STRATIGRAPHY OF THE SABHAYA KHOLA REGION, SANKHUWA SABHA DISTRICT, EASTERN NEPAL.

ELIZABETH ANDREWS
Department of Geoscience
New Mexico Institute of Mining and Technology
Socorro, New Mexico 87801

सारांश

पूर्वी नेपालको सभाया खोला क्षेत्रको प्रस्तर स्तर विन्यास (Lithostratigraphy) प्रस्तुत गर्दै उक्त क्षेत्र-लाई तीन मुख्य प्रस्तर इकाईमा विभाजन गरिएको छ; मिल्के नाइस, काठमार्डो एवम् नुवाकोट कम्प्लेक्स अन्तरगतका चट्टानहरू।

काठमाडौ कम्प्लेक्स भित्र पर्ने चेनपर ग्रुप चट्टानको उत्तर–दक्षिण लम्बाई भएको सांघुरो कटिवन्ध (Zone) मा अलमण्डाइन गार्नेटको खनिज भण्डार रहेको छ। खनिज जन्य उक्त कटिबन्धस्तर विन्यासद्वारा नियन्त्रित भएको बिश्वास गरिएको छ। त्यस्तै, काठमार्डो कम्प्लेक्सको फाकुवा ग्रुप चट्टान भित्र मुख्य मध्यवर्ती प्रधातको तलतिर बहुमुल्य पत्थर (Gems) पिग्माटाइट पाइन्छ।

ABSTRACT

Litho-stratigraphy of Sabhaya Khola region of eastern Nepal is worked out. The area is divided by thrusts into three main units viz; Milke Gneiss, Kathmandu Complex and Nuwakot Complex. The units are further subdivided into groups and formations mainly based on lithological characteristics. An attempt is also made to correlate these rocks with previous investigations in and adjacent to the present study area.

Economic deposits of almandine garnet occur within a N-S extending narrow zone in the Chainpur Group of Kathmandu Complex. The mineralization in the zone is considered to be controlled statigraphically. Also, gem-bearing pegmatites occur in a definite statigraphic horizon within the Phakuwa Group of Kathmandu Complex, just below the Main Central Thrust.

PREVIOUS WORK

Earlier geological works in eastern Nepal were carried out by European mountaineers in the late 19th century. Hooker traversed eastern Nepal in 1848, and left notes on the geology in his Himalayan journal (Hooker, 1855). Loczy (1907) published a geologic cross-section from Kanchenjunga to Darjelling, which included most of the major structural elements of eastern Nepal that are still accepted today. Wager (1934) studied the geology of the Arun River. Auden (1935) established the general outlines of the nappe theory first proposed by Loczy (1907). Lombard (1953) emphasized schuppe rather than nappe structures in his geologic cross-section from Mt. Everest to the Gangetic plain, 30 miles west of the Arun Valley. Bordet (1961) proposed a stack of large-scale nappes and older transverse structures after studying the structure and stratigraphy of the Arun River region. Anma and Akiba (1967) described the general petrography along the Arun River and the Dudh Kosi, and supported the schuppe theory proposed by Lombard (1953). Hagen (1963,1969) proposed a series of multiple nappes and recognized many of the major structural features of the region.

Yadav (1970) worked on the geology of the present area under investigation. Talalov (1973) proposed a normal straitgraphic relation for the metamorphic rocks. Hashimoto et al (1973) divided the Arun river region into autochthonous and allochthonous masses with a series of nappes and schuppen. They also defined a regional stratigraphy. Jaros and Kalvoda (1976) proposed a group of relief thrusts in the Everest-Makalu area.

Maruo et al (1979) did regional mapping and detail that includes much of the area of this study.

INTRODUCTION

The study area covers about 450 square kilometers in the Lesser Himalaya (Bordet, 1961) and falls in Sankhuwa Sabha district in eastern Nepal, the Survey of India toposheet Nos. 72 M/3 and M/7. It extends from the Arun River east to the Milke Danda, and from the town of Chainpur north to the Sabhaya Khola. The map area is drained by the Sabhaya Khola and its southern tributaries, including the Chinde, Dingla, Samla, Kusuwa, Hangduwa, Khekuwa, and Hinuwan Kholas.

The area lies on the eastern limb of the Arun anticline (Bordet, 1961; Hagen, 1969) and the westren limb of the Jaljale syncline (Hagen, 1969; Yadav, 1970). This results in a generally uniform ENE dip of all strata. The main orographic and tectonic zones of the Himalaya included in this study are the 1. High Himalaya (Bordet, 1961), represented by the Milke gneiss and underlain by the Main Central Thrust, which separates it from the 2. Lesser Himalaya (Bordet, 1961) composed of the Kathmandu complex and the Nawakot complex.

A series of imbricate thrusts divides the Lesser Himalaya into at least three distinct sections.

The Kathmandu complex is composed of two sections of gneiss, each of which is overlain by fairly high-grade metasediments, separated by thurst faults. In addition, the Khandbari gneiss, of probable intrusive origin, occupies the northwestern part of the map area. No palentological or radiometric dates are available for this region, but Stocklin & Bhattarai (1977) indicate that the Kathmandu complex near Kathmandu is the Lower Paleozoic and Precambrian age.

The Nawakot complex underlies the Kathmandu complex, and is separated from it by a thrust. The Nawakot complex is represented by low-grade metasetimentary rocks, primarily phyllites and quartzites. Paleontological and radiometric data are generally lacking. Krummenacher et al (1980) proposed an Upper Precambrian age for the Nawakot phyllites based on potassium-argon dating. Stocklin & Bhattarai (1977) also suggests an Upper Precambrian age for this complex near Kathmandu. This "reverse metamorphism", or superposition of the high-grade Kathmandu complex on the low-grade Nawakot complex, is typical of the Lesser Himalaya throughout Nepal.

GEOLOGY OF THE AREA

Stratigraphy and Lithology

The stratigraphy of the Sabhaya Khola region was developed primarily from lithological observations as both paleontogical and radiometric data are lacking. The Geological map of the are presented in fig. 1.

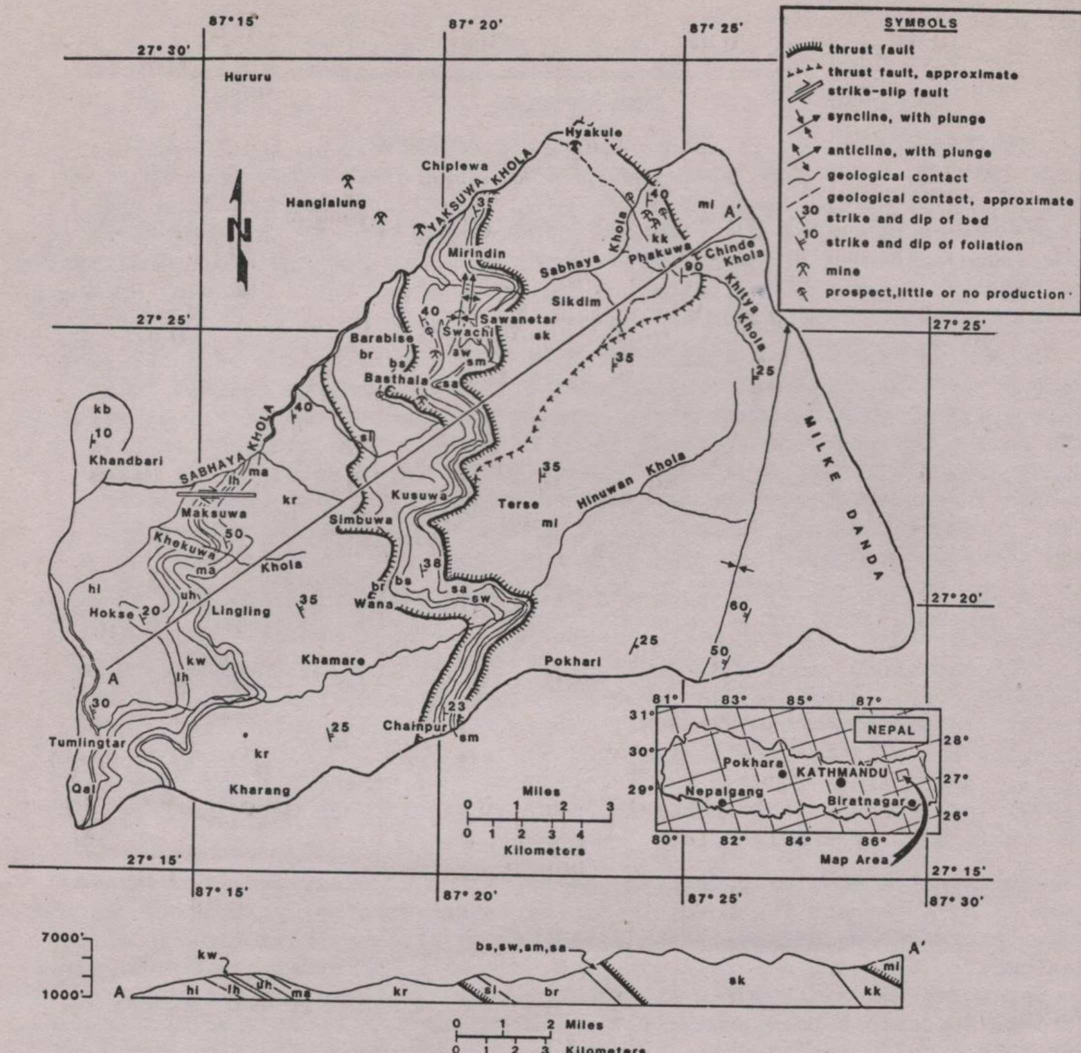


Fig-I

LEGEND

HIGH HIMALAYA

mi Milke gneiss

LESSER HIMALAYA

Kathmandu Complex
Phakuwa Group

kk Khitya Khola formation

sk Sikdim gneiss

Chainpur Group

sa Sawanetar formation

sm Samla Limestone

sw Swachi formation

bs Basthala schist

br Barabise gneiss

si Simbuwa schist

Gneiss, possibly intrusive

kb Khandbari gneiss

Nawakot Complex

kr Kharang phyllite

ma Maksuwa graphitic phyllite

uh Upper Hokse quartzite

kw Khekuwa phyllite

lh Lower Hokse quartzite

hi Hinuwan phyllite

QUATERNARY

Qal River terrance deposits

The rock units derive their names from their type localities. The stratigraphic position and lithology of each unit is given for its type locality, with reference to any variations that occur in other localities.

Main Subdivisions

The rocks of the Sabhaya Khola region fall into three main subdivisions: 1. the Milke gneiss of the High Himalaya, 2. the Kathmandu complex of the Lesser Himalaya, and 3. the Nawakot complex, also of the Lesser Himalaya (Table 1). The primary lighological differences between these subdivisions are in their metamorphic grade. The Milke gneiss rests on the Kathmandu complex, which is divided into two groups. The Phakuwa Group (upper) is of almandine-amphibolite facies, and it overlies the Chainpur (lower) Group, of epidote-amphibolite facies. Below the Kathmandu Complex is the Nawakot Complex, which is greenschist facies.

The contact between these subdivisions are rarely well-exposed or clearly defined. The angle of most contacts appears to be extremely shallow, almost parallel to the attitude of bedding. Thus metamorphic grade provided the only solid criterion for dividing the formations into groups and complexes. Divisions were made wherever contrasting metamorphic grades were obvious, e.g. at the contact between the high-grade Phakuwa Group and the relatively lower-grade underlying Chainpur Group.

The nature of these contacts, or even their existence, would undoubtedly be disputed by proponents of reverse metamorphism being due to the effects of grantitic intrusions (e.g. Nadgir, 1973; and other Indian geologists), or to block-faulting (Talalov, 1972; Hashimoto et al., 1973). The author prefers to explain the juxtaposition of different metamorphic grades through the agent of thrust faulting (Ganser, 1964; Hagen, 1969; and other). The shallow angle of the contacts suggests thrust faulting as a mechanism rather than block faulting. Granitic intrusions would tend to create sub-rounded or symmetrical metamorphic zones, instead of the distinctly linear contacts which continue for long distances along strike evident here. There is some lithologic and stratigraphic evidence that the Phakuwa Group is a higher-grade repetition of the Chainpur Group, which would be most easily explained by thrust faulting. Finally, the consistent lineation of many beds, which parallels the dip of the contacts, also favours thrusting as a mechanism.

The stratigraphic subdivisions of the Sabhaya Khola region are shown in Table 1. The formations are arranged in the order of their superposition, from Tumlingtar east to the Milke Danda.

The correlation of the stratigraphy developed by the author to those suggested by earlier investigators is included in Table 2. The synonymy is approximate at best, since the studies listed were done on a broad regional scale, without the benefit of detailed mapping in the Sabhaya Khola region. Three of the four studies that appear in the table (Bordet, 1961; Akiba et al., 1973; and Maruo et al. 1979) did not extend their mapping to the eastern most part of the present study area, so the syno-

Table 1. Stratigraphic Subdivisions

Name of Unit	Main Lithology	Approximate Thickness
High Himalaya		
Milke Gneiss	biotite gneiss	3500 m
------------ MAIN CENTRAL THRUST ------------		
Lesser Himalaya		
Kathmandu Complex		
Phakuwa Group		
Khitya Khola Formation	marble, quartzite, schist	900 m
Sikdim Gneiss	biotite gneiss	2500 m
------------ THURST ------------		
Chainpur Group		
Swanetar Formation	quartzite, schist	100 m
Samla Limestone	marble, calcareous schist	50 m
Swanchi Formation	mica schist, quartzite, phyllite	150 m
Basthala Schist	mica schist	100 m
Barabise Gneiss	biotite gneiss	1500 m
Simbuwa Schist	mica schist	250 m
------------ THURST ------------		
Nawakot Complex		
Kharang Phyllite	phyllite, amphibolite, carbonate	3000 m
Maksuwa Graphitic	graphitic phyllite	240 m
Upper Hokse Quartzite	argillaceous quartzite	270 m
Khekuwa Phyllite	green and gray phyllite	150 m
Lower Hokse Quartzite	argillaceous quartzite	290 m
Hinuwan Phyllite	green phyllite	800 m

STRATIGRAPHIC CORRELATION

TABLE-2

Present Study	Bordet (1961)	Hagen (1969)	Akiba et al. (1973)	Maruo et al. (1979)	Stocklin et al. (1977)
High Himalaya	Haut Himalaya	Tibetan sediment zone & Kanchenjunga nappes & Khumbu nappes	Tibetan zone & Basement gneiss zone	Tethyszone & Himalaya gneiss zone	
Milke gneiss	gneiss ectinites du Barun		Irkhua crystalline nappe	Himalayan gneiss	
Lesser Himalaya		Kathmandu nappes & Angbung zone & Nawakot nappes	Midland schuppe zone & Midland autochthonous	Lower Himalaya & Augen gneiss zone & Calc-silicate schist zone	
Kathmandu complex		Kathmandu nappes	Irukhua crystalline nappe		Kathmandu Complex
Phakuwa group					
Khitya Khola formation				Calc-silicate schist zone	
Sikdim gneiss	migmatites			mica gneiss	
Chainpur group					
Sawanetar formation	micaschists & quartzites superieurs			Calc-silicate schist zone	
Samla limestone					
Swachi formation	phyllades inferieurs & quartzites inferieurs				
Basthala schist	micaschistes				
Barabise gneiss	migmatites				
Sirmbuwa schist	micaschistes				
Khandbari gneiss	migmatites			augen gneiss	Nawakot Complex
Nawakot complex		Nawakot nappes	Gudel phyllite schuppe & Tumlingtar autochthonous window		Nawakot Complex
Kharang phyllite	calcschistes & phyllades superieurs & phyllades inferieurs		green and black phyllite & crystalline limestone & amphibolite	pelitic-psammitic phyllite & carbonaceous graphitic phyllite & limestone	
Maksuwa graphitic phyllite	calcschistes & phyllades superieurs			carbonaceous graphitic phyllite	
Upper Hokse quartzite	quartzites superieurs		quartzite	quartzite	Dunga Quetzite
Khekuwa phyllite			green phyllite		
Lower Hokse quartzite			quartzite		
Hinuwan phyllite	phyllades inferieurs		green phyllite	pelitic-psammitic phyllite	

nymy becomes progressively more vague in the upper, more easterly units.

Descriptions of the individual units follow in the same order that they are listed in Table 1. A stratigraphic column is presented in Figure 1.

LESSER HIMALAYA

Nawakot Complex

The name of this complex is derived from the term "Nawakot nappes" used by Hagen (1969) to describe this complex in the Sabhaya Khola region.

The Nawakot complex consists of pelitic and psammitic metasediments rarely exceeding the sericite-chlorite grade (greenschist facies). They are primarily chlorite-sericite phyllities, graphitic phyllities, and argillaceous quartzites, with occasional discontinuous beds of crystalline limestone or amphibolite.

The total thick-ness of the Nawakot complex is about five kilometers. It covers the western part of the map area along the lower reaches of the Sabhaya Khola, from Tumlingtar east to Chainpur. It is overlain by the Chainpur group to the east.

Some evidence exists which suggests that the author's Nawakot complex may be correlative with the Nawakot complex of Stocklin (1977). Its stratigraphic position above the Main Boundary Thrust (Bordet, 1961; Maruo, 1979) and below a complex of higher-grade metasediments is significant. Lithological similarities, particularly to Stocklin & Bhattarai's (1977) Robang phyllites and Dunga Quartzites, are striking. The metamorphic grade of their complex is compatible with the Nawakot complex of the present author.

Finally, the Nawakot nappes of Hagen (1969), which were the basis for Stocklin's unit, are synonymous with the Nawakot complex of the present study.

Hinuwan Phyllite

The name is derived form the Hinuwan Khola, a tributary of the Sabhaya Khola.

The unit consists predominantly of sericitic-chloritic phyllites of a green-gray colour. Occasional minor interbeds of quartzite and graphitic phyllite are also present. The dominant green-gray phyllite is composed of fine flakes of sericite and chlorite, with abundant quartz grains less than one millimeter in diameter. Often the quartz forms lenses or augen in the rock, averaging one centimeter in lenght and three centimeters in diameter. Some of the phyllites have slaty cleavage, but more commonly the chlorite-sercite layers are undulatory, with irregular cleavage. Garnets were not noted in the Hinuwan phullite. Weathering produces a silky sheen and red hematite stain. Under a microscope, minor amounts of biotite and feldspar are visible. Accessory minerals include tourmaline, apatite, sphene, and epidote.

The quatzite interbeds are sparse and average only a few meters in thickness. They are medium-grained and equigranular, with well-developed blocky cleavage along layers of mica concentrations. Fresh outcrops are white, tan or yellow in colour, but weathered colour is pink. The thickness of the Hinuwan phyllite is about 300 meters.

Lower Hokse Quartzite

The name Hokse was adopted from the village of Hokse, which lies on the western end of the ridge between the Khekuwa Khola and the Hinuwan Khola.

The Lower Hokse quartzites is mica-and clorite-rich quartzite with a strong lineation and predominantly greenish colour. Green-gray phyllites similar to the Hinuwan phyllite are interbedded throughout the unit, making up approximately ten percent of the total thickness (approximately 290 meters). The phyllite interbeds vary from a few millimeters to nearly a meter in thickness. Small-scale folding is common in the quartzite, with foliated micaceous layers parallel to the fold axis. The lineation is generally parallel to the overall dip direction of beds. The quartzites is fine-to medium-grained with occasional veins of recrystallized quartz. It is generally greenish with rare outcrops of gray or white, but weathered blocks display a variety of colours, including red, orange, yellow, dark green, brown and black. It wheathers into rectangular blocks and slabs.

Under microscope, the quartzites show a fine-grained slightly foliated matrix of cracked, angular quartz grains with undulatory extinction and dissolution of grain boundaries. Elongate crystals of muscovite, chlorite and sericite make up two percent of the rock.

Khekuwa Phyllite

The name was taken from the Khekuwa Khola, a tributary of the Sabhaya Khola.

The Khekuwa phyllite is nearly identical to both the Hinuwan phyllite and the green-gray phyllite interbeds in the Hokse quartzites. It has been mapped as a separate unit because it can be traced continuously for the extent of the study area, with a thickness of about 150 meters. It is possible to consider the Hinuwan phyllite, Khekuwa phyllite, and Hokse quartzites as a single unit of interbedded green-gray phyllites and micaceous quartzites. However, in the interests of detailed mapping, and considering the stratigraphic continuity of the units, they are differentiated.

Upper Hokse Quartzite

The unit, having a thickness of about 270 meters, resembles the Lower Hokse quartzite closely, differing mainly in its more pronounced lineation and paler colour. The Pale colour ranging from pale green to yellowish-white, is probably due to a smaller chlorite content. The strong lineation is again parallel to the dip direction. The unit is fine-to medium-grained.

It weathers to blocks and slabs of a variety of colours. Green-gray phyllities are interbedded throughout the unit, making up about five percent of the whole.

Under a microscope, the Upper Hokse quartzite shows a fine-grained, slightly foliated nature consisting of anhedral equigranular quartz (98%) grains.

Maksuwa Grapitic Phyllite

The name is derived from the village of Maksuwa, at the confluence of the Khekuwa Khola and the Sabhaya Khola.

This unit consists of various phyllites with black graphitic phyllite as the dominant lithology. Graphitic phyllites of a gray or blue-gray colour and chloritic-sericitic phyllites are commonly interbedded. The unit is about 240 meters thick. The black graphitic phyllite is distinguished by its black stain on the fingers, an even, laminated, powdery texture, blocky cleavage, and fine grain. Some outcrops show slaty cleavage or crenulations. It is frequently interbedded with gray phyllites of various types. The contacts are gradational. The gray phyllites may closely resemble the black graphitic phyllite, with the only distinguishing marks being colour and a silver finger stain, rather than black. However, the gray phyllites may also exhibit other differences, such as a wavy, undulatory texture with irregular cleavage, silky luster, or the presence of garnets. Garnets, when present, are generally one millimeter in diameter or smaller. Chloritic-sericitic phyllite of a green-gray colour, similar to the Hinuwan and Khekuwa phyllites, is frequently interbedded with the graphitic phyllite. The contacts between these two lithologies are sharp rather than gradational.

Under a mircoscope, the graphitic phyllites show a fine-grained, foliated matrix of quartz (50%), graphite (40%), phlogopite (8%) and carbonate (2%) crystals.

Kharang Phyllite

The name was adopted from the village of Kharang, on the Chainpur ridge, five kilometers southwest of Chainpur bazar.

The unit consists predominantly of green-gray and silver phyllites with occasional lenses of amphibolite and carbonate rocks. It has a thickness of about 3000 meters. The green-gray chloritic-sericitic phyllite is similar to the Hinuwan and Khekuwa phyllites but shows a slightly higer metamorphic grade. Slaty interbeds are absent, and garnets of one to three milimeters in diameter are common. The green-gray phyllite grades frequently in and out of silver phyllite, both being equally dominant. The silver muscovitic-sericitic phyllite is composed of tiny flakes of mica with abundant quartz. The quartz often forms lenses of about three centimeters in lenghts and fifteen centimeters in diameter, and occasionally continuous quartz veins were noted. The surface of outcrops is wavy or undulatory with a shiny, silky luster. Garnets of one to three millimeters diameter are commonly, but not necessarily, present. Both the silver and the gray-green phyllite weather to a bright red colour, and weathered spcimens are nearly impossible to distinguish.

Under a microscope, the chloritic-sericitic phyllite shows a fine-grained matrix of interlocking quartz (65%) crystals with fibrous agrregates of chlorite (15%) and sericite (10%) and tiny blades of muscovite (5%). Subhedral metacrysts of garnet (3%) and subhedral crystals of tourmaline (2%) are also present.

Minor phyllite interbeds include a gun-metal-gray phyllite that is similar to silver phyllite but darker in colour due to its graphitic content. Whitish-green and gray phyllite are powdery, fine-grained, with blocky cleavage and a flour-like texture.

Amphibolites form discontinous lenses of a few meters to a few tens of meters in extent, and rarely more than a couple of meters in thickness. They are soft, fine-to medium-grained, black, dark gray or dark green rocks, presumably of meta-volcanic origin (Bordet, 1961). They weather into blocks and slabs. Under a microscope, hornblende (82%) is the most abundant mineral. Its prismatic crystals have a sub-radial structure, with pleochroism from colourless to green to blue green. Minor amounts of hornblende have altered to biotite (1%). Other minerals are quartz (15%), Plagioclase (2%) and accessories as apatite and aqaques.

Limestone also occurs as discontinuos layers of several meters thickness. It is typically a fine, crystalline, sugary gray and white laminated rock, with intercalations of coarsely crystalline white marble. Some layers contain conspicuous siliceous matter. Weathered sufaces are occasinally coated with sugary travertine, precipitated from the action of surface waters.

Khandbari Gneiss

The name is adopted from the district administrative center of Khandbari, located on the ridge north of Tumlingtar.

The Khandbari gneiss is of uncertain stratigraphic position. It is not included in the primary map area, and only a brief description is presented here. Stratigraphically, it appears to be thrust over part of the Nawakot complex. It forms a thin wedge begining at the town of Khandbari and thickening to the north. The contact between the Khandbari gneiss and the Hinuwan phyllite dips at about 20° NE. Less distinclty, the Khandbari gneiss also appears to be in contact with the Chainpur group in the northernmost part of the map area. The nature of this contact is uncertain.

The Khandbari gneiss is primarily an augen gneiss, but whether the augen represent uncrushed fragments or prophyroblasts is as yet undetermined. Heim and Gansser (1939) and Mitchell (1979) propose the former, suggesting intrusive granite as the origin of the augen gneiss. Fuchs (1975) and Valdiya & Gupta (1972) prefer the latter, explaining the unit as tectonized gneisses of the High Himalayas. Pecher and LeFort (1977) also discuss the origin and significance of the augen of the Lesser Himalaya.

The Khandbari augen gneiss generally shows a stong lineation and strong foliation, with potassium feldspar augen averaging two centimeters in diameter. The augen may be angular or lenticular in shape, with or without an enclosing shell of mica. Quartz veins five to ten centimeters thick are abundant. Pegmatite and micropegmatite bands of a meter or less in thickness are common. Granite gneiss,banded biotite gneiss, and various schists are commonly interbedded with the augen gneiss.

Kathmandu Complex

The name of this complex is derived from the term "Kathmandu nappes", introduced by Hagen (1969) to describe this complex in the Sabhaya Khola region. All of the known gem-bearing strata in the Sabhaya Khola region are contained in the Kathmandu complex.

The Kathmandu complex consists of two groups of metasediments ranging from epidote-amphibolite facies to almandine-amphibolite facies (kyanite subfacies), each of which rests on banded biotite gneiss. The metasedimentary sequences consist of quartzites, crystalline limestones, high-to low-grade schists and occasional phyllites. The upper, higher-grade Phakuwa group contains the gem-bearing pegmatites. The lower Chainpur group contains the almandine garnet deposits.

The complex is internally divided by two or more thrust faults. The contact between the Phakuwa Group and the Chainpur Group is mapped as a thrust fault. The total thickness of the Kathmandu Complex is about five and a half kilometers. It covers the central portion of the map area, extending to the northern-and southernmost limits.

Chainpur Group

The name is taken from the town of Chainpur, on the ridge between the Piluwa Khola and the Hinuwan Khola.

The Chainpur Group is of economic importance due to the garnet-bearing horizons within its lowermost formation, the Barabise gneiss. A minor thrust repeats the garnet horizon in the central part of the study area.

The Chainpur Group consists of a metasedimentary sequence of epidote-amphibolite facies containing quartzites, marble, schist and some lower-grade phyllite, which rests on a thick unit of banded biotite gneiss. The total thickness of the group is about 2100 meters.

Simbuwa Schist. The name was adopted from the village of simbuwa, which lies in the saddle between the source areas of the Yangduwa Khola and the Khekuwa Khola.

The Simbuwa schist is the lowermost unit in the Kathmandu Complex. It is intermediate in metamorphic grade between the underlying Kharang phyllite and the overlying higer-grade Barabise gneiss. The unit consists primarily of a biotite-muscovite garnetiferous schist with abundant quartz in veins and lenses. It is fine-to medium-grained with a wavy, undulatory texture and shiny surface. Garnets average three to six millimeters in diameter. Superficially it resembles the Kharang phyllites, but the features mentioned above are generally present to distinguish it.

Barabise Gneiss. The name adopted from the village of Barabise, at the confluence of the Sabhaya Khola and the Warang Khola.

The Barabise gneiss is a banded pelitic biotite gneiss with occasional mica schist lenses. In its upermost portion it contains lenses of chlorite schist which form the host rock for almandine garnet deposits of proven economic importance.

The gneiss is generally characterized by even bands four to six millimeters thick of alternating light and dark minerals. Quartz and feldspar form the light bands, while biotite with occasional muscovite or pyroxene form the darker bands. Imperfect garnets of a few millimeters diameter are common In some areas, irregular potassium feldspar porphyroblasts of one centimeter or smaller are spaced throughout the gneiss, averaging 150 per square meter. In thin section, the Barabise gneiss shows a medium-grained, foliated matrix of anhedral quartz (62%), orthoclase (25%) plagioclase (5%), biotite (5%) and muscovite (2%) Discontinuous layers of dark, fine-grained, mica-rich gneiss and a few meters in thickness are occasionally interlayered.

The upper portion of the unit, particularly the areas associated with garnet deposits, often takes the character of a granitic gneiss. The typically banded Barabise gneiss changes gradationally to a more homogeneous, white quartz-dominated gneiss, with the foliation apparent only in a slight elongation of crystals.

Near the village of Wana another variation in the Barabise gneiss occurs. Here a rock formed almost entirely of quartz augen, separated by paper-thin layers of muscovite and biotite, forms cliffs of thirty meters or more in height. The quartz augens measure about six millimeters thick and thirteen millimeters in diameter. Minor amounts of feldspar are present.

Basthala Schist. The name is adopted from the village of Basthala, which lies between the Kuswa Khola and the Sabhaya Khola.

This unit consists of various mica schists, ranging from a nearly pure muscovite silver to schist to a three-mica schist containing chlorite with biotite, muscovite, and phlogopite. The schists are quartz-rich, with abundant quartz augen and veins. They sometimes contain garnets of two to six millimeters diameter. Their surfaces are wavy or undulatory, with irregular cleavage. Muscovite schist is most common, with biotite-muscovite schist of silver and balck colour next in abundance. Frequently chlorite and phlogopite are also present. In thin section, the muscovite silver schist shows a medium-grained, strongly foliated matrix of interlocking anhedral quartz (80%) and muscovite (7%), with fibrous agregates of sericite (13%). Under a microscope, the two-mica schist shows a medium-grained strongly foliated matrix of clear recrystallized interlocking quartz (50%), muscovite (28%) and biotite (12%), garnet (4%) and graphite

(4%).

Occasional amptibolite lenses are interbedded in the Basthala schist. In thin section, they show a medium grained foliated matrix of subhedral hornblende crystals (50%), anhedral orthoclase (30%), quartz (16%) and biotite (3%).

Swanchi Formation. The name is derived from the village of Swanchi, which lies two kilometers southeast of the confluence of the Yaksuwa Khola and the Sabhaya Khola.

The Swanchi formation is primarily micaceous quatzites with gradationally interbedded schists and phyllites. The quartzites are typically white, pale yellow or pale gray in colour although occasional dark-coloured bands are present. Muscovite is generally abundant, often shiny cleavage planes along the foliation. Phlogopite is present in lesser amounts. Depending on the degree of recrystallization, grain size may be medium or coarse. Under a microscope, the quartzite shows a medium-to coarse-grained foliated matrix of largely recrystallized quartz (97%) crystals, muscovite (2%) and phlogopite (1%).

Interbedded throughout the quartzites are schists and phyllites of various types. The schist is commonly a two-mica schist with about twice as much muscovite as biotite, and with or without garnets. A pure muscovite schist and a dense, dark gray quartz-rich schist are also present. Dark gray or black phyllite is commonly interbedded in the northern part of the unit, north from the village of Wana. This phyllite generally forms a single bed of only about a meter in thickness.

South of Wana, phyllites are more varied and abundant, at the expense of schist. Gray-green chloritic-sericitic phyllite and silver muscovite phyllite are most common. They may or may not contain garnets. Dense, slaty gray phyllite with a silver finger stain and flour-like texture, plus a similar phyllite of white colour, are occasionally interbedded. Under a microscope, this flour-like gray phyllite shows a fine-grained strongly foliated matrix of anhedral quartz (48%), bladed muscovite (32%) and biotite (2%), and fibrous sericite (15%).

Near Chainpur, at the southern limit of the map area, the phyllites are again replaced by schist interbeds, and the formation regains its more northerly characteristics.

Samla Limestone. The name is adopted form the Samla Khola, which runs north into the Sabhaya Khola, about two kilometers above the confluence of the Sabhaya Khola and Yaksuwa Khola.

Throughout the major part of the map area, the Samla limestone forms a thin but continuous layer of coarsely crystalline calcium carbonate marble. It does not contain fossils, or it did, they have been obliterated during metamorphism. Occasional intercalations of laminated and fine-grained or magnesian limestone occur. A few notable exceptions to the dominant lithology occur. Near the village of Swachi, a thin layer of sugary calcium carbonate limestone caps the marble. This is a friable rock with a distinctive,sugary texture. This particular lithology has also been a host för leadzinc deposits in other areas of Nepal.

Near the village of chipluwa in the north, an interesting variation in lithology occurs in the Samla limestone. Finely bedded cryptozoan dolomite and black cryptozoan schist are distinguished by odd tabular shapes that stand out in relief on weathered surfaces. These cryptozoans are vitreous, soft, and non-calcareous. They probably are the result of replacement of metacrysts rather than fossils, although the mechanisms of their formation are as yet unknown. The cryptozoans average three to six centimeters in length and one centimeter in diameter. Some outcrops of dolomite show a green colour, due to the presence of diopside. Accretions of phlogopite are common in the dolomite.

Under a microscope, the cryptozoan dolomite shows a martix of equigranular medium-grained hypidiomorphic dolomite (95%) crystals, with small amounts of tremolite (3%) and quartz (1%). Elongate crystals of phlogopite (2%) are aligned in parallel veins.

The cryptozoans in the black schist are identical to those in the dolomite. The schist itself is largely a fine-grained, foliated rock with (50%).

Sawanetar Formation. The name is derived from the village of Sawanetar, which is located southeast of the confluence between the Samla Khola and the Sabhaya Khola.

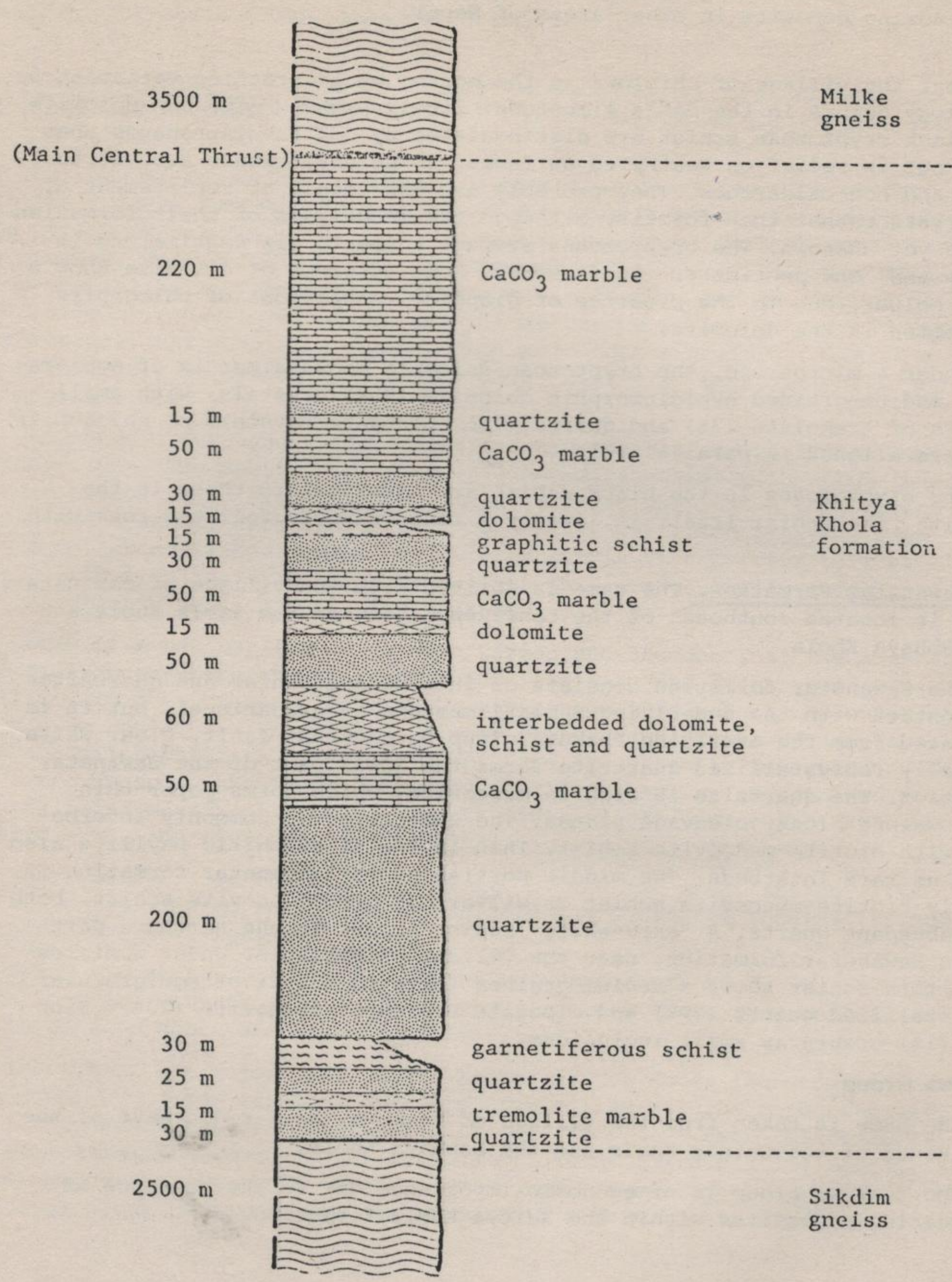
The Sawanetar formation consists of interbedded schist and quartzites. The contact with the underlying Samla limestone is gradational, but it is separated from the overlying Phakuwa group by a thrust fault. Clear white partially recrystallized quartzite forms the lower part of the Sawanetar formation. The quartzite is rich in muscovite, which forms paper-thin layers along blocky cleavage planes. The quartzite is commonly interbedded with biotite-muscovite schist. Thin layers of graphitic phyllite also occur as rare interbeds. The middle portion of the Sawanetar formation is largely biotite-muscovite schist or silver-coloured muscovite schist, both with abundant quartz. A "snow-white" schist occurs in the northern part of the Sawanetar formation, near the village of Mirindin. Under a microscope, this schist shows a medium-grained foliated matrix of equigranular recrystallized quartz (79%) and elongate blades of muscovite (20%). Diopside (1%) occurs as small inclusions.

Phakuwa Group

The name is taken from the village of Phakuwa, on a ridge east of the confluence of the Chinde Khola and the Sabhaya Khola.

The Phakuwa group is of economic importance due to the presence of gem-bearing pegmatites within the Khitya Khola formation.

Figure 3. Stratigraphic Column through the Khitya Khola Formation



The Phakuwa group consists of a metasedimentary sequence of almandine-ampliholite facies, kyanite subfacies, which rests on a thick unit of banded biotite gneiss. The gneiss pinches out rapidly north of the Sabhaya Khola. The metasediments include various limestones, dolmites, quartzites, and schists. The Phakuwa group is separated from the underlying Chainpur group by a thrust and from overlying Milke gneiss by the Main Central Thrust. The apparent thickness of the Phakuwa group is about three and one-half kilometers, south of the Sabhaya Khola.

Sikdim Gneiss. The name is derived from the village of Sikdim, near the confluence of the Dingla Khola and the Sabhaya Khola.

The Sikdim gneiss is a banded biotite gneiss, very similar to the Barabise gneiss. The bands average five millimeters in thickness, and are composed of biotite and other dark minerals alternating with quartz and feldpar. Imperfect garnets of a few millimeters in diameter are abundant. Occasionally interbeds of biotite-muscovite schist or a sugary-textured gneiss are present.

The lower portion of the formation is best developed in the village of Deorali. It is a high-grade fine-grained cliff-forming schist. Quartz (35%), orthoclase (34%) Plagioclase (25%) and biotite (5%) are the major constituents. Remnant subhedral crystals of forsterite (1%) and a opaque mineral in trace amounts are present.

The Sikdim gneiss appears to pinch out to the south, where the imbricate thrust that separates the Phakuwa group from the Kasuwa group merges with the Main Central Thrust. This point could not be determined with any certainty, partly due to the inacessibility of the terrain and partly because of the stong lithological similarities between the Sikdim gneiss and the Milke gneiss.

Khitya Khola Formation. The name is adopted from Khitya Khola, a southeastern tributary of the Chinde Khola.

The Khitya Khola formation (Figure 2.) includes schists, quartzites, and limestones of various types. The quartzities are extremely compact, partly recrystallized, foliated, and schistose with thin schist interbeds. The schist is generally muscovite or biotite-muscovite schist with abundant quartz and small garnets. Black graphitic schist and kyanite schist are also present. Under a microscope, the black graphitic schist shows a non-foliated finegrained matrix of graphite (50%) needles and anhedral quartz (48%) crystals. Elongate crystals of biotite (2%) are pleochroic from colourless to brown.

The limestones are both dolomitic and $CaCO_3$ marble. The dolomite tends to be dark and fine-grained with a sugary texture. Occasionally euhedral calcite metacrysts one to two centimeters across form aggregates in the dolomite. Layers of coarse-grained, foliated tremolite marble about five centimeters in thickness are common in the dolomite, as well as small amounts of phlogopite and spinel. The $CaCO_3$ marble is generally light in colour and coarsely crystalline.

Contact metamorphism near the pegmatite instrusions is common, and gives rise to a wide variety of lithologies. A few of the ones noted are hornblende schist, actinolite-tremolite schist, kyanite gneiss, diopside and pure hedenbergite. The pegmatites are known for their deposit of semi-precious stones.

Milke Gneiss

The name is derived from the milke Danda, a ridge forming the eastern most boundary of the map area. The Milke gneiss is synonymous with the lower portion of Bordet's (1961) gneiss ectinites du Barun, Hagen's (1969) Khumbu nappes, and Maruo's (1979) Himalayan gneiss.

The Milke gneiss is typically an evenly banded, medium-grained biotite gneiss of epidote-amphibolite facies. The bands alternate white, of quartz and feldspar, with black, of biotite. Euhedral and poikilitic garnets are abundant, ranging in size from less than a millimeter to more than a centimeter in diameter. Kyanite is locally common, as euhedral blades, Muscovite is occasionally found associated with biotite. Sillimanite is also locally present. Under a microscope, the Milke gneiss typically shows a medium-grained foliated matrix of interlocking quartz (35%), potassium feldspar (26%) and plagioclase (24%). Biotite (10%) and muscovite (3%) form aggregates of elongate blades, oriented along the foliation.Garnet (2%) occurs as euhedral or poikilitic crystals.

The Milke gneiss is generally consistent in lithology, but a few variations occur. Fine-grained equigranular interbeds with homogeneous texture, but similar in mineral composition to the surounding gneiss, occur occasionally.

Interbeds of hornblende gneiss are also encountered occasionally. In thin section, this rock shows a medium-grained, strongly foliated matrix of elongate blades of hornblende (35%), anhedral quartz (37%) and subhedral crystals of highly fractured colourless pyroxene (24%).

Quartzite is also rarely interbedded. The quartzite is medium-grained and dark-coloured, with blocky cleavage and abundant recrystallized veins. The contact between gneiss and quartzite is completely gradational.

Intrusives are common and distributed in small bodies (a few meters in thickness)throughout the Milke gneiss. They include primarily tourmaline granites and pegmatites. The tourmaline granites are made up of quartz, feldspar, boitite mica or muscovite mica (but usually not both), black tourmaline, and occasional garnets. The pegmatites are a coarser-grained version of the same. The pegmatites of the Milke gneiss do not appear to have any economic importance.

Occasional allogenic boulders of plagioclase-rich rock are also included in the Milke gneiss, but whether they represent xenoliths (in orthogneiss)or shear breccia (in paragneiss) is yet undetermined. Under a microscope, these allogenic boulders show a medium-grained nonfoliated martix of interlocking plagioclase (45%), quartz (27%), orthoclase (10%) subhedral garnet (7%) and clinopyroxene (1%).

The Milke gneiss extends beyond the eastern and northern boundaries of the study area, and presumably is significantly thicker than the three and one-half kilometers apparent within this map area.

STRUCTURE

The structure of the Sabhaya Khola region may be simply described as an ENE-dipping limb that joins an anticline-syncline pair and is internally split by imbricate thrusting.

The extent of metamorphism that preceded thrusting is unknown, but it appears that shear strain during episodes of thrusting resulted in the development of primary foliation in the metamorphic rock, including primary schistosity and gneissosity. These primary foliations lie generally parallel or at a very low angle to bedding planes. Abundantly distributed mica flakes are the most common markers of foliation planes. Primary lineations were also formed during thrusting. These lie generally in the plane of foliation and parallel or sub-parallel to the dip direction. The intrusion of pegmatite swarms and accompanying contact metamorphism may have occurred prior to thrusting.

Following the stages of overthrusting and uplift of the Tibetan plateau, old transverse structures in the Himalayas, such as the Arun anticline, became strongly active again (Hagen 1969). In the Sabhaya Khola region a north-plunging anticline-sycline pair is formed by the Arun anticline and the Jaljale syncline. The Arun anticlinal axis lies at the western boundary of the research area (Bordet, 1961; Hagen, 1969). A large synclinal axis runs the length of the Milke Danda, Gidde Danda, and Jaljale Himal (Yadav, 1970; Bassett, personal communication) and forms the eastern boundary of the research area. Between these the Sabhaya Khola region forms the connecting limb, which dips fairly uniformly about 35° ENE. The development of secondary foliation and lineation accompanied folding. Small-scale folds of a few centimeters or meters in amplitude, as well as the north-plunging syncline in the village of Swachi, are parallel to the principal fold axes.

GEMSTONE DEPOSITS

Almandine Garnet Deposits

Economic deposits of almandine garnets are located within the upper Barabise gneiss of the Chainpur group in the Kathmandu complex. All known deposits (Figure 3.) were observed to occur approximately thrity meters below the Barabise gneiss-Basthala schist contact. It seems reasonable to assume that further deposits will also be located along this line. Most of the existing mines are located on well-exposed cliffs or steep-gradient slopes, where normal weathering processes have exposed the garnet-bearing rock. Other economic deposits undoubtedly exist, but have not yet been

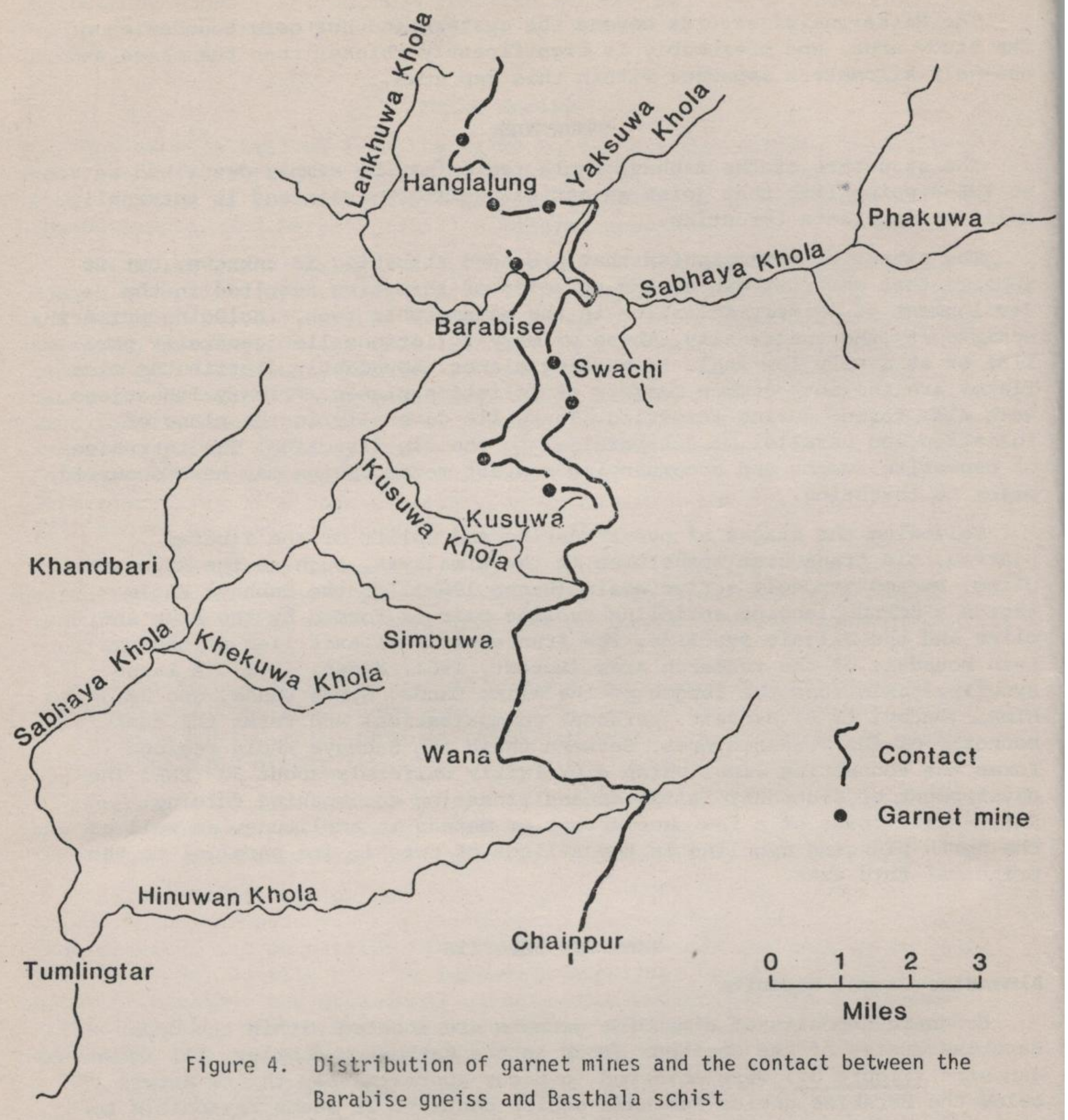


Figure 4. Distribution of garnet mines and the contact between the Barabise gneiss and Basthala schist

found because of their unfavorable location, either on gentler slopes or obscured by vegetation or agriculture. The garnet-bearing horizon appears to extend well to the north of the area covered in this research. Deposits have been reported as far north as the Haunga Khola and Sursing Khola, tributaries of the northern Arun.

The Barabise gneiss contains small lenses of chlorite schist, whcih serve as the host rock for the almandine garnets. The lenses are tubular in shape, lying parallel to the lineation of the Barabise gneiss and generally perpendicular to the strike of the gneissosity. Their dimensions vary from non-economic deposits of a few cubic meters. to the largest and best mine of the area, Bhote Khani near the village of Swachi, which comprises about 780 cubic meters. Good quality almandine garnets occur only in the larger deposits, i.e. those with a volume of twenty cubic meters or more. The garnets are invariably concentrated in the upper parts of the chlorite schist lenses. Thin section study confirms the presence of only three minerals: Chlorite, quartz and garnet.

The lithology of the chlorite schist is strikingly simple. The garnets range from a few millimeters to four centimeters in diameter. Their crystal form is either rhombic dodecahedral or trapezohedral. Good quality garnets are reasonably clear and red or violet in colour.

The exact genesis of the almandine garnet deposits is uncertain. Apparently a series of "pressure shadows" were created along the lineation of the gneiss during thrusting, due to the presence of irregularities in the gneiss. Within these areas of reduced stress, retrograde metamorphism occurred, changing the gneiss to chlorite schist with almandine garnets (Bassett-personal communication).

The obvious objection to the above concept of pressure shadows is that pressure is not a significant variable for retrograde metamorphism. However, a low pressure zone could reasonably accumulate a concentration of fluids, and possibly even have a lower temperature than the surrounding rock. The concentration of fluids would then result in retrograde metamorphism. Assuming that the pressure shadows were created on the low-stress side of irregularities during thrusting, the presence of allogenic block or shear breccia in the chlorite schist would not be unusual. Finally, the orientation of the chlorite schist in long tubular lenses along the lineation of the country rock is strongly suggestive of their formation during thrusting.

Gem-bearing Pegmatites

Gem-bearing pegmatites of proven economic value occur in the Khitya Khola formation of the Phakuwa group in the Kathmandu complex. Detailed investigation of the pegmatites has not been attempted since the main portion of the pegmatite belt lies to the north of the study area. However, certain observations are presented below.

The pegmatites occur as small swarms of discordant dikes within the Khitya Khola formation, directly below the Main Central Thrust. They appear to be located throughout the metasediments of the Khitya Khola formation, directly below the Main Central Thrust. They appear to be located throughout the metasediments of the Khitya Khola formation, i.e., in a belt one and half kilometers wide, beginning just south of the Khitya Khola and extending north beyond the study area.

The mineralogy of the pegmatites consists of intergrowths of quartz, microcline, and albite, with books of biotite, lepidolite, and occasional muscovite mica. Euhedral crystals of tourmaline and beryl are abundant, and some spessartite garnet and grossular garnet are present. The tourmaline includes elbaite, dravite, and schorlite, but only the elbaite is considered economic. The best crystals are, of course, found in cavities at the center of larger pegmatite bodies. Contact metamorphism of the country rock occurs in narrow zones around the pegmatites (see the lithologies described under "Khitya Khola formation"). Xenoliths of country rock are frequently contained in the pegmatites. Shmakin, B. (Personal Comm.) believes that these pegmatites are of the rare-metal-beryl-moscovite type, formed at about five Kilobars of over-pressure, corresponding to depth of four to six kilometers. The source of the pegmatitic materials is probably a eutectic melt from a granite body at depth. Ion-rich solutions that cause the post magmatic reactions would come either from a granite body at depth, or the country rock. Solutions were structurally controlled, moving along existing fault planes.

Bassett (Personal Communication) suggests that frictional heat, produced due to movement of Main Central Thrust Sheet, may have generated magmatic components in the country rock, which combined with metasomatism resulted in the formation of pegmatites. Ion-rich fluids would also be generated by frictional heat along the thrust. Thus the pegmatites would have been injected from above rather than below. According to him most economic pegmatites contain either gem-quality beryl or elbaite tourmaline, but not both. Lepidolite mica is usually associated with elbaite. He also notes the presence of niobia danburite, yttrain apatite and grossular garnet in some pegmatites.

The economic prospects for the gem-bearing pegmatites seem good. Fixing their stratigraphic location within the metasediments of the Khitya Khola formation and just below the Main Central Thrust should allow prospecting to be more systematic than in the past. As with the garnet deposits, present excavations include only those deposits already exposed by natural erosion. Many more pegmatites undoubtedly exist.

Acknowledgements

I am grateful for consistent support from the Department of Geology, Tribhuvan University, Kathmandu, Nepal. In particular, Professor Biswa Man Pradhan offered invaluable help and encouragement.

Dr. Allen Bassett contributed in many ways to the completion of this paper.Dr. Hermann Stigzelius and Dr. Boris Shmakin of the United Nations offered helpful comments concerning the almandine garnet deposits and the pegmatite bodies, respectively.

The Department of Mines and Geology (DMG), Kathmandu, was most helpful in use of laboratories. I am particularly indebted to Mr. J.M. Tatar, Deputy Director General, and Ms. Ramhba Chitrakar. The staff of the Mineral Development Project of UNDP/HMG also provided valuable suggestions and information.

REFERENCES

Anma, S. and Akiba, C., 1976. Geology of the area along the Arun River, Dudh Kosi, East Nepal: Jour. Geol. Soc. Japan, Vol. 73, 369-376 (in Japanese with English abstract.)

Auden, J.B., 1935. Traverses in the Himalaya: Rec. Geol. Surv. India, 69 (2) 123-167.

Bassett, A.M., 1979. Hunting for Gemstones in the Himalayas of Nepal: Lapidary Journal, 33 (7), 1492-1520.

Berkman, D.A., 1976. Field Geologist's Manual: Australian Institute of Mining and Metallurgy, Victoria, 295 pp.

Bordet, P., 1961. Recherches geologigues dans l 'Himalaya du Nepal, Region du Makalu, CNRS, Paris 275 pp.

Fuchs, G., 1975. On the geology of the Karnali and Dolpa region, west Nepal : Mit. Geol. Gesel. 66-67.

Gansser, A., 1964. Geology of the Himalaya, Wiley-Interscience, London, 289 pp.

Gansser, A., 1966. The Indian Ocean and the Himalayas: Eclogai Geologicae Helvetiae, vol. 59. no. 2, Birkhauser Printers, Basel, 20 pp.

Geological Survey of India, 1954. Rules for the Guidance of Officers of the Department, 100 pp.

Hagen, T., Dyrenfurth, G:O: Fürer-Haimendrof, Ch. Von. and Schneider, E., 1964. Mount Everest, Oxford University Press, London, 195 pp.

Hagen, T., 1969. Report on the geological survey of Nepal, vol. 1 (preliminary reconniassance), Denkschr. Schweiz, Naturf. Gesell., bd. 86, hf. 1, Zurich, 185 pp.

Heim, A. and Gansser, A., 1939. Central Himalaya, Geological observations of the Swiss expedition 1936: Mem. soc. Helv. Sci. nat., 73 (1) 1-245

Hooker, J.D., 1855. Himalayan Journals, John Murry, London.

Hashimoto, S., Ohta, Y. and Akiba, C. 1973. Geology of the Nepal Himalayas, Hokkaido University, Sapporo, 286 pp.

Johns, R. H. and wright, L. A., 1951. Gem-and Lithium-Bearing Pegmatites, California Division of Mines, special Report 7-A, San Francisco, 72 pp.

Jahns, R. H., 1955. The study of pegmatites: Economic Geology 1955 (2), 1025-1130.

Jaros, J. and Kalvoda, J., 1976. Geological Results of the Czechoslovak Makalu Expendition: Himalayan Geology, vol. 6, 176-196.

Jhingran, A. G., 1981. Geology of the Himalaya: The Himalaya, edited by J.S. Lall, Oxford University Press, Delhi, pp. 77-98 (481 pp.).

Khan, R. H. and Tatar, J.M., 1969. An outline on the geology and mineral resources of Nepal: Nepal Geological Survey, unpublished report, Kathmandu, 25 pp.

Khan, R. H. and Tater, J.M., 1970. Radiometric dates of some Nepalese rocks: Nepal Geological Survey, unpublished report, 6 pp.

Krummenacher, D. Bassett, A.M. Kingery, F.A. and Layne, H. 1980 Petrology, Metamorphism, and K/Ar Age Determinations in Eastern Nepal: Tectonic Geology of the Himalayas, Editor: P. Saklani, University of Delhi, India.

Loczy, L.V., 1907 Beobachtungen im östlichen Himalaya (vol 8-28. Febr. 1878), Földrajzi Kőzlemenyek, bd. 35, 95-117.

Lombard, A., 1953. Presentation d'un profil geologique du mont Everest a la plaine du Gange (Nepal oriental): Bull. Soc. Belge. Geol. Pal. Hydr., t. 42, 123-128.

Lombard, A. and Bordet, P., 1956 Une coupe gelogique dans la region d' Okhaldhunga (Nepal oriental): Bull. Soc. Geol. France, Ser. 6 to 6, 21-25.

Lombard, A., 1958. Un itineraire gelogique dans la'Est du Nepal (Massif du mont Everest): Mem: Soc. Helv. Naturf., bd. 82, 1-107.

Maruo, Y., Pradhan, B.M. and Kizaki, K, 1979. Geology of Eastern Nepal between Dudh kosi and Arun: Univ. of the Ryukyus, no 28, Okinawa, 36 pp.

Mitchell, A.H.G., 1979. Guides to metal provinces in the central Himalayan collision belt; the value of regional stratigraphic correlations and tectonic analogies: Memoir of the Geol. Soc. of China, 3, 167-194.

Nadgir, B.B., 1973. Report on geological mapping in Sheopuri-Goshainkund area, Nuwakot and Kathmandu Valley districts, Nepal: Geol. Surv. India, unpublished report, 49 pp.

Nath, M., 1956. Mineral Resources of Nepal: Geol. Surv. India, unpublished report, 15 pp.

Nepal Bureau of Mines, Mineral Resources development and her Problems, unpublished report, undated, 13 pp.

Newer Metal Mission 1970. Abstract from Report on New Metal Research in Nepal and Africa, unpublished report, 6 pp.

Pecher, A. and LeFort, P., 1977. Origin and significance of the Lesser Himalaya augen gneisses: Himalaya, Sciences de la Terre, CNRS, 268, 319-329.

Pradhan, B.M., 1975. Mineral Potential of Nepal: Tribhuvan University, unpublished report, 16 pp.

Sharma, C.K., 1966. Geology of South-Eastern Nepal: Nepal Burea of Mines, unpublished report, 20 pp.

Shrestha, P.L., 1969. Present Mineral situation in Nepal and the Need for a Comprehensive approach to Future Mineral Resource Exploration Assessment and Development Program in the Country: Nepal Burea of Mines, unpublished report, 34 pp.

Sinkankas, J., 1970. Prospecting for Gemstones and Minerals, Van Nostrand Reinhold Co., New York, 397 pp.

Smirnov, V.I., 1976. Geology of Mineral Deposits, MIR Publishers, Moscow, 520 pp.

Stocklin, J. and Bhattarai, K., 1977. Gelogy of Kathmandu Area and Mahabharat Range, Nepal Himalaya: HMG/UNDP Mineral Exploration Project, Kathmandu, unplublished technical report PG/11/77, 86 pp.

Talalov, B.A., 1973. Geology and Ores of Nepal, unpublished UNDP report, Kathmandu, vol. 1-4.

Turner, F.J. and Verhoogen, J., 1960. Igneous and Metamorphic petrology, McGraw-Hill Book Co., New York, 694 pp.

Valdiya, K.S. and Gupta, V.J., 1972. A contribution to the geology of northeastern Kumaon, with special reference to the Hercynian gap in Tethys Himalaya: Him. Geol. 2, 1-33.

Wager, L.R., 1934. A review of the geology and some new observations: H. Rutledge, Everest 1933, Hodder and Stoughton, London, pp. 321-337.

Wager, L.R., 1937. The Arun River drainage pattern and the rise of the Himalaya: Geogr. Jour., 89, 239-250.

Yadav, R.N., 1970. Geology of a Portion of Sankhuwa Sabha and Taplejung Districts (Eastern Nepal): Nepal Geol. Surv., unpublished report, 30 pp.