Journal of Nepal Geological Society, 2011, Vol. 43 (Special Issue), pp. 153–166

Exploration results of iron ore deposit of Thoshe, Ramechhap, Nepal

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ABSTRACT

Thoshe iron ore deposit is located at about 200 km east of Kathmandu in Thoshe VDC of Ramechhap District, Central Nepal. Small scale mines were in operation for about 100 years till 1952 A.D. Existence of over 1000 of old working pits, scattered slag and few smelting places around, and the remnants of a gun factory at Thoshe Megchan are the solid evidences of the operation of small scale mines there.

Thoshe area is represented by Dorje Khola Formation of Nawakot Complex. This Formation is divided into Arubote Schist Member and Dorjekhola Phyllite Member. Arubote Schist Member is further divided into (i) Calcareous Mica Schist and (ii) Chloritic Mica Schist occasionally with few minor basic rock bodies and quartz chlorite veins. 1-3 m thick two mineralized bands lie at the upper part of this unit just below the calcareous mica schist.

N & C Minerals (P.) Ltd. explored the deposit in four phases. A regional geological map covering the whole lease area, semi detail geological map of 12 sq. km. area (1:10,000 scale) is prepared and traced the mineralized body by trenching and pitting. During second and third phase, topographic maps and detail geological maps (1:1000 scale) of two separate blocks (Arubote - Sanodadakharka sector and Singati - Barappu sector) covering 100 hectare and geological cross sections were prepared. The area was extended further south from Jhoreni to Singati and further west from Singati to Barappu. Chip, channel and bulk samples were collected and analyzed. On the basis of geology, nature of mineralization, size and shape of the ore body, it has recalculated the possible geological reserve as 15.91 million metric tons with an average grade of 45.3% Fe. Preliminary beneficiation by simple crushing and washing of the ore samples to remove unwanted gangue minerals helped to up grade the ore up to 62% Fe.

Keywords: Ore, hematite, gangue minerals, geological reserve and grade, Thoshe iron deposit

Recieved: 10 December 2010 **revision accepted:** 25 April 2011

INTRODUCTION

Location

Thoshe iron deposit lies in between latitude 27°32'30" to 27° 35' 30" North and longitude 86°16'00" to 86°18'15" East in toposheet no. 278606. It is located at ward no.1 and 2 of Thoshe VDC and ward no. 1 of Priti VDC in Ramechhap District, Central Nepal. The prospect area can be accessed from Jiri via Thoshe Megchan to Singati by 26 km seasonal rough road (Fig. 1). The nearest airstrip is in Manthali, the District Headquarter of Ramechhap. A small air strip for Pilates Aircraft exists at Jiri. Suitable helipads are also possible at Chautari Danda near Arubote and Pokhari near Singati. There is a regular public bus service from Kathmandu to Bhandara which passes through Singati mine area.

The highest point of the lease area is 3109 m at Tabe Dada and the lowest point is the junction of Dorje Khola and Khimti Khola (1722 m). The elevation of the deposit area ranges from 2480 m to almost 3000 m above msl (Fig. 1). Most of the area has low to moderate slope towards west, southwest and south east and south. The main drainage of the area is

Fig. 1: Location map of Thoshe iron prospect area, Ramechhap District (Scale: per square line is 1km)

Fig. 2: Northern and central parts of Thoshe iron deposit (Arubote - Silili - Sanodadakharka - Kopu Bhalukuna - Kopu - Pahare - Jhoreni - Kuwakopakha - Bhosbhose sector (Old working mine sites)

Dorje Khola which joins Khimti River at Thoshe Megchan. Minor tributaries flowing from Ganuanepani, Dharmashala, Lapchane, Pokhari, Singati and Tabe Danda join Dorje Khola at different points (Figs.1, 2 and 3). Other minor tributary streams from Barappu, Ghyangdada and Singati area flow towards southeast direction (Figs. 1 and 3).

Previous Works

Jhingran (1961), Suwal (1965), Manandhar (1963), Weise (1960), Good (1963), Rana (1964, 1965, 1966), Talalov (1972), Kaphle and Khan (1995, 1996) visited the area and did some exploration works. A preliminary feasibility report prepared by Nepal Bureau of Mines (NBM 1965), DMG/ ESCAP Geology and Mineral Resources of Nepal (1993), Mineral Resources of Nepal (2004), and N & C Minerals P. Ltd.'s first phase preliminary exploration (2008) and second and third phase follow up semi detail and detail exploration (2009), the old people of Thoshe and Priti villages who were directly or indirectly involved in mining activities in this area are the main sources of information.

Preliminary geological field investigation and assessment of Thoshe iron ore deposit was carried out by Kaphle and Khan (1995, 1996). They prepared a regional geological map of 100 sq. km around Thoshe and small part of Khimti Khola area (in 1:63,360 scale), and Semi detail geological map of Thoshe iron deposit site (1:16,000 scale) covering about 24 sq. km and also a detail geological map of 2 sq. km all along the mineralized zone by Compass and Tape survey at 1:2500 scale. Iron mineralization bands extend at about 4 km strike length from Arubote to Singati were traced by digging 16 trenches, 2 pits and locating existing numerous old working pits. 47 chip and channel, 34 grab, 15 bulk samples from the ore body as well as 35 rock, 102 stream sediments and 20 heavy concentrate samples were collected for chemical analysis, petrographic/ mineralogical studies. This field investigation was successful to trace a 1 - 3 m thick

Fig. 3: Singati - Ghyangdada - Barappu sector of Thoshe Iron deposit (Old working sites) (Most part covered by topographic survey and detail geological mapping 2009)

(combined) hematite ore body (Fe = <30% to 66%) locally with some magnetite layers/ bands and rarely minor quartz ilmenite lenses.

N & C Minerals P. Ltd. after obtaining the prospecting license from DMG has conducted first Phase - I exploration and prepared a Semi-detail Geological map of Thoshe Iron deposit area (12 km^2) at 1:10,000 scale (Fig. 4) and did some additional trenching and pitting works to expose the mineralized band and collect fresh 6 chip, 26 channel, 20 grab and 20 bulk samples of the ore for chemical analysis, mineralogical study, beneficiation and metallurgical testing. It was also able to calculate geological ore reserve roughly 10.5 million ton ore with average grade 42.5% iron. About 3 tons of bulk and grab samples (ore) were collected from old and new trenches and pits to perform beneficiation, metallurgical and industrial tests. Some bulk samples were also prepared by mixing channel and chip samples from the same trench.

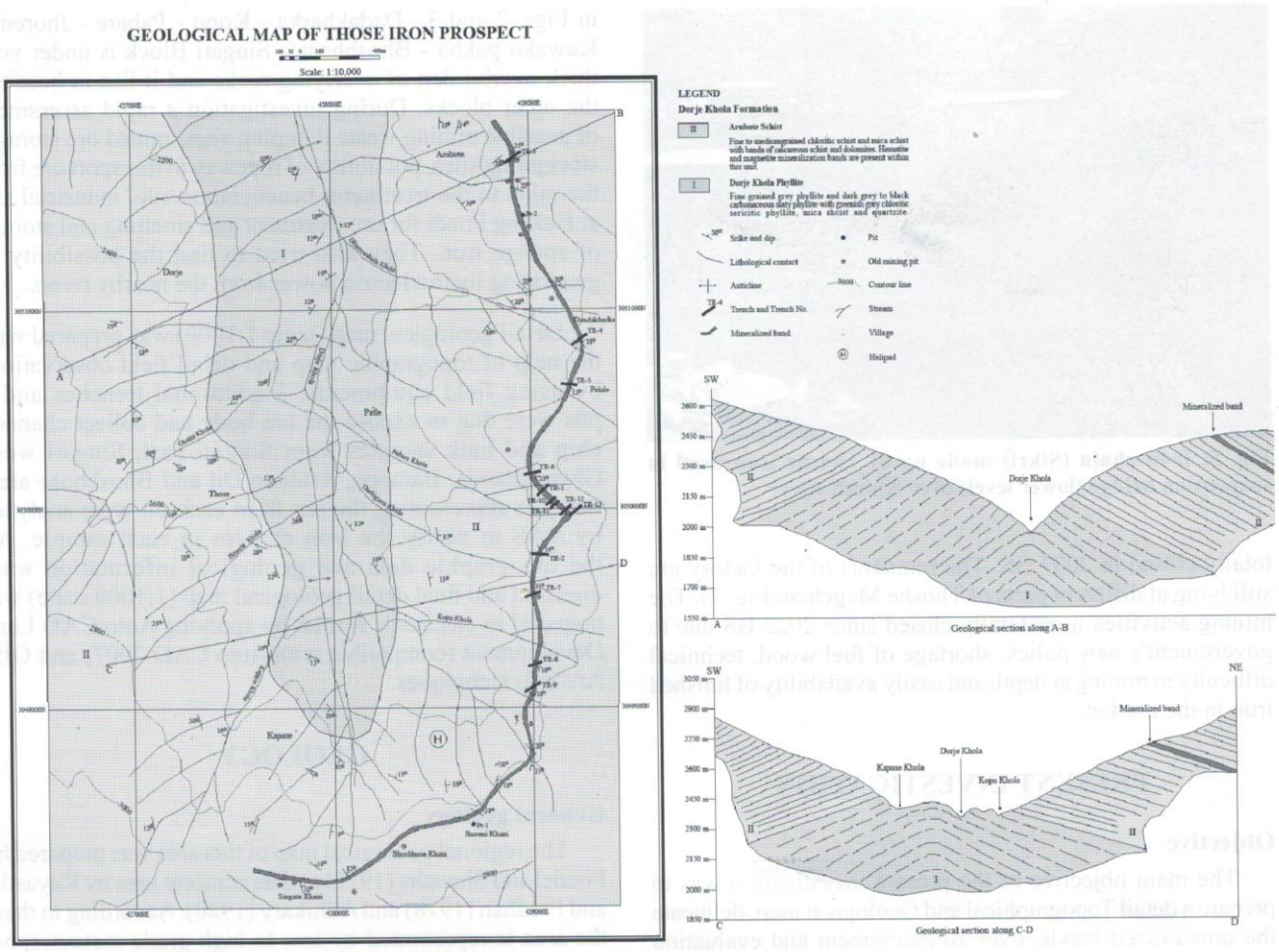

Fig. 4: Geological map of Thoshe iron prospect area

BACKGROUND HISTORY AND MINING ACTIVITIES

From the literature study it is known that small scale domestic iron mines were in operation by the local miners since 1864 AD and it was continued till 1966 AD (2022 BS). They mined the ore only from the easily mineable and best part of the mineralization from more than 18 mines (15 mines in Thoshe, 2 mines in Priti and one in Ghunsa). More than 1000 such old working pits apart from the exposed ore body, can be seen there even to day. Present measurement of some of the pits is found to be 5 –18 m deep. They have mined the ore in NE – SW direction along a strip of 30 to 70 m wide zone. Generally the pits are 1.5 to 2 m wide on the surface and much wider at mining depth. The distance from one pit to another pit is generally 3 to 5m x 5 to 10 m apart. Old miners informed that most of the pits are interlinked at mining depth to transport ore and manage ventilation in the pits. According to them Gairi Khani at Singati was more than 65 ft. deep where three mineralized horizons exist. In this case the total thickness of the iron ore body could reach up to 4 - 6 m (combined). But it has yet to be reconfirmed by test drilling. Some of the excavated loose ores are still lying in Bhosbhose Khani area. In early days the annual production of the ore was around 50 tons and later increased up to 500 tons ore (150 to 200 tons sponge iron) per year. The iron ore collected from different mines used to smelt in 29 smelting places located in the surrounding regions e.g. at Aahal Dada (Fig. 6a) where smelters use to get necessary water from a pond located near by (Fig. 6b). With the help of charcoal prepared from local fire woods as a fuel and red clay as flux they used to smelt the ore. Such smelting procedure normally took 12 – 14 hours to smelt about 225 kg ore into a sponge iron (about 65 - 100 kg) depending on the quality of the ore. From the sponge iron the blacksmith used to prepare different agricultural tools, dagger, utensils, Iron chains, nails etc. The miners use to hand crush the ore to about minus - 40 mesh size fraction and wash them in slow running water to get the clean concentrate and upgrade the ore for smelting.

In those days the people use to sell their finished iron products and get necessary food grains in exchange. Based on Thoshe Iron deposit the government had also established a small gun factory in Thoshe Megchan in 1921 BS. The factory was capable to produce nine barrels of the gun every day and submit to the military authority. The factory

Fig. 5: Iron chain (Sikri) made up of Thoshe iron used in suspension bridge (lower level) over Khimti River

totally closed in 2007 BS. The remnants of the factory are still lying at different parts of Thoshe Megchan (Fig. 7). The mining activities were totally closed since 2022 BS due to government's new policy, shortage of fuel wood, technical difficulty in mining at depth and easily availability of finished iron in the market.

PRESENT INVESTIGATION

Objective

The main objective of the present investigation was to prepare a detail Topographical and Geological map, delineate the mineralized bands, over all assessment and evaluation of the deposit, calculate geological reserve and compile all the results of the exploration activities and present all these results/ findings in this paper.

Methodology and work completed

All available information and data were reviewed. Present investigation work was mainly concentrated to explore Thoshe iron deposit which was completed in four different stages of exploration. At the very first stage a topographic map of 100 hectare (1: 1000 scale) was prepared; in second stage a detail geological map of the same 100 hectare in the same scale was prepared by geological investigation team along with surveyor; and in the third stage supervision of all the works was carried out by the author along with his subordinates in December 2009. The field investigation included geological traverse of the lease area (30 km^2); field check up of previously prepared semi-detail geological map of 12 sq. km (1: 10,000 scale); trial check up of detail topographic map (1:1000 scale) in the field, and also finalize the detail geological map (1:1000 scale) of Arubote - Silili - Sanodadakharka Block and, Singati - Ghyangdada - Barappu Block. At this time few additional trenching/ pitting (240.5 m^3) work was done, 20 channel/chip samples and 5 grab samples were collected from the ore body for chemical analysis and beneficiation tests. Detail map area is shown in Figs. 2 and 3. Dadakharka - Kopu - Pahare - Jhoreni - Kuwako pakha - Bhosbhose - Singati Block is under very thick overburden of overlying rocks and it lies in between the other blocks. During investigation a rapid assessment of possible mining waste dumping sites, mined ore storage/ stockpiling sites, possibility of ropeway to transport ore from the mine to the treatment/ beneficiation site, industrial site at Hekang Phedi for ore treatment and smelting and storage of sponge iron. They also tried to find the possibility of generating hydroelectric power from the nearby rivers.

Detail geological map (scale 1:1000) was prepared with the help of topographic map and detail field observations by using field equipments. 3 additional trenches and 5 pits were dug to expose the ore body and collect channel, chip and bulk samples from Singati east, Singati west, Ghyangdanda, Barappu, Arubote Dil and Bhosbhose area. Samples representing the ore from each pit were analyzed by AAS to verify the iron content in each sample. All the topographic data and geological information were digitized and final detail geological map (1:1000 scale) was prepared in electronic format by applying Auto CAD Land Development (compatible with Auto CAD 2007) and GIS/ Arc info techniques.

GEOLOGY

General geology

The regional geological map of this area was prepared by Poudel and Shrestha (1977) and its adjacent area by Kayastha and Pradhan (1978) and Adhikary (1980). According to them the area is represented by low to high grade metamorphic rocks which can be broadly divided into low grade metamorphic rocks of Nawakot Complex and high grade metamorphic rock of Crystalline Complex separated by Main Central Thrust (MCT). Lesser Himalayan Gneiss (Ulleri gneiss) occurs towards southern part of the investigated area. Regional geology of this region is very complex because of presence of low to very high grade metamorphic rock and a number of geological structures like thrusts, transverse faults and folds. Kaphle and Khan (1995, 1996) prepared a regional geological map of Thoshe and part of Khimti Khola area (100 sq. km) at 1:63360 scale and compiled various litho-tectonic units. They also prepared a semi-detail geological map of Thoshe area (24 sq. km) in 1:16,000 scale. For the present work the name of the rock units are taken from previous works of Kaphle and Khan (1995, 1996) with further modification during detail geological mapping (Table 1). N & C Minerals Pvt. Ltd. in its Phase -I mineral exploration did the geological assessment of the whole lease area (30sq km) and prepared a semi-detail geological map (1:10,000 scale) of Thoshe prospect area (12 sq. km).

Geology of Thoshe iron ore deposit

In this paper only the local geology of Thoshe iron ore deposit is described just to give clear picture of geological situation of the mineralization and host rock.

Table 1: Lithological units in Thoshe Iron deposit area (Kaphle and Khan 1996, modified by Kaphle 2010)

Complex/ Group	Formation/ Member	Sub Members/ units	Lithological description
Nawakot Complex (?)	III. Yalung Formation		Medium to coarse grained chloritic garnet mica schist, quartzite, and calcareous mica schist and silicified marble bands.
	II. Dorje Khola Formation (B) Arubote Schist Member		Fine to medium grained chloritic mica schist, calcareous mica schist with crystalline dolomite/ marble layers and bands. Hematite bands are located below calc mica schist with crystalline dolomite/ marble. At very few places minor amphibolite bodies also recorded.
		(B.2) Calcareous Mica Schist with silicious dolomite bands (CAS)	Medium to coarse grained light gray to gray calc mica schist locally with few silicious crystalline dolomite/marble bands. (The Hematite mineralization band lies below this sub member.)
		(B.1) Chloritic Mica Schist (CLS)	Fine to medium grained, greenish gray chloritic mica schist occasionally with few minor basic rock bodies and quartz chlorite veins. The Hematite mineralized ore body lies at the upper part of the unit below the calcareous mica schist.
	(A) Dorje Khola Phyllite Member		Fine grained gray to dark gray carbonaceous slaty phyllite, green to greenish gray chloritic sericitic phyllite, quartzite and chloritic mica schist..
	I. Thoshe Megchan Quartzite		Fine to medium grained sericitic white to grayish white quartzite. At places feebly calcareous quartzite bands and silicious dolomite with talc lenses.

Dorje Khola Formation

Dorje Khola Formation overlies the Thoshe Megchan Quartzite. An anticline structure is formed and its axis more or less follows Dorje Khola (Fig. 4). In the prospect, rocks of this formation are well exposed on both limbs of the anticline. The thickness of the formation and lithology slightly varies at different sections. This Formation is represented by thinly bedded, fine to medium grained, shining gray calcareous mica schist and crystalline dolomite/ marble towards upper part and gray to dark gray (black) slaty phyllite, quartzite and green to greenish gray chloritic mica schist and thin layers of quartzite towards basal part. Locally minor basic rock bodies (amphibolites) and barren chlorite and quartz veins are recorded. Quartz + ilmenite and quartz + pyrite + pyrrhotite lenses and veins are also recorded close to or within the mineralization bands at Arubote area. At places mica schist is poorly garnetiferous. Hematite with some magnetite bands occur at the basal part of calc mica schist and upper part of chloritic mica schist. Isolated crystalline dolomite/ dolomitic limestone blocks and bands are also recorded near Arubote, Patale and Barappu within this unit.

Foliated shining steel grey specular hematite is the main ore. The mineralized body which locally also consists of massive magnetite lenses which is highly magnetic and quite hard, compact and also comparatively rich in iron content (up to 66% Fe). On the basis of lithology, grade of metamorphism and mineral content Dorje Khola Formation is subdivided into two members like (a) Dorje Khola Phyllite Member and (b) Arubote Schist Member (Table 1).

(A) Dorje Khola Phyllite Member

This unit is well exposed along Dorje Khola section and forms the core of the Dorje Khola anticline (Fig. 4). It consists mainly of grey phyllite and grey to black carbonaceous slaty phyllite with greenish grey chloritic sericitic phyllite. Bands of mica schist and quartzite are fairly common.

(B) Arubote Schist Member

This unit overlies the Dorje Khola Phyllite Member and well exposed on both the limbs of the anticline. It consists of fine to medium grained greenish grey chlorite schist and chloritic mica schist, calcareous mica schist with crystalline dolomite/ marble layers. The hematite ore body can be traced in 5 km strike length (Fig. 4) from Arubote to Singati and further west to Barappu. During Detail Geological mapping Arubote Schist Member is further divided into two Sub-Members/ units (B.1) Chloritic Mica Schist (CLS) and (B.2) Calcareous Mica Schist (CAS). The hematite mineralization band locally with few magnetite and rarely ilmenite is located towards the upper part of chloritic mica schist and just below the Calcareous mica schist (Table 1).

(B.1) Chloritic Mica Schist Sub Member (CLS)

Well foliated, medium grained, soft, greenish gray to gray chloritic mica schist occasionally with thin quartzite layers and bands. At places minor amphibolite are also recorded within this unit. The specular (micaceous) shining silver gray hematite ore body at places with few magnetite lenses and rarely ilmenite is located at the upper part of this unit.

(B.2) Calcareous Mica Schist with Silicious Dolomite Sub Member (CAS)

It comprises of well foliated, medium grained, light gray to almost white calcareous mica schist occasionally with few crystalline dolomite/ marble bands layers/ bands (Fig. 8). The mineralization band lies below this unit.

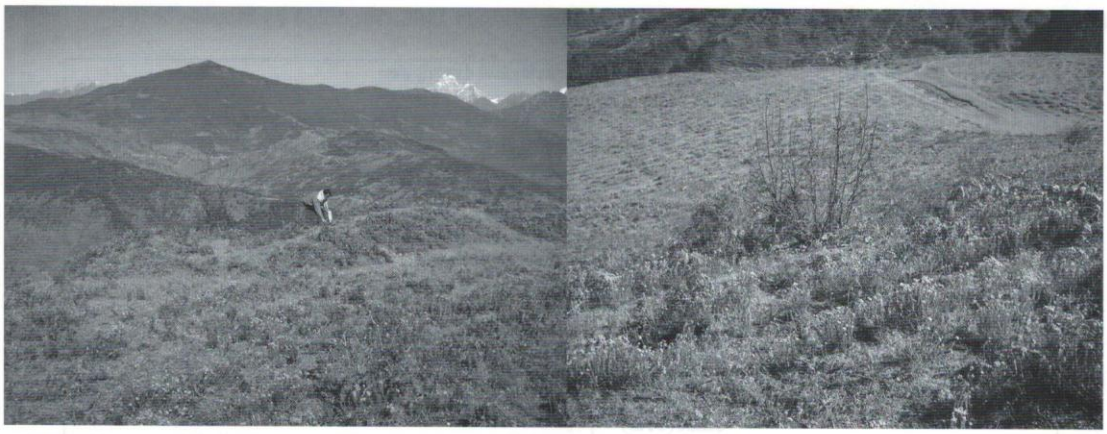

Fig. 6: (a) Old Iron ore smelting place (Aaffar), (b) Old pond (Aahal/Pokhari) used by the and slag dumping sites at Aahaldada smelter for water collection

Fig. 7: Remnants of a gun factory to manufacture the barrels of the guns from Thoshe iron deposit

General trend of the rock is in NW – SE direction and dip 10^0 - 40^0 towards north east or south west. However, at places the trend and the dip direction/ amount changes locally due to local geological structures like fault and fold and some other local disturbances. Dorje Khola Anticline is a prominent structure in this area. Its axis more or less passes through Dorje Khola.

MINERAL EXPLORATION

Mineral exploration activities e.g. detail topographic survey (1:1000 scale), semi detail (1:16,000 and 1:10,000 scale), detail geological mapping (1:1000 scale), and trenching pitting, chip/ channel, bulk and grab sampling of the ore were conducted in three stages. All these works were able to trace the iron ore body (mineralization bands) mainly in the eastern limb and crest of Dorje Khola anticline and isolated local patchy mineralization in Salleni Khani in the western limb. Few local transverse faults e.g., Arubote fault, Kopu fault, Singati fault, Ghyangdada fault, Barappu fault and Kapase faults have locally affected the mineralized body and displaced it at certain distance (Fig. 4). Ore microscopic study of selected ore samples was carried out to know other associated ore and gangue minerals present in the ore. All types of ore samples were chemically analyzed to know the iron content in the ore. Preliminary evaluation of the deposit, their shape, size and the tonnage and grade were calculated during detail exploration.

The hematite ore body is not exposed throughout the prospect area. Therefore to expose the ore body/ mineralization bands and collect fresh and representative ore samples, altogether 1792.5 m^3 (35 trenches and 15 pits) earth materials were excavated (Figs. 4, 9, and 10) during 4 different stages of exploration. On the whole about 86 channel, 123 chip, 74 grab samples, and 55 bulk samples from the ore bodies were collected for microscopic study, chemical analysis and metallurgical testing. Simple beneficiation test of 17 bulk/ grab ore samples were carried out to upgrade the quality of the ore.

MINERALIZATION

Scattered small scale mines were in operation by local minors for about 100 years but no proper geological study of deposit was carried out before in spite of many visits of mining engineers and metallurgists of than Nepal Bureau of Mine. Kaphle and Khan (1965, 1996) did the preliminary and preliminary follow up exploration and assessment of the deposit and prepared a semi-detail geological map of Thoshe iron prospect and surrounding area at 1: 16,000 scale, and also tried to trace the mineralized ore body by compass - tape survey / traverse as well as by digging 16 trenches and 2 pits.

Only after these studies it is clearly known that Thoshe iron deposit occurs within the low dipping chloritic mica schist (host rock) of Dorje Khola Formation. It is overlain by calcareous mica schist locally with silicious crystalline dolomite/ marble and underlain by green chloritic sericitic mica schist and carbonaceous chloritic schist (Fig. 4). The mineralized bands lie on the upper most part of the chloritic sericitic quartz mica schist. At places, especially in Bhosbhose, Singati, Ghyangdada and Barappu area (Figs.10 and 11) the mineralized body is covered either by loose residual soil or collapse earth materials and old mining dumps.

Detail geological mapping of the deposit was able to trace shining silver gray 2 - 3 m thick hematite bodies (locally with some magnetite) which are at places combined as one and other places two to three as separated by few cm to 6m thick incipiently mineralized ferruginous sericitic quartz mica schist and green chloritic mica schist bands. Therefore, the combined thickness of the ore body appears to be around 2.5 - 3 m thick which can be traced over 5km strike length from Arubote to Singati (about 4 km) and from Singati to Barappu (1 km). The ore body was exposed by digging more than 35 shallow trenches and 15 pits as well as with the help of existing old working pits scattered within a 30 m to 70 m wide zone along the mineralization bands (at Arubote, Silili, Sanodadakharka/Patale, Dadakharka, Kopu Bhalukuna, Kopu, Pahare, Jhoreni, Kuwakopakha, Bhosbhose, Singati, Ghyangdada and Barappu (Figs. 2, 3, 4, 9, 10, and 11). Iron concentration within the ore body is not uniform and varies considerably from 20 to 66%. However, for reserve calculation only the ore having >30% iron is taken as ore. Kaphle and Khan (1995, 1996) have also analyzed few selected samples for Ag, Ni, Ti, and Cr (Table 2). The iron content in the ore appears better in Arubote, Singati and Barappu as compared to Ghyangdada, Bhosbhose, Jhoreni and Pahare. Hematite mineralization are also known from nearby areas at Salleni, Dangadinger, Sotre and Ghunsa area which is yet to be studied in detail.

Fig. 8: Calc mica schist with crystalline dolomite/marble layers

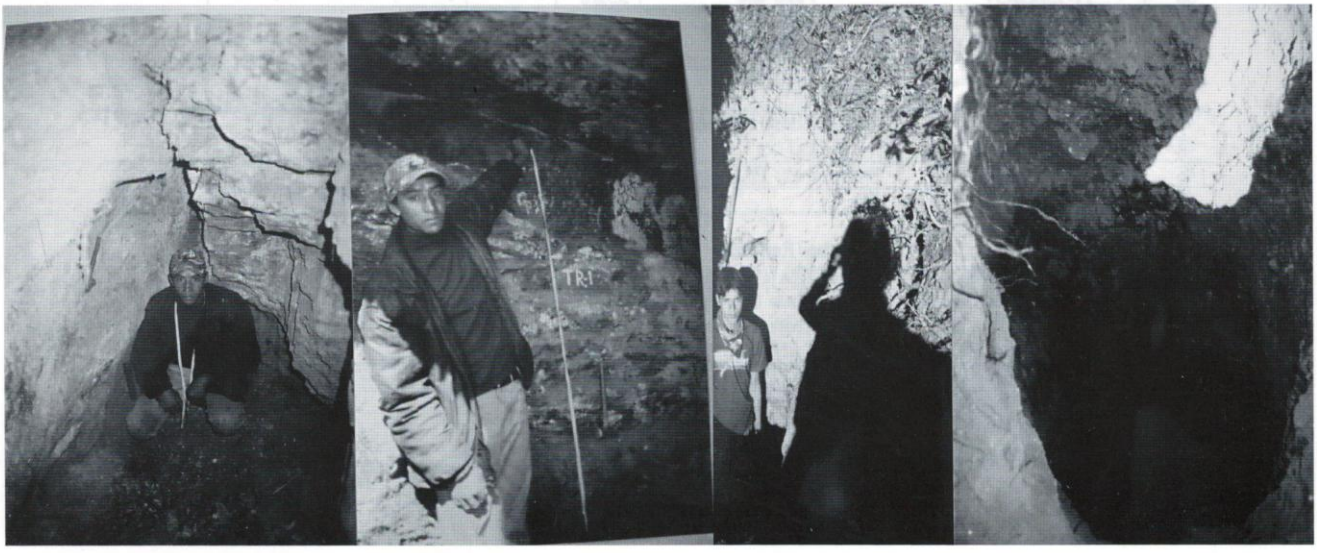

Fig. 9: Mineralized bands exposed by Trench-10 in Kopu Devithan, Trench-8, Kopu Bhalukuna, and pit in Arubote

Table 2: Chemical analysis of Hematite ore samples from Those prospect (DMG, Kaphle and Khan 1996)

S.N.	Sample Number (Chip/Channel samples)	Location/ Remarks	Fe (%)	Cr (ppm)	Ti (ppm)	Ni ppm)	Ag (ppp)	Remarks
1	RM/2052/53 KK/Th/Jh/Tr-1/Cp-1	Jhoreni Khani/ LG ore	32.50	-	-	-	-	Result compiled
2	" " Jh/Tr-1/Cp-2	Jhoreni Khani/ LG ore	40.00	-	-	-	-	
3	" " Jh/ Tr-1//Cp-3	Jhoreni Khani/ LG ore	37.50	-	-	-	-	
4	" " Ph/Tr-2/Cp-4	Pahare Khani/ MG ore	42.50	-	-	-	≤1	
5	" " Ph/Tr-2/Cp-5	Pahare Khani/ LG ore	37.50	-	-	-	≤1	
6	" " Ph/Tr-2/Cp-6	Pahare Khani/ MG ore	45.00	-	-	-	-	
7	" " Ph/Tr-2/Cp-7	Pahare Khani/LG ore	40.00		-	-	-	
8	" " Ph/Tr-3/Cp-8	Pahare Khani/ MG ore	47.50	-	-	-	-	
9	" " Ph/Tr-3/Cp-9	" " "	45.00	-	-	-	-	
10	" "Kp/Tr-5/Cp-10	Kopu Khani/ LG ore	30.00	-	-	-	-	
11	" "/Kp.Tr-5/Cp.11	Kopu Khani/ LG ore	40.00	-	-	-	-	
12	" "Kp/Tr-5/Cp-12	Kopu Khani/ LG ore	40.00	-	-	-	-	
13	" " " Tr-6/Cp-13	Kopu Khani / MG ore	32.50	-	-	-	-	
14	" " " Tr-7/Cp-14	Kopu Khani/ MG ore	47.50	-	-	-	-	
15	" " " Tr-7/Cp-15	Kopu Khani/ LG ore	32.50	-	-	-	-	
16	" "Kp/Tr-7/Cp-16	Kopu Khani/ MG ore	47.50	-	-	-	-	
17	" " " Tr-8/Cp-17	Kopu-Bhalu Kuna/LG	32.50	-	-	-	≤1	
18	" " " Tr-8/Cp-18	" " "	32.50	-	-	-	≤1	
19	" " " Tr-8/Cp-19	" " "	4.00	-	-	-	≤1	
20	**" " " Tr-8/Cp-20**	**" "/ HG ore**	**52.50**	-	-	-	**≤1**	
21	" "Tr-9/Cp-21	" "/ LG ore	32.50	-	-	-	-	
22	" " "Tr-9/Cp-22	" "/ LG ore	37.50	-	-	-	-	
23	" " "Tr-10/Cp-23	Kopu Devisthan/ LG ore	30.00	-	-	-	2	
24	" " "Tr-10/Cp-24	" "/ MG ore	45.00	-	-	-	≤1	
25	" " Dk/Cp-25	Dandakharka/ LG ore	35.00	-	-	-	≤1	
26	" " Dk/Cp-26	" "/ LG ore	35.00	-	-	-	-	
27	" " Dk/Cp-27	" "/ MG ore	45.00	-	-	-	-	
28	" " SDkTr-12/Cp-28	Sano " "/ LG ore	40.00	-	-	-	-	
29	" " Tr-12/Cp-29	" " "/ LG ore	37.5	-	-	-	-	
30	" " " Tr-12/Cp-30	" " "/LG ore	35.00	-	-	-	-	
31	" " " Tr-13/Cp-31	" " " / LG ore	37.50	-	-	-	≤1	
32	" " " Tr-13/Cp-32	" " " / LG ore	40.00		-	-	≤1	
33	" " Sl/Pt-1//Cp-33	Silili / **HG ore**	**50.00**		-	-	≤1	
34	" " Sl/Pt-1/Cp-34	" " / **HG ore**	**52.50**		-	-	≤1	
35	" Ab/Tr-14/Pt-2/Cp-35	Arubote/ LG ore	27.50		-	-	-	
36	" "Ab/ Tr-14/Cp-36	Arubote Khani/ **HG ore**	**52.50**		-	-	-	
37	" " Tr-14/ Cp/36 A	" " / LG ore	33.70	-	-	-	-	
38	**" " Tr-15/ Cp-37**	**" " / HG ore**	**55.00**	-	-	-	-	
39	" " Tr-15/Cp-38	" " / MG ore	45.00	-	-	-	-	
40	**" "Tr-15/Cp-39**	**" " / HG ore**	**55.00**	-	-	-	≤1	
41	KK/Th /Cps-16A	" " / LG ore	40.00	-	-	-	-	
42	KK/Boll/Cps-40	Guns/ LG(?)	20.00	-	-	-	-	
43	KK/Th /Sll/Cp-41	Salleni Khani/ MG ore	47.50	-	-	-	≤1	
44	KK/Th /Sll/Cp-42	" " / LG ore	27.50	-	-	-	≤1	
45	**KK/Bml /Cps-43**	Barmasthali/ **HG ore**	**55.00**	-	-	-	-	
46	Cp-44	(?0	NA	-	-	-	-	
47	CP-45	(?)	37.50	-	-	-	-	
	Bulk Samples	**Location/Remarks**						
48	KK/Th /Jr/Tr-1/Blk-1	Jhoreni Khani/ LG ore	31.50	-	-	-	-	
49	" "Ph/Tr-2/Blk-2A	Pahare Khani /MG ore	42.50	-	-	-	-	
50	" "Ph /Tr-2/Blk-2B	Pahare Khani/ LG ore	40.00	-	-	-	-	
51	" " Kp/Tr-5/Blk-3A	Kopu " / MG ore	42.50	-	-	-	-	
52	" " Kp/Tr-5/Blk-3B	Kopu " / LG ore	40.00	-	-	-	-	
53	" "/Kp/Tr-7/Blk-4A	Kopu " /LG ore	35.00	-	-	-	-	
54	" "Kp/Tr-8/Blk-5A	Kopu Bhalukuwa/LG ore	32.50	-	-	-	-	
55	" "Kp/Tr-8/Blk-5B	" " / LG ore	22.50	-	-	-	-	

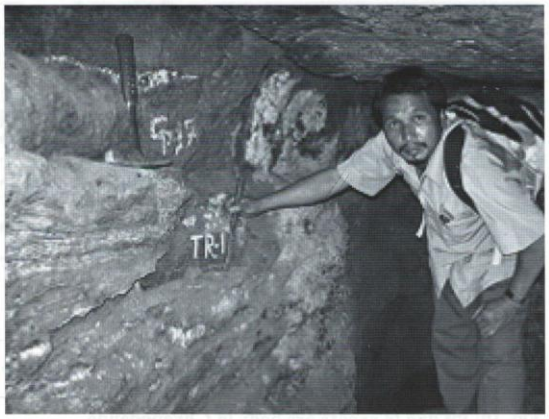

Fig. 12: Upper and lower mineralization bands occur together. Both exposed by Trench No. 8, in Kopu Bhalukuna

Fig. 13: Upper mineralization band (Tr. 2)

Fig. 14: Lower mineralization band (Tr. 2) at Pahare Khani

ORE GENESIS

Field observations combined with laboratory investigations and tests as well the nature of the mineralization clearly revealed that it is a synsedimentary hematite deposit which was later metamorphosed during regional metamorphism. As a result the hematite has recrystallized into foliated micaceous shining silver gray specular hematite with minor amount of magnetite in the south at Jhoreni, Bhosbhose, Pahare and Kopu khani and gradually becomes less micaceous and locally more or less massive hematite with few magnetite, pyrite and occasionally pyrrhotite in Arubote area. It is a stratabound hematite (iron) deposit. Locally minor hydrothermal effect has indicated by the presence of few small quartz veins and quartz + magnetite and ± ilmenite veins and lenses as well as quartz + pyrite (±) pyrrhotite lenses within the hematite bands and lots of quartz veins in the host rock very close to the contact with the mineralized bands. The iron content in the ore body varies considerably from <30 to 66% Fe locally with minor amount of other ferrous metals like titanium (up to 1600 ppm), chromium (up to 50 ppm), Nickel (up to 60 ppm) and rare amount of Silver (up to 2 ppm, Tables 2 and 3).

CHEMICAL ANALYSIS RESULTS

Four types of ore samples (Channel, Chip, Bulk and Grab samples) were collected from exposed part of the mineralized body after excavating trenches and pits. Depending on the concentration of iron in the ore (visual expression), samples were selected and crushed and pulverized to minus -80 mesh and analyzed to know iron content in them.

Out of 86 channel, 123 chip, 74 grab and 55 bulk samples only 143 samples were analyzed in DMG Chemical laboratory and 6 samples in NESS laboratory (for cross checking) and 17 samples in Soil Test Laboratory to know the iron content in the ore. In all the three laboratories AAS method was used for chemical analysis. Analytical results of

Table 3: Analytical results of grab samples (DMG, Kaphle and Khan 1995)

S.N.	Sample Number	Location	Fe(%)	Cr (ppm)	Ti (ppm)	Ni (ppm)	Ag (ppm)	Remarks
64	RM/2051/052 **KK/S-6A**	Arubote Khani **Very High grade ore**	**66.00**	-	**<800**	**40**	-	Near Tr-14
65	" KK/S-6B	Arubote Khani/ MG ore	45.00	NA	1600	60	NA	Near Tr-13
66	**" KK/S-8A**	Pahare Khani/ **HG ore**	**57.00**	40	<800	40	NA	
67	" KK/S-8A-1	Pahare Khani/ MG ore	48.00	40	800	50	NA	
68	" KK/S-8B	Pahare Khani/ LG ore	31.00	-	<800	40	-	
69	" KK/S- 23A	Bhosbhose Khani/ LG ore	30.50	-	-	-	-	
70	" KK/S- 23B	Bhosbhose Khani/MG ore	49.50	-	1600	-	-	
71	" KK/S- 23C	Bhosbhose Khani/MG ore	50.00	50	<800	-	-	
72	" KK/S- 25	Singati Khani/ MG ore	45.00	-	-	-	-	
73	" KK/S- 26	Singati Khani/ MG ore	45.00	-	-	-	-	
74	" KK/S- 26A	Singati Khani/ LG ore	34.00	30	<800	20	-	
5	" KK/S- 28	Barappu Khani/ LG ore	38.00	-	-	-	-	
76	" KK/S - 30	Salleni Khani/ LG ore	31.50	-	-	-	-	
77	" KK/S - 30A	Salleni Khani/ LG ore	NA	-	-	-	-	
78	" KK/S - 31	Pahare Khani/ LG ore	33.50	-	-	-	-	
79	" KK/S - 32	Pahare Khani/ LG ore	NA	-	-	-	-	
80	" KK/S - 34	Jhoreni Khani/ LG ore	32.00	-	-	-	-	
81	" KK/S - 35	Jhoreni Khani / LG ore	40.00	-	-	-	-	
82	" KK/S - 36	Kuwa Khani/ MG ore	43.00	-	800	-	NA	
83	" KK/S - 38B	Pahare Khani/ LG ore	34.50	-	-	-	-	
84	" KK/S - 39A	Darim Danda/ MG ore	42.00	-	800	40	-	
85	" KK/S - 39B	Darim Danda/ LG ore	40.00	-	-	-	-	
86	" KK/S - 41	Kopu Khani/ LG ore	29.50		800		-	
87	" KK/S -42A	Kopu Bhalukuna/ LG ore	37.00	-	-	-	-	
88	" KK/S -42B	Kopu Bhalukuna/ HG ore	55.50	-	800	-	-	
89	" KK/S -43	Kopu khani/ LG ore	38.00	-	-	-	-	
90	" KK/S -66	Silili Khani/ LG ore	NA	-	-	-	-	
91	" KK/S -67	Sano Dandakharka/MG ore	49.50	50	<800	<20	-	
92	" KK/S- 67A	Sanodandakharka/LG ore	35.00	-	-	-	-	
93	" KK/S- 70	Danger Dinger/ LG ore	31.50	-	-	-	-	
94	" KK/S- 78	-	-	-	-	-	-	
95	" KK/S- 001	-	-	-	-	-	-	
96	" KK/S- 117	- MG ore	-	-	-	-	-	
97	" KK/S -141B	- LG ore	-	-	-	-	-	

Ch = Channel sample, Cp = Chip sample, Blk = Bulk sample, S = Grab sample, Low grade =31- 40%Fe, MG = Medium grade = 41- 50%Fe, HG =High grade = 51-60%Fe, Very High grade >60%Fe.

155 hematite ore samples are presented in Tables 2, 3, 4 and 5. Beneficiation test of 17 ore samples were performed and it helped to upgrade the ore quality (Table 5). The analytical results indicate that the distribution of iron in the ore is not uniform and it varies considerably from 20 to 66%. Present study revealed that on average the grade is just around 45.3%. Because of non-uniform grade of the ore only selective mines could be possible. However, metallurgical beneficiation of the low to medium grade ore should help to upgrade the quality of the ore and make it possible to mine the whole deposit.

BENIFICIATION AND METALLURGICAL TESTS

Upgrading of the low to medium grade hematite ore of Thoshe by a cheap and simple beneficiation technique is necessary to prove it as an economic deposit. Therefore, a simple beneficiation (crushing and washing) method was applied at small scale to upgrade few ore samples. By this method it was possible to remove some unwanted gangue minerals like mica, chlorite and quartz to upgrade hematite ore. Such simple beneficiation tests of 17 selected samples were performed by hand crushing and washing of the crushed sample to remove 20 to 30 % of gangue minerals from the original ore sample with a view to upgrade the ore. This process was successful to upgrade the ore of 42% Fe to 50% Fe, 45% Fe to 60% Fe, 47.5% Fe to 60% Fe and 50.5% Fe to 62.5% Fe (Table 5). It is also known that the Metallurgical beneficiation test of bulk iron ore samples (Fe = 48.4%) carried out by UNDP, MED/ DMG, Nepal, National Mineral Development Corporation Limited, Hyderabad, India in September 1987, could upgrade it first up to Fe = 54.22% and Pilot scale Beneficiation up to 63.04% iron (Manandhar 2044 BS) which is quite suitable to produce sponge iron. These results are the positive indication to exploit Thoshe iron deposit economically. However, it is necessary to conduct additional beneficiation and metallurgical testing of the ore (industrial testing) in one of the well known metallurgical laboratory. All these test results will help to the company for economic calculation and make the deposit feasible for mining.

GEOLOGICAL ORE RESERVE AND GRADE

During third phase of investigation topographic map (at 1:1000 scale), detail geological map and cross sections at the same scale were prepared and traced the south and westward continuation of the mineralized body from Jhoreni

Table 4: Chemical analysis of the ore samples (sample numbers and location in bracket is equivalent to Kaphle and Khan (1996) (N&C Minerals P. Ltd. 2008, analyzed in DMG laboratory)

S.N.	Sample No.	Location	Sample type	Thickness of channel(m)	Fe Content (%) DMG Lab	Fe % after Beneficiation	Remarks
1	**TH/TR-1/Ch-1 (TR-8)**	**Pahare Khani (Kopu Bhalukuna)**	**Channel**	**0.46**	**45.16**	-	**Medium**
2	TR-1/Ch-2	Pahare Khani	Channel	0.32	32.67	-	Low
3	TR 1/Ch-3	Pahare Khani	Channel	0.30	42.28	-	Low – Med
4	TR-1/Ch-4	Pahare Khani	Channel	0.30	37.58	-	Low
5	**TR-1/Ch-5**	**Pahare Khani**	**Channel**	**0.36**	**45.87**	-	**Medium**
6	**TR-1/Ch-6**	**Pahare Khani**	**Channel**	**0.40**	**51.94**	-	**Med – High**
7	**TR-1/Ch-7**	**Pahare Khani**	**Channel**	**0.44**	**47.15**	-	**Medium**
8	TR-2/ Cp-1 (TR-6)	Pahare Khani (Kopu Khani)	Chip	0.50	10.63 (?)	-	Very low/ Recheck
9	TR-3/Ch-1 (TR-15)	Arubote Khani	Channel	0.68	39.94	-	Low
10	**TR-3/Ch-2**	**Arubote Khani**	**Channel**	**0.40**	**51.52**	-	**Med - high**
11	**TR-4/Ch-1 (TR-12)**	**Arubote Khani** (Sanodadakharka	**Channel**	**0.48**	**49.01**	-	**Medium**
12	TR-5/Ch-1 (TR-11)	Arubote Khani (Sanodadakharka)	Channel	1.50	16.89 (?)	-	Very low/ Recheck
13	TR-6/Ch-1 (TR-10)	Pahare Khani (Kopu Devithan)	Channel	0.60	29.56	-	Low grade
14	TR-6 /Ch-2	Pahare Khani	Channel	1.14	30.18	-	Low grade
15	**TR-6/Ch-3**	**Pahare Khani**	**Channel**	**0.40**	**46.22**	-	**Medium**
16	TR-6/Cp-1	Pahare Khani	Chip	0.60	42.54	-	Medium grade
17	TR-7/Ch-1 (TR-5)	Kopu Khani	Channel	0.40	43.37	-	Medium grade
18	**TR-7/Ch-2**	**Kopu Khani**	**Channel**	**0.36**	**45.26**	-	**Medium**
19	TR-8/Cp-1 (TR-4)	Kopu Khani	Chip	0.30	34.51	-	Low grade
20	TR-9/Ch-1 (TR-2)	Kopu Khani (Pahare Khani)	Channel	0.36	29.15	-	Low grade
21	**TR-9/Ch-2**	**Kopu Khani**	**Channel**	**0.28**	**45.13**	-	**Medium**
22	TR-9/Ch-3	Kopu Khani	Channel	0.30	43.45	-	Low – Med
23	TR-9/Ch-4	Kopu Khani	Channel	0.32	34.62	-	Low grade
24	TR-10/Ch-1 (Tr-7D)	Pahare Khani (Kopu Khani)	Channel	1.00	34.77	-	Low grade
25	**TR-10/Ch-2**	**Pahare Khani**	**Channel**	**0.36**	**49.52**	-	**Medium**
26	TR-10/Ch-3	Pahare Khani	Channel	0.20	34.95	-	Low grade
27	**TR-11/Cp-1** (TR-7C)	**Pahare Khani** (Kopu Khani)	**Chip**	**0.36**	**49.07**	-	**Medium**
28	**TR-11/Cp-2**	**Pahare Khani**	**Chip**	**0.34**	**44.87**	-	**Medium**
29	TR-12/Ch-1 (TR-7B)	Pahare Khani (Kopu Khani)	Channel	0.48	38.66	-	Low grade
30	TR-12/Ch-2	Pahare Khani	Channel	0.42	39.22	-	Low grade
31	TR-13/Ch-1 (TR-7A)	Pahare Khani (Kopu Khani)	Channel	0.90	42.08	-	Low -Med
32	Pt.1/Cp-1 (Pit3)	Jhoreni	Chip	0.50	**44.54**	-	**Medium**
33	**TH/S-53**	**Jhoreni Khani**	**Ore**	**1.00 (?)**	**53.33**	-	**Med - High**
34	**TH/S-55**	**Singati Khani**	**Ore**	**1.00 (?)**	**52.34**	-	**Med - High**
35	**TH/Bds-75**	**Singati Khani**	**Ore float**	**x**	**48.59**	-	**Medium**
36	TR-1/Ch/Blk-	**Pahare Khani**	Bulk	(6kg)		NA	Report not

to Kuwakopakha, Bhosbhose and Singati in the south and from Singati east, Singati west, Ghyangdada and Barappu to the west. The mineralization band is not exposed in this area. However, presence of numerous old working pits within a strip/ zone of 30 to 70 m width and their cleaning works helped us to trace the mineralized body almost throughout. Chemical analysis of the ore from Barappu, Ghyangdada and Singati show that the ore contains up to 52.50%, 46.25% and 50.00% iron respectively. Now the left out Jhoreni - Kuwakopakha- Bhosbhose sector (strike length 600 m) and then Singati - Ghyangdada - Barappu sector (strike length 1025 m) were added and recalculated for possible Geological reserve. The available data of Singati - Ghyangdada - Barappu sector and calculation clearly indicates that additional 4.536 million tons of iron ore is possible in this sector.

Table 5: Ore samples upgraded by simple beneficiation

S.N.	Sample no.	Sample Type	Iron content % (Before beneficiation)	Iron content % (After beneficiation)	Remarks
1	TH/Tr-1/Ch-1-7 (7 samples mixed)	Bulk ore sample	45.00	50.00	Out of 1700g only 1000g washed to 750g
2	TH/Tr-3-6/Ch-1-3 (3 samples mixed)	"	42.00	50.00	Out of 200 only 1000g washed to 750g
3	TH/Tr-7-9/Ch-1-3 (3 samples mixed)	"	45.00	60.00	Out of 1500g only 1000g washed to 850g
4	Tr-10&12/Ch1-4 (4 samples mixed)	"	42.0 (?)	47.50	Out of 1550g only 1000g washed to 800g
5	TH/Tr.1/Ch-Blk	"	47.50	60.00	Out of 1000 all 1000g washed to 800g
6	TH/Tr-7&9/Ch2 2 samples mixed)	"	52.50 (?)	62.5	Out of 1000g all 100g washed to 650g
7	TH/Tr-11/Blk-7		37.50	Analysis in process	Out of 500g all 500g washed to 300g (Sanodadakhark)
8	TH/ Blk/S-36	"	43.00	" "	Out of 500g all 500g washed to 400g Jhoreni
9	TH/ Tr-5/Blk	"	43.37	" "	Out of 500g all 500g washed to 400g (Kopu)
10	TH/Grab/S-55	"	52.34	" "	Out of 500g all 500g washed to 400g (Singati)
11	TH/Pt.6/ S-401	Bulk sample	47.50	55.00	Out of 500g all 500g washed to 400g (Singati West)
12	TH/Pt.7/S-402	"	40.00	45.00	Out of 500g all 500g washed to 400g (Ghyangdada East)
13	TH/Pt.9/S-405	"	52.50	60.00	Out of 500g all 500g washed to 400g Barappu
14	TH/Pt.4/S-406	"	52.50	55.00	Out of 500g all 500g washed to 400g (Bhosbhose)
15	TH/Pt.5/S-408	"	50.00	57.00	Out of 500g all 500g washed to 400g (Singati East)
16	TH/Pt.2/S-413	"	47.50	57.00	Out of 500g all 500g washed to 350g (Arubotedil)
17	TH/Pt.8/S-415	"	52.50	55.00	Out of 500g all 500g washed to 400g (Ghyangdada West)

On the basis of the topography, overburden, mining condition, nature of the mineralization and the analytical results the whole Thoshe iron deposit area is divided into 3 major Blocks e.g., (1) Arubote - Sanodadakhark Block (2) Dadakharka - Bhosbhose Block and (3) Singati - Barappu Block for present calculation of the possible Geological ore reserve and average grade of the ore in each block. All the results of these three blocks are combined (3.74, 7.63 and 4.54 million tons respectively) and recalculated as possible total geological ore reserve as 15.91 million tons ore with an average grade of 45.3% iron.

FINDINGS AND CONCLUSIONS

The preliminary and follow up investigation/ exploration of Thoshe iron deposit is able to confirmed that it is the oldest known iron deposit in Nepal which was mined by the local miners for a long time in the past. Over 1000 iron old working pits and few smelting places with scattered slag are the solid proof old mining activities.

Three stages of exploration of Thoshe iron deposit was completed except test drilling. Topographic map of 100 hectare at 1:1000 scale and a detail geological map of the same area in the same scale are prepared. 35 Trenches and 15 Pits were excavated to expose the ore body and collect fresh ore samples for laboratory tests. On the basis of the nature of the ore, chemical analysis results, the geological ore reserve and its grade is calculated as 15.91 million tons with an average of 45.3% iron.

1.5 - 3 m thick iron ore body with almost 5 km in strike length is well traced by geological mapping, trenching and pitting. Iron content in the mineralized body is not uniform as a result the analytical results of the ore samples show

considerable variation in iron content from 30% to 66%. The combined overall average is low (45.3%). Therefore, further upgrading of low and medium grade ore by beneficiation (metallurgical process) and its industrial testing is necessary to produce sponge iron which can be used in iron and steel industries and to judge whether the mining is feasible or not.

Geophysical exploration (Magnetic/ IP) is recommended to trace the mineralized body and find out its tentative shape and size at depth. It helps not only to confirm the ore body at depth but also for locating drilling sites and also plan for mine development. At the same time exploratory drilling (5 to 10 drill holes) at a depth of 85 to 125 m is essential before making decision for mining.

Simple beneficiation of different types of representative ore samples from different sectors of Thoshe iron deposit indicate that upgrading of Thoshe Hematite ore up to certain percent is possible e.g. from 52 to 63% iron. Therefore, it is almost sure that proper mechanical beneficiation would be able to upgrade up to 63% Fe which is quite suitable for the production of sponge iron.

It is a synsedimentary iron deposit which was later affected by regional metamorphism. Iron ore is a shining silver gray specular hematite locally with some massive magnetite and rare amount of ilmenite. The nature of the mineralization, its extension length, combined thickness and over all tonnage of the deposit appears to be suitable for mining. However, it is necessary to upgrade the ore to >60% Fe by simple and cheap beneficiation method. The ore as such can be used in some cement industries and upgraded ore to make sponge iron which can be used in iron and steel industries.

Topographical and geological condition of the deposit in (1) Arubote - Silili - Sanodadakharka sector and (2) Singati - Ghyangdada - Barappu sector is suitable for opencast mining although 5 to 18 m thick overburden of residual soil, collapse loose materials and some rock mass have to be removed during mine development process. The rest part (3) Dandakhark - Kopu - Pahare - Jhoreni - Bhosbhose sector only underground mining is possible.

Basic infrastructure like approach road, electricity line, water supply and telephone facilities has to be improved to run heavy vehicles to transport heavy machinery equipments, voluminous ore and other construction materials as well as necessary power and water supply. Smelting of Hematite into a sponge iron requires huge amount electricity or coal therefore, these things have to be considered well in advance before start mining.

Overburden materials and mine waste can be dump at the lower level in a very low angle to almost flat ground around by constructing strong retaining wall and plantation to control possible downward flow of the waste materials.

ACKNOWDGEMENTS

The author would like to express his sincere thanks to Mr. S.P. Mahato, Director General, Department of Mines and Geology and Mr. Wangchhu Sherpa, Entrepreneur of N & C Minerals (Pvt.) Ltd. Bauddha, for allowing him to use the data obtained during different stages of exploration to publish in this paper. The author would like to thank the unanimous reviewers to improve the manuscript.

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