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STRATABOUND ZINC-LEAD MINERALIZATION IN THE PHAKUWA AREA SANKHUWASABHA DISTRICT, EASTERN NEPAL.

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ABSTRACT

A massive to disseminated stratabound zinc-lead mineralized horizon confined within the metamorphosed sequence (Phakuwa Group) of the Kathmandu Complex has been traced for over a strike length of one kilometer in the Phakuwa area of the Sankhuwasabha District in eastern Nepal. Its geotectonic setting, metamorphism and deformation and above all, style of mineralization are comparable with the Ganesh Himal zinc-lead deposit. Detailed ore-mineralogical studies from both areas revealed similar mineralogical assemblages and associations. Electron microprobe analyses of common sulphides resulted in analogous mineral chemistry which is strongly indicative of similar depositional environment of these two deposits.

INTRODUCTION

The occurrence of zinc-lead ores in the Sankhuwasabha District of eastern Nepal was known to exist since nearly two decades, when Yadav (1970) mentioned about the same in his geological work of eastern Nepal. It was latter rediscovered during the geological mapping of gem-bearing pegmatite bodies around the remote village Phakuwa (Joshi, 1982), situated between the latitudes 27 26'50" - 27 26'58" and the longitudes 87 24'45" - 87 24'50" respectively (Fig. 1). Following the encouraging assay results (13% Zn, 1% Pb, 0.05% Cu) of some grab samples, a semi-detailed geological exploration was launched by the Department of Mines and Geology (DMG).

Meanwhile the present author have had an opportunity to work as a co-geologist in the Phakuwa Zinc-Lead Exploration Project conducted by the DMG. A total of about 8 weeks (in two field seasons of 1986 and 1987) was spent in the field work during which various geological aspects linked to mineralization were studied. This paper is an outcome of the above work and a handful of lab-work carried out by the author at his own. Here, an attempt has been made to define, elaborate and establish the type of zinc-lead mineralization in the Phakuwa area on the basis of geologic setting, metamorphism and deformation, ore mineralogy, mineral chemistry and above all style of mineralization. Finally, it is compared with the Ganesh Himal Zinc-Lead Deposit, the only economic base-metal deposit so far discovered in Nepal. It is emphasized that there is a great similarity in the zinc-lead mineralizations occuring within the MCT zone.

GEOLOGIC SETTING

Several workers have mapped the Sankhuwasabha Region in various scale and to various extent. They include: Hagen (1969), Yadav (1970), Hashimoto et al (1973), Maruo et al (1979), Joshi (1982), Andrews (1985) and Jyanwali (1985).

The present study area is limited to the Sabaya Khola in the north-west and the Khitiya Khola in the south-east lying within the Lower Himalayan geographic belt of eastern Nepal (Fig. 1). In the present context, geologic setting has been discussed in the frame of lithostratigraphy established recently by Andrews (1985) for the Sabaya Khola Region which is in consistent with the most established stratigraphy of central Nepal (Stocklin, 1980). Following geotectonic units are encountered in this region.

I. Milke Gneiss of the Higher Himalaya
II. Kathmandu Complex of the Lower Himalaya
III. Nawakot Complex of the Lower Himalaya.

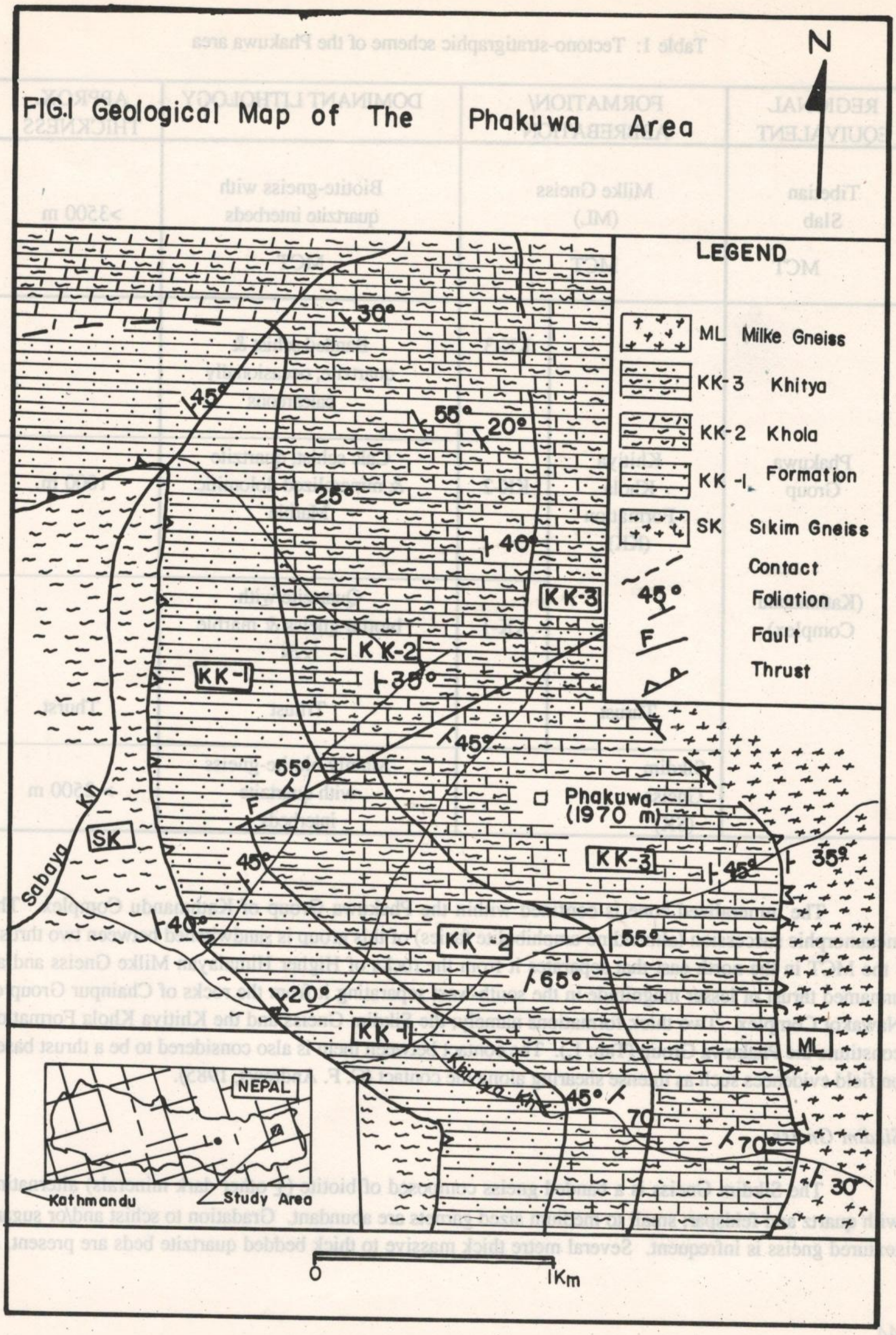


FIG.I Geological Map of The Phakuwa Area

Table 1: Tectono-stratigraphic scheme of the Phakuwa area

REGIONAL EQUIVALENT	FORMATION/ ABBREBATION		DOMINANT LITHOLOGY	APPROX. THICKNESS
Tibetian Slab	Milke Gneiss (ML)		Biotite-gneiss with quartzite interbeds	>3500 m
MCT	MCT		MCT	
Phakuwa Group (Kathmandu Complex)	Khitiya Khola Formation (KK)	KK-3	Banded schist & quartzite, occasionally calcareous	1000 m.
		KK-2	Calc schist, quartzite & mineralized dolomitic Marble	
		KK-1	Quartzite with biotite-gneiss & marble beds	
	Thrust		Trhust	Thurst
	Sikdim Gneiss (SK)		Mainly biotite-gneiss with quartzite interbeds	> 2500 m

The mineralized zone is confined within the Phakuwa Group of Kathmandu Complex. The metamorphic succession (almandine-amphibolite facies) of this group is sandwitched between two thrusts - the MCT in the north-east that separates it from the rocks of Higher Himalayan Milke Gneiss and an unnamed thrust of lesser magnitude in the south-west separating it from the rocks of Chainpur Group of Nawakot Complex. Two thick formations namely; the Sikdim Gneiss and the Khitiya Khola Formation constitute the Phakuwa Group (Tab. 1.). The contact between them is also considered to be a thrust based on field evidences such as intense shearing along the contact (C. F. Andrews, 1985).

Sikdim Gneiss

The Sikdim Gneiss is a banded gneiss composed of biotite (± other dark minerals) alternating with quartz and feldspar; small to medium sized garnets are abundant. Gradation to schist and/or sugary textured gnéiss is infrequent. Several metre thick massive to thick bedded quartzite beds are present, at least, close to its upper contact which resemble to those of the Milke Gneiss of the Higher Himalaya at its lower contact i.e. the MCT, which however may be deciphered by their tectonic level.

Khitiya Khola Formation

While the Khitiya Khola Formation is the host formation of the Phakuwa zinc-lead mineralization, it is described slightly in detail. It consists largely of metamorphosed areno - argillaceous sediments that include: quartzites, quartzitic schists, mica schists, biotite gneiss, calc schists and marble beds. Concordant amphibolite and/or hornblende-gneiss and in rare cases eclogite bodies constitute an essential component of the succession. Pegmatite bodies of varying shape and size are abundant which seem to gain significance towards north-west. Largely on the basis of dominant lithology the Khitiya Khola Formation can be divided into three local members such as KK-1, KK-2, and KK-3.

KK-1

This member is dominated by quartzite which is frequently interbedded with garnet-mica schist, quartz-mica schist and occasionally marble beds. Thin amphibolite layers are commonly present. The bottom-most quartzite is a typical milky white, fine to medium-grained, platty quartzite bed which grades to grey-white marble bed. Between these quartzite and marble there may occur a few metre thick biotite gneiss which does not persist laterally. Towards the top, quartzites become massive through a thicker and frequent schist interbeds containing garnet.

KK-2

Calc schists of varying composition and texture are the major constituents of this member. These include; diopside marble schist, tremolite - actinolite marble schist and calc arenaceous schist. However, kyanite-garnet-mica schist constitutes a significant portion which tends to increase towards north-west and seems to be linked to post-tectonic pegmatites. Several concordant bodies of pretectonic basic rocks of varying composition and texture are some of the remarkable features. Such bodies consisting predominantly of red-brown garnet and secondary grass-green chlorite with minor remnant of green pyroxene were most probably original eclogites. Towards the top calcareous component gains significance and ultimately grades to impure dolomitic marble which frequently holds the base-metal sulphides. This mineralized horizon have been marked as the upper limit of this member.

KK-3

This member is rather a monotonous sequence of thin to thick quartzite and schist interbeds with minor compositional and textural variations. The rocks are, in general, banded due to regular intercalations of quartzite and schist. Quartzite beds are usually micaceous except for the dark coloured dense quartzite. Banding within schist rocks are due to alternations of muscovite and biotite with granular garnets. Towards the top, thickness of schist and quartzite beds becomes thicker which grades to a thick grey crystalline limestone through a narrow zone of graphitic schist. This in turn, is overlained by the crystalline rocks (Milke Gneiss) of the Higher Himalaya.

Metamorphism and Deformation

While metamorphism prior to thrusting does not exist in the study area it is thought to have been overprinted by the superposition of younger metamorphism of the almandine - amphibolite facies linked to the development of MCT which is so characteristic for the area. The degree of metamorphism broadly ranges from the biotite-grade of greenschist facies (Nawakot Complex) to the kyanite-grade of almandine - amphibolite facies (Kathmandu Complex) in reverse order except for minor local variations probably due to the emplacement of migmatitic rocks. Some compositional and textural changes are due to latter pegmatitic intrusions.

The orientation of metamorphic minerals is, in general, compatiable with that of the deformations. Thereby the metamorphism is attributed to the thrusting episode. Although it is not conclusive, the discovery of eclogite pockets in the study area provokes earlier conclusions on the almandine - amphibolite facies of metamorphism. Eclogites occur in a wide range of environments (Winkler, 1979) but essentially under high pressure and very low water conditions.

The map area forms a part of an ENE-dipping limb of the Arun Anticline which governs the dominant tectonic trends and is internally split by imbricate thrusting. However, it appears that there have been four different phases of deformations namely: D1, D2, D3 and D4 represented by various planer and linear structures as shown in Table 2.

Table 2. Deformation phases in the Phakuwa area.

Deformation Phase	Dominant Orientation	Representive Structure	Status
D1	NNE-SSW	Primary foliations - S1, outcrop scale tight isoclinal folds, intersection lineations and mineral lineations	Well preserved
D2	NW-SE	Secondary foliations-S2, and outcrop scale to mesoscopic tight or open folds parallel to Arun Anticline	Fairly preserved
	ENE-WSW WNW-ESE	Outcrop scale to mesoscopic open folds	Poorly preserved
	NE-SSW NW-SSE	Broad open flexure folds	Poorly preserved

MINERALIZATION

All known zinc-lead ore bodies in the study area are confined within the silicified dolomitic marble beds of KK-2 which is considered to be of the Pre-Cambrian age on the basis of litho-stratigraphic correlation (Andrews, 1985). A generalized lithological column of the entire mineralized zone is illustrated in Figure 2.

The ores occur mainly in the form of dissemination which frequently grades to stringers and massive bands occasionally exhibiting excellent post-sedimentary folds parallel to the host rock. This strongly suggests syngenetic nature of ore formation. Further, the unprecedented strike continuation of mineralization for several kilometre or more as evidenced by the occurrence of exactly similar ore bodies in the Shisakhani and Gornjude areas approximately 10 km north-west of Phakuwa. These, however, lies at an upper tectono-stratigraphic levels which is attributed to first phase isoclinal mega fold (D1).

The zinc-lead mineralization at Phakuwa is in the form of sulphide ores and is distinctly of a zinc dominant category over lead (Tab. 3). It can be traced for over 1 km with an average thickness of about 1.25 m. On the basis of surfacial exploration data the ore reserve has been estimated as 1.14 million ton with an average 4% (+) zinc and lead combined plus traces of silver (Sharma and Adhikari, 1986). Several localized bodies with up to over 35% zinc and lead combined are reported. However, the quantitative evaluation of the Phakuwa zinc-lead mineralization is premature and at the present state of investigation it can at best be considered "probable". In any case, it should not eliminate the multiplication possibility of ore reserve and grade as exploration advances.

On close view, the bulk of Phakuwa zinc-lead mineralization can be classified into three types depending on their fabrics, composition and mode of occurrence.

Disseminated type

This type consists of fine-grained (0.01-0.05 mm) equigranular mass of dolomite, quartz, pyrite, pyrrhotite, chalcopyrite, sphalerite and galena. The ore minerals are disseminated within the fine siliceous dolomite gangue. The ratio of ore : gangue is about 1:10 by volume. Within the mineralized zone, disseminated type tends to occur towards the margin but is not always true. With diminution in the ore content this type grades into the rock type typical of the crystalline dolomite.

Stringer type

Medium to coarse-grained (0.02-2 mm) sphalerite and less commonly galena arranged in parallel rows embedded in siliceous dolomite form the main constituent of the stringer type. Pyrite, pyhhrotite, chalcopyrite and others are present in insignificant quantity. The ore stringers usually parallel to the bedding (S0) are separated by a few mm to several cm thick silica-dolomite gangue. The ratio of ore : gangue is estimated volumetrically as 1:3. This is the most common ore type and with the increase in thickness of ore stringers it grades to massive type.

Table 3. Chemical Analyses of some ore concentrates (Method: AAS)

Sample NO	Name of Ore	Zn %	Pb %	Fe %	Ag PPM	Cd PPM	Bi PPM	Mn PPM
T-3A	Mainly Sphalerite	20.0	8.5	2.4	300	800	<50	400
T-3B	Mainly Galena	14.5	51.0	0.4	430	360	<50	200
T-22A	Sphalerite	28.0	0.05	2.4	50	950	<50	400
T-22B	Sphalerite+Galena	12.0	11.6	3.2	230	640	1300	520
O/C52	Sphalerite	23.6	0.32	6.4	30	760	100	720

Table 4: Mineral assemblage of the Phakuwa ore environment

Ore Environment		Mineralization Pase	
Group	Mineral Assemblage	Synsedimentary	Syntectonic
Major Ore Mineral	Low Fe++ Sphalerite	------------	
	High Fe++ Sphalerite		------------
	Galena	- - - - - -	------------
	Chalcopyrite	- - - - - -	------------
Minor Ore Mineral	Pyrrhotite	- - - ------	
	Pyrite	------------	------------
	Boulangerite (Sulphosalt)		
	Unkonwn Arsenide		
	Covellite	Secondary Minerals	
	Digenite		
	Malachite		
	Fe-Oxides		
Gangue Mineral	Dolimite	------------	------------
	Quartz	------------	------------
	Siderite	------------	------------
	Calcite	------------	------------
	Graphite	- - - ------	------------
	Phyllosilicates		

Massive type

This type predominantly comprises medium to coarse-grained (0.05-4 mm) euhedral sphalerite and fine to medium-grained subordinate galena. Free pyrite, pyrrhotite, chalcopyrite and others are less common. A few cm to several tens of cm thick pure ore bands occasionally separated by minor chert or siliceous dolomite gangue is typical of massive type and more rarely such bands converge into a lens-like bodies. The ratio of ore : gangue varies between 7:1 to 10:1. With diminution in thickness and content of ore this type grades into stringer type or even into the barren siliceous dolomite.

ORE MINERALOGY

Broad textural and structural features exhibited by the sulphides have been discussed in terms of their occurrence in ore types. More mineralogical aspects relevant to the Phakuwa zinc-lead mineralization as a whole are considered here. A number of representative polished specimens inclusive of all mineralization types were examined microscopically. Characteristic features of ore and gangue minerals are separately discussed.

The mineral assemblage of the Phakuwa ore environment on the whole is - sphalerite, galena, pyrrhotite, chalcopyrite, pyrite, boulangerite (sulphosalt) and an unknown arsenide as primary component and covellite and/or digenite, malachite and minor iron oxides as secondary products. These ore minerals are embedded in siliceous micritic to sparitic dolomite and calcite gangue. An unusual association of graphite gangue especially with sphalerite and galena is volumetrically minor but genetically significant. Above mentioned mineral assemblage on the whole may conviniently be divided into three groups as shown in Table 4.

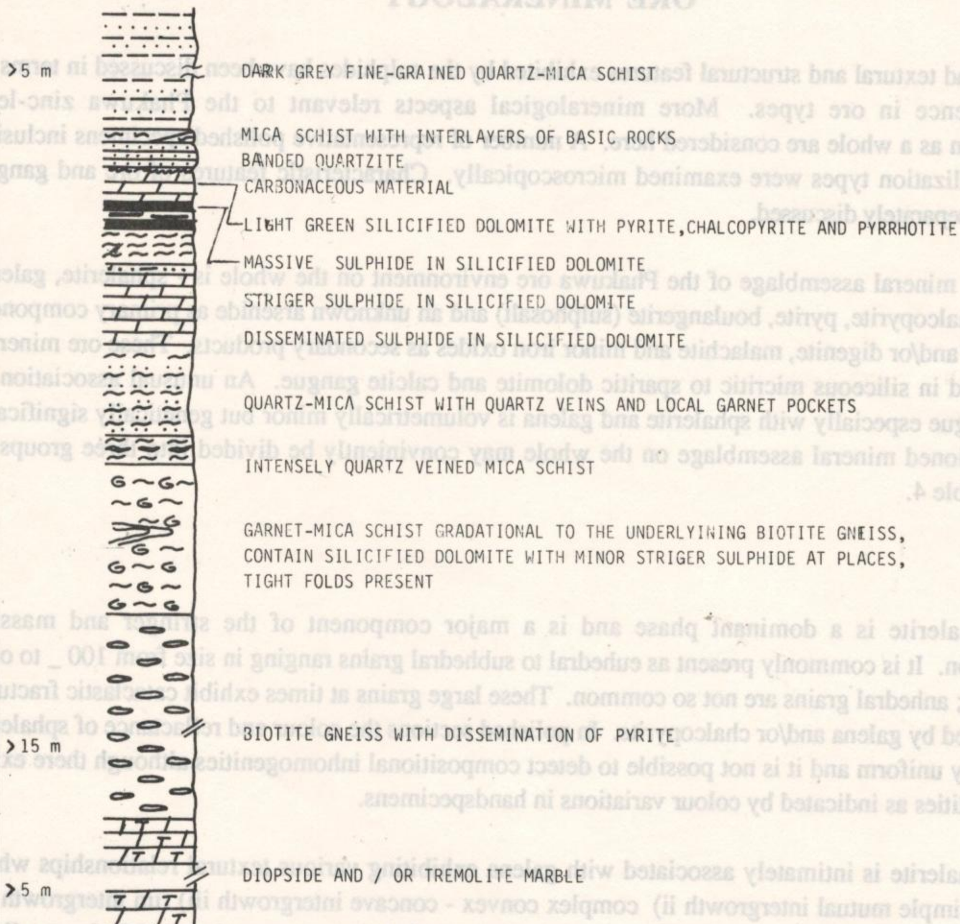
Sphalerite

Sphalerite is a dominant phase and is a major component of the stringer and massive mineralization. It is commonly present as euhedral to subhedral grains ranging in size from 100 _ to over 4 mm across; anhedral grains are not so common. These large grains at times exhibit cataclastic fractures often annealed by galena and/or chalcopyrite. In polished sections the colour and reflactance of sphalerite are extremely uniform and it is not possible to detect compositional inhomogenities although there exists such possibilities as indicated by colour variations in handspecimens.

Sphalerite is intimately associated with galena exhibiting various textural relationships which include : i) simple mutual intergrowth ii) complex convex - concave intergrowth iii) rim intergrowth iv) mutual replacement along grain boundaries and v) inclusions. Sphalerite is associated with almost all ore and gangue minerals listed above in that, that it has common boundary at one or several places. Inclusions of pyrite, pyrrhotite and chalcopyrite in sphalerite are not uncommon. Replacement of sphalerite by secondary minerals along grain boundaries is present. Association with graphite is most spectacular and unusual. Euhedral lamillar crystals of graphite ore grown in sphalerite matrix indicating reducing environment during ore formation.

FIGURE 2.

COLUMNAR SECTION OF THE MINERALIZED ZONE



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Galena

This is the second dominant phase after sphalerite although it constitutes only a minor portion of the stringer and massive ores. Galena occurs largely as fine to medium-grained anhedral to subhedral grains usually occupying space left between harder minerals and/or gangue matrix. Coarse-grained galena is rare and when present is usually in the form of cross-cutting veinlets. Cleavage planes (triangular pits) are strongly developed which are wavy indicating post-mineralization mobilization.

Galena is closely associated with sphalerite as described earlier. Similarly it's association with sulphosalts is inherent as evidenced by their mutual intergrowth, replacement along grain boundaries and inclusions. Pyrite is either attached or included within galena. Secondary minerals such as covellite/digenite may in rare case replace galena along grain boundaries. Alteration of galena to anglesite is uncommon. Like sphalerite, galena is distinctly associated with graphite and occasionally the latter is deformed to take a disc shape.

Chalcopyrite

It is a minor phase and occurs often as inclusions in sphalerite and galena. Free chalcopyrite is rare and when present occurs as fine shapeless anhedral grains occupying left over spaces between coarser minerals. Exsolution texture with sphalerite and star-shaped inclusions in sphalerite, generally observed in high temperature deposits are absent.

Pyrrhotite

Pyrrhotite is the most dominant minor phase and occurs as fine subhedral prismatic grains frequently adjacent to sphalerite. It is relatively fresh and alteration to marcasite or alike is insignificant. As inclusions in sphalerite, pyrrhotite is numerous.

Pyrite

Pyrite is a minor phase less in amount than pyrrhotite. Usually it is present as minor inclusions in sphalerite and galena. Free pyrite occurs as isolated subrounded anhedral grains but it is rare.

Boulangerite (Sulphosalt)

Boulangerite is the most common sulphosalt in the Phakuwa zinc-lead mineralization. It occurs as large lath-shaped grains frequently penetrating into galena matrix and is also present as large inclusions in galena. It is essentially associated with galena.

It is very difficult to identify other sulphosalts without going into quantitative investigation. However, microscopic observations suggest that there exist other sulphosalt minerals too.

Table 5. Representative microprobe analyses of some ore minerals (elements in average wt %)

A. Sulphides

Sample No.	Location	Mineral	Zn	Fe	Cu	Pb	Sb	Ag	S	Total
PR 1-1	Phakuwa	High Fe++	58.26	7.74	0.00	0.08	0.01	0.09	33.71	100.23
CH-138-1		Sphalerite	59.93	5.42	0.00	0.00	0.00	0.01	33.61	98.97
T-3A-1		Low Fe++	63.51	3.71	0.00	0.00	0.01	0.00	33.67	100.57
T-38-5	Phakuwa		66.62	3.51	0.00	0.04	0.01	0.00	31.00	101.18
T-8-2		Sphalerite	68.03	0.47	0.00	0.00	0.00	0.00	34.64(±2)	103.14
G2-1	Ganesh	High Fe++	60.47	8.45	0.00	0.00	0.04	0.05	32.25	101.26
G7-2	Himal	Sphalerite	56.93	8.62	0.00	0.00	0.00	0.04	33.59	99.18
T-38-1			0.03	NA	NA	86.94	0.03	0.02	12.02	99.04
T-3A-1	Phakuwa	Galena	0.05	NA	NA	86.62	0.02	0.03	13.37	100.04
CH-138			0.06	NA	NA	86.76	0.00	0.00	13.41	100.23
G-7-2	Ganesh		0.00	NA	NA	85.96	0.00	0.01	12.77	98.74
G-2-3	Himal	Galena	0.56	NA	NA	86.88	0.00	0.00	12.81	100.25

B. Sulphosalt and arsenide

Sample No.	Location	Mineral	Zn	Fe	Cu	Pb	Sb	Ag	Ni	Co	As	S	Total
T-3A-3			0.08	0.00	1.48	61.87	19.35	0.03	NA	NA	0.30	17.33	100.44
	Phakuwa	Boulangerite											
T-3B-1			0.00	0.00	1.14	61.38	20.25	0.05	NA	NA	0.45	16.51	99.78
T-38-5		Unknown	0.31	15.83	NA	0.00	0.43	0.01	13.72	0.11	68.17		
T-38-5	Phakuwa		0.24	16.52	NA	0.00	0.27	0.00	13.53	0.00	67.95	0.52	99.03
T-38-5		Arsenide	NA	NA	NA	NA	NA	NA	27.09*	0.34*	NA	NA	-

NA- Not Analysed

* - Values at the rim of mineral grain.

Unknown Arsenide

Only in one polished section few distinct grains of bright white mineral with pinkish tinge were observed which in course of this investigation were identified as an arsenide of unusual composition. It occurs as small (300 - 1000 _) subrounded grains adjacent to galena and sphalerite. Zoning towards the margin may be observed on high magnification.

Secondary Minerals

Common secondary minerals are covellite, digenite, malachite, anglesite, limonite and rarely marcasite. They replace primary minerals partly or wholely and their growth are insignificant to ascribe any hypogene alteration.

Gangue Minerals

Dolomite, quartz, calcite, siderite, phyllosilicates and graphite are the common gangue minerals encountered in the mineralized zone in order of abundance.

Carbonates occur as fine (micritic), medium to coarse-grained (sparitic) euhedral grains and act as the main matrix for ore minerals.

Quartz is another common gangue and occurs as clean anhedral crystals usually with triple-junction (recrystallized). Fine aggregate quartz is also present. It is distributed rather uniformly within the mineralized zone except for the quartz veins.

Graphite is a minor gangue but its occurrence in masses typically within the sulphide matrix is rather unusual. It could be of great genetic significance.

MINERAL CHEMISTRY

Microprobe analyses of some selected samples from both the Phakuwa and Ganesh Himal areas were carried out by using a ARL-SEMQ Electron Microprobe Analyser in the Institute of Mineralogy and Petrography, Montan University, Austria. The aim of this investigation was primarily to explore silver carrier minerals which are hard to identify by microscopic methods. However, failing to detect any silver carrier, the study was diverted to explore the chemistry of some sulphides that has genetic and mineralogical implications. Microprobe analyses on the scale of a single grain to several polished sections were carried out and the results (Table 5) are discussed below.

Sphalerite

The iron content in the sphalerite of Phakuwa varies approximately between less than 1 and 8%. Coarse grained sphalerite of the massive type mineralization tends to contain lesser iron, a maximum of 4% while finer grained sphalerite of the stringer type mineralization contains higher iron, i.e. between 4 and 8%. On this basis sphalerite is classified into two types as low iron and high iron probably representing synsedimentary and syntectonic mineralization phases.

In case of Ganesh Himal, only one type of sphalerite samples were available for analysis in which iron content is slightly more than 8% which is compatiable with that of the stringer type of Phakuwa.

Willian and Hall (1980) estimated a confined pressure of 5 kilobars for the content of about 14 mol % FeS which is in the same range as that of the stringer type of the Phakuwa mineralization.

Galena

In absence of any silver carriers, several galena grains from Phakuwa were tested for silver content by EMA. The results revealed extremely low silver values - a maximum of 600 ppm. These values are attributed to silver inherant in crystal lattice which were confirmed by X-ray scanning text.

Sulphosalts

Several sulphosalt grains from the Phakuwa ores were tested for silver content and analysed. Silver is present in negligible amounts (upto 600 ppm) only. All analysed sulphosalts turned out to be boulangerite with traces of copper, arsenic and silver.

Arsenide

Microprobe analysis of unknown arsenide resulted in the discovery of mineral having an intermediate composition (Table 5) between rammelsbergite (Ni As_2) and loellingite (FeAs2). The zoning in this mineral is due to variation in nickel content which increases from centre (13.6 wt% Ni) towards rim (27.1 wt % Ni) where the composition almost coinsides with rammelsbergite.

COMPARISION WITH THE GANESH HIMAL ZINC - LEAD DEPOSIT

Presence of the zinc-lead mineralization in the Ganesh Himal region was known since over last four decades. Detailed geological investigations were carried out only in seventies. At present Nepal Metal Company Limited is developing the ore-body into a producing mine. Recently a zinc-lead mineralized zone was discovered in the Phakuwa region in a geotectonic setting similar to that of the Ganesh Himal region. In view of this, a casual attempt is made to compare these two mineralizations based largely on the present investigation at Phakuwa and the published data on Ganesh Himal (Chakravarti, 1982; Kumar, 1980).

Geological Setting

The mineralized zone of Ganesh Himal is included in the root zone of crystalline Kathmandu Nappes (Hagen, 1969), the Main Central Thrust Zone (Schuppen Zone) (Arita et al, 1973) and the Himal

Group (Tater et al, 1977). Thus, the mineralized zone is confined between the crystalline rocks of the Higher Himalaya and the metasediments of the Lower Himalayas.

Similarly the mineralized zone of Phakuwa area under investigation belongs to the crystalline rocks of Kathmandu Complex (Andrews, 1985) lying distinctly below the MCT. This is a narrow highly tectonized zone and consists of various metamorphosed argillo-arenaceous sequence with calcareous affinity.

Thus the broad geologic setting in both areas is identical but bed to bed correlation is not possible due to intense imbrication and large spatial separation. However, there is a broad similarity in the petrography of rocks within (siliceous dolomite), below (quartz-mica schist) and above (banded mica schist) the mineralized bed.

Metamorphism and Deformation

Existence of the almandine - amphibolite facies metamorphism in and around the mineralized area of Ganesh Himal have been claimed by earlier workers. In addition, concordant hornblende-gneiss is reported to occur which is also metamorphosed to the almandine-amphibolite facies (Chakravarti, 1982). Four deformation phases have been described from the zinc-lead prospect area of Ganesh Himal of which first phase is linked to almandine-amphibolite facies metamorphism.

The metamorphic minerals encountered in the Phakuwa mineralized area undoubtedly allows us to assign an almandine-amphibolite facies metamorphism. Concordant layers of basic rocks of variable composition and texture also agree with this. The orientation of various structural elements observed in the study area reflects four deformation phases (D1-D4).

It is evident from above that both the Ganesh Himal and the Phakuwa areas have been evolved through similar metamorphic and deformation conditions.

Style of Mineralization

Three modes of mineralization namely: disseminated mineralization, massive sulphide and en-echelon veins are known to exist in the Ganesh Himal. Besides these, glacier deposit is also present at places.

Three types of mineralization described earlier in the Phakuwa are compatible with those of the Ganesh Himal. However, glacier deposit is absent in the latter one.

Both the Ganesh Himal and the Phakuwa mineralizations are characterized by : i) carbonate host, ii) stratabound and stratiform nature, iii) structural control, i.e. by first-phase deformation iv) high zinc : lead ratio, and v) low silver. From these, it seems that both mineralizations belong to one single mineralization system.

Ore Mineralogy

Ore mineralogical details of the Ganesh Himal mineralization is not available. Present study of few polished samples revealed that sphalerite and galena are the main ore minerals while pyrite, pyrrhotite, chalcopyrite are present in subordinate amount. Granoblastic magnetite is frequently present within the sulphide phase and is characteristic for the Ganesh Himal ores.

Broad ore mineralogical features of the Phakuwa mineralization described in previous chapter is more or less comparable with that of Ganesh Himal. In detail, however, there exist some discrepancies. The major differences are due to the presence of sulphosalts, arsenide and graphite in the Phakuwa ores which are so far not reported in the Ganesh Himal ores. Likewise typical granoblastic magnetite in the Ganesh Himal ores is completely absent in the Phakuwa ores.

However, since there is a strong similarity in broad mineralogical features as well as principal ore minerals between the two deposits, they are considered comparable.

Mineral Chemistry

Two major types of sphalerite are described by Chakravarti (1982). They are: dark brown sphalerite and light to medium brown sphalerite. Experience shows that dark brown type contains relatively high iron than light brown type. Microprobe analysis of dark brown sphalerite revealed about 8% Fe. Other type was not available for analysis.

Microprobe analyses of sphalerite from the Phakuwa ores revealed two types, namely high iron sphalerite (8%) and low iron sphalerite (4%). These two sphalerite types probably correspond to dark brown sphalerite and light brown sphalerite of the Ganesh Himal ores.

From the above discussions it is evident that there are similarities in fundamental geological and mineralogical features between the Ganesh Himal and the Phakuwa mineralizations.

SUMMARY AND CONCLUSIONS

The crystalline rocks of the Kathmandu Complex lying below the Main Central Thrust has now emerged as a host formation (Khitiya Khola Formation) for the Phakuwa zinc-lead mineralization. Silicified dolomitic marble beds within the middle member (KK-2) actually hosts the ores and is of prime importance while exploring for the zinc-lead mineralization in similar geotectonic setting within the Himalayas.

On the basis of metamorphic minerals encountered in the Phakuwa area, the almandine - amphibolite facies of metamorphism is ascribed which by analogy is linked to the Main Central Thrust. However, discovery of some equivocal eclogite pockets in this area imposes constraints on the metamorphic conditions as desired by the ascribed metamorphism. It thus emerges a new dimension for the metamorphic concept in the Main Central Thrust Zone.

The thickening and thining of the Phakuwa zinc-lead mineralization is governed by the first phase deformation linked to the Main Central Thrust. It is experienced that crest parts of first phase isoclinal folds are the best sites for locating new ore bodies.

It is apparent from the present study of ores in terms of mode of occurrence and ore mineralogy that the Phakuwa zinc-lead mineralization was originally syngenetic which was latter reactivated by the Himalayan movements. Changes in ore textures (recrystallization) and in mineral chemistry (high iron to low iron sphalerite) are the direct evidences of reactivation. Thus, the Phakuwa ores, as it is now, has evolved through two major mineralization phases namely: the synsedimentary and the syntectonic. In spite of these, stratabound-stratiform nature of mineralization is largely retained and in view of this, it may be categorized under the broad group "the carbonate hosted stratabound type zinc-lead mineralization".

Comparison of the Phakuwa zinc-lead mineralization with the economically viable Ganesh Himal zinc-lead deposit resulted in the establishment of their similarities in fundamental geological and mineralogical features. This has now gained intrinsic significance for further exploration of base-metals in the Main Central Thrust Zone which could be rewarding.

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