
1 = This study;
2 = Dud'a and Rejl, (1986);
3 = Spry and Scott (1986); Ech. 145054

DISCUSSION AND CONCLUSION

The diagnostic geochemical features of the Lalamila deposit include, in addition to iron values, high contents of zinc and lead which constitute geochemical anomalies. According to the electron microprobe results, these geochemical anomalies can be attributed to the presence of gahnite and plumbogummite containing zinc and lead respectively. Compared with the composition of gahnite and plumbogummite obtained from literature (Table 2), the gahnite from Lalamila is depleted both in ZnO and Al_2O_3 relative to that reported by Dud'a and Rejl (1986) which can be considered as classic ones. With respect to the gahnite from Chiapaval and Sterling Hills (Spry and Scott, 1986), the Lalamila species contains higher zinc and lower aluminium values. As for plumbogummite, it is more enriched in lead and slightly depleted in aluminium and phosphorus compared with species reported in Table 2 (Dud'a and Rejl, 1986).

The association of gahnite and plumbogummite with steel grey hematite and magnetite leads to genesis questions. In fact, gahnite is known as magmatic mineral associated with granitic pegmatite or metasomatic replacement vein in Zn-Pb sulphide mineralization (Deer et al., 1962). It is also encountered in Precambrian metamorphic terranes (Boni, 2003; Ciobanu and al., 2002), in oxydation zones of Zn-Pb sulphide ores, or in banded iron formation (Spry et al., 2003). According to these authors, gahnite, originally, could be formed either from exhalative or inhalative hydrothermal alteration of pelagic sediments or from a metamorphic hydrothermal solution. The mineral could also form by desulphidation of sphalerite under higher metamorphic conditions (Ciobanu et al., 2002). Plumbogummite is a common secondary lead phosphate mineral only observed in oxidised zones of galena – sphalerite ore bodies (Nickel, 1982; Dud'a and Rejl, 1986; Williams, 1990; Skwarnecki and Fitzpatrick, 2003). It forms by precipitation of Pb in a phosphate-rich environment where Al^{3+} is also a dominant cation (Nickel and Daniels, 1985; Scott, 2002).

Hematite is an ubiquitous iron oxide mineral encountered especially in sedimentary, weathering and metamorphic environments. It forms in different ways: 1) by oxidizing exhaled Fe^{2+} from seafloor vents into early oceans (Beukes and Klein, 1992); 2) by alteration of igneous rocks due to oxidizing O_2-rich surface (Catling and Moore, 2003); 3) by direct transformation of magnetite or precipitation of iron from dissolution of magnetite (Lagoeiro et al., 2004; Mücke, 2003) or 4) by dehydration of goethite (Bose, 1958; Morris, 1980). The mineral structure depends upon its process of formation. For example, hematite derived by alteration or sedimentary processes has finely divided reddish grains. According to Powell et al., (1999), and Taylor et al., (2001), thermal processes convert microcrystalline or amorphous iron oxides to coarse-grained crystalline hematite. The temperature needed in this transformation is estimated at about 140°C (Bischoff, 1969; Langmuir, 1971). Direct transformation of magnetite or direct precipitation of iron from the dissolution of magnetite gives rise to granular to tabular hematite (Lagoeiro et al., 2004). According to Catling and Moore (2003), grey crystalline hematite in terrestrial BIFs results from low-grade metamorphism and /or hydrothermal recrystallization of precursor minerals like goethite, hematite or magnetite.

Magnetite Fe_3O_4, a natural magnet mineral, is one of the three main series of spinels with hercynite MgA_2lO_4 and chromite $FeCr_2O_4$, generally formed at high temperatures via hydrothermal processes (Williams, 1990). Magnetite is the dominant mineral of most of ancient iron formations. Same workers believe it is the primary iron mineral formed by hydrothermal processes. It is known in "Kiruna type" iron deposits of El Laco in northern Chile, Iron Springs of Utah and Kiirunavaara in northern Sweden (Bookstrom, 1995; Hitzman, 2000), iron formations from Iron Quadrangle Brazil (Lagoeiro et al., 2004), and Djamdé and Labo iron formations in northern Togo (Kpalma et Seddoh, 1983). In these formations, magnetite is believed to be generally a primary iron mineral. Compared with the "Kiruna type" iron ore which is characterized by the assemblage magnetite-hematite-apatite, no free-apatite mineral is seen in Lalamila iron deposit.

Table 3 states the possible origin of the mineral species studied and some sulphide minerals, galena and sphalerite. According to the texture and the grey crystalline nature of hematite, it could be said that the hematite was formed from altered magnetite. This is supported by the presence of relics of magnetite porphyroblasts disseminated in the ore. Likewise, the gahnite was derived from sphalerite by desulphidation during metamorphism and metasomatism. Plumbogummite represents the final oxidation product of galena. The forgoing processes explain the genesis of the Lalamila ore mineralization and its peculiar mineralogy. Its primary nature would be magnetite – galena – sphalerite. These three minerals were probably deposited by emanations exhaled from volcanic activity that occurred in the vicinity of the ore before the Pan African event. It was probably during the Pan African event that the volcanics were metamorphosed and the magnetite and sphalerite transformed to hematite and gahnite, respectively. Later, galena was oxidized into plumbogummite, with aluminium and phosphorus supplied by the country rocks.

Table 3: Possible origin of the mineral species discussed in this paper

Mineral species	Origin	References
Hematite	hydroth, metamorp., sedim.	Deer et al, Dud'a et Rejl
Magnetite	hydroth, metasom, metamorp.	Deer et al, Dud'a et Rejl
Gahnite	pegm., metasom., metamorp.	Deer et al, Dud'a et Rejl
Plumbogummite	supergene oxydation	Dud'a et Rejl, Stanley et Vaughan, Williams, Nickel E.H, Scott K.
Galena	hydroth., metasom.,	Deer et al., Dud'a et Rejl
Sphalerite	hydroth., magm., pegm. pneuma. sedim.	Stanley et Vaughan, Dud'a et Rejl,

magm = magmatic ; pegm = pegmatitic ; pneum = pneumatolitic ; hydroth = hydrothermal ; metasom = metasomatic ; metamorp = metamorphic ; sedim = sedimentary ; supergene oxidation.

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