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Mode of Occurrence of Nepheline Syenites in the Gorkha-Ampipal Area, Central Nepal Lesser Himalaya

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ABSTRACT

In the Gorkha-Ampipal area, low-grade metamorphic rocks of the Kuncha Formation are delimited in the north by the Masel Thrust. The Kuncha Formation is characterised by doubly-plunging, en-echelon types of noncylindrical folds which are 2 to 20 km long (essentially in NW-SE direction), and have wavelengths of a few km. Mineral and stretching lineations are gently plunging due NNE or SSW. The hangingwall of the Masel Thrust is represented by garnet-biotite schists and gneisses. The schists and gneisses make up a steeply northward dipping homocline. In contrast to the rocks of the footwall, they are generally gently dipping and constitute several mesoscopic folds. Further north, the homocline is discordantly overlain by the intensely deformed unit of phyllites, graphitic schists, marbles, crystalline limestones, and calcareous quartzites. The Main Central Thrust sharply overrides the latter unit and brings with it gently northward dipping kyanite-garnet-biotite schists, quartzites, feldspathic schists, and mylonitic gneisses.

There are several nepheline syenite intrusive bodies in the Kuncha Formation in the vicinity of the villages Harmi Bhanjyang, Ampipal, Chanp Bhanjyang, Bhulbhule Khar, and Luintel Bhanjyang. Two separate bodies are also encountered at the confluence of the Masel Khola and the Daraundi Khola. The nepheline syenite bodies observed in the study area vary widely in their shape, size, and orientation. The largest pluton is observed in the vicinity of the villages Ampipal and Chanp Bhanjyang. It is about 7.5 km long in NNE-SSW direction and about 2 km wide. The second largest body is observed between the villages Bandre and Luintel Bhanjyang. It is about 2.5 km long approximately in east-west direction and 300 m wide. Numerous other smaller bodies ranging in size from hundreds of m to a few cm also occur in the region. The nepheline syenites show sharp and irregular contacts with the country rock, they are crosscut by numerous dykes, and occasionally the effect of contact metamorphism is also observed in the country rock.

The northeastern part of the largest nepheline syenite pluton (which occurs between Ampipal and Chanp Bhanjyang) is covered by about 500 m thick band of impure marbles. Rare, thin alternations of impure marble with phyllite as well as large (more than 10 m in diameter) scattered marble boulders are seen on the slopes NE of Chanp Bhanjyang, N of Bhulbhule Khar, at the saddle of Lagamkot, and at Khanigaun. The secondary mineralisation in the marbles is represented by magnetite, actinolite, biotite, and chlorite. There exist a few old iron mine workings in the magnetite mineralisation zones. Similar minerals are also seen in the nepheline syenite suggesting a direct relationship between the mineralisation in the nepheline syenite and the marbles. Generally, the nepheline syenite bodies exhibit the same trends of foliation and lineation as those of the country rock, and therefore, they must be intruded before the development of the secondary structures.

There are a few hot springs at Bhulbhule Khar, which contain a high amount of H_2S gas and sulphur, and are coming through the nepheline syenite. The development of copper as well as other secondary ore minerals and several generations of veins in the country rock, and the presence of hot springs probably indicate a continued hydrothermal activity in that area up to the recent times.

INTRODUCTION

Nepheline syenites are quite unique rocks in the Nepal Lesser Himalaya. Being rather rare rocks in the Himalayan Region as a whole, they have attracted several researchers who have proposed various models and hypotheses on the origin of the alkaline rocks in the context of plate tectonics.

The presence of alkaline gneisses in the Ampipal area was reported by A. Pêcher and P. Le Fort (Lasserre et al. 1975 and Pêcher 1977). They put them at the base of the early Palaeozoic to Precambrian Kuncha Formation (Stöcklin 1980). Lasserre (1977) studied the petrological characteristics of the rocks and compared them with the similar rocks of the Deccan Traps. According to him, the igneous rocks of the Ampipal area belong to nepheline syenites and are crosscut by basic and ultrabasic alkaline rock dykes (melteigite, jacupirangite). He inferred the Lower Oligocene age for the emplacement of the alkaline rocks and proposed an island arc environment for their origin. On the geological map prepared by Colchen et al. (1980), two nepheline syenite bodies are shown to crop out from tectonic windows. On the other hand, on the geological map prepared by the Department of Mines and Geology (DMG 1987), a large intrusive body is shown to crosscut a thrust fault in the north. Koide et al. (1992) classified the alkaline rocks into nepheline syenite, olivine clinopyroxenite, shonkinite, and malignite. They stated that the plutonic rocks of the Ampipal area are in tectonic contact with the surrounding Kuncha Formation. Gautam and Koshimizu (1991) carried out fission track dating and obtained the exhumation rates of 2.00-2.22 mm/year and the corresponding cooling rates of 80 degrees/Ma for the period between 2.81 Ma and the present. Adhikari (1993) did the preliminary palaeomagnetic study of the ultrabasic and basic dykes and concluded that their most probable age of primary magnetic remanence acquisition was 54-49 Ma (Early-Middle Eocene).

One of the prime factors leading to above discrepancy and contradictory conclusions on the age, origin, and distribution of nepheline syenites seems to be the lack of detailed field observations. The present study, therefore, focuses basically on the detailed geological mapping and structural analysis. A considerable portion of the region was mapped to reveal the lithostratigraphy and structure of the area as well as the distribution pattern and mode of occurrence of the nepheline syenites.

LITHOLOGY

The low-grade metamorphic rocks in the Gorkha-Ampipal area, Central Nepal Lesser Himalaya, constitute a rather monotonous and thick succession, which was called *série de Kunchha* by Bordet (1961). The study area lies in the Kunchha-Gurkha anticlinorium zone of Ohta et al. (1973) or Kunchha-Gorkha anticlinorium of Pêcher (1977). The rocks belong to the Midland Metasediment Group of Arita et al. (1973). Stocklin (1980) classified the rocks of Central Nepal into the Nawakot and Kathmandu Complexes, and a large portion of the present area belongs to his Kuncha Formation, which is the lowest unit of the Nawakot Complex (Fig. 1).

Geological mapping in 1:50,000 scale was carried out in the Central Nepal Lesser Himalaya, between Anbu Khaireni (south), Barpak and Bhachek (north), the Chepe Khola (west), and Khanchok (east). The main lithological units in the study area are the following from south to north, respectively (Fig. 1):

1. Kuncha Formation (phyllite and quartzite),
2. Garnetiferous schist with augen and banded gneisses,
3. Graphitic schist and marble, and
4. Kyanite schist and gneiss.

KUNCHA FORMATION

The rocks of the Kuncha Formation are extensively distributed in the area between Anbu Khaireni, Mankamana, Gorkha, and Ampipal. They are delimited in the north by the Masel Thrust which brings the garnetiferous schist over the Kuncha Formation. When weathered, the Kuncha Formation yields orange, red, and yellow-brown coloured soil.

The Kuncha Formation is a thick (more than 4 km) succession of green-grey, dark grey, and bluish grey phyllite, phyllitic meta-sandstone, granular phyllite, and quartzite. Sometimes, tiny muscovite flakes (0.5-1 mm) are observed along the foliation plane in phyllite and meta-sandstone. Rarely, pebbly phyllite with stretched clasts are present. Occasionally, a few amphibolite bands are also found in it (eg south of Mankamana). A band of white quartzite (20 m thick) was observed to the north of Mankamana. A typical succession of the Kuncha Formation is shown in Fig. 2.

In the study area, the topmost part of the Kuncha Formation is represented by light green to white calcareous quartzite, siliceous crystalline limestone, and marble. Probably, it is equivalent to the Banspani Member of the Kuncha Formation (cf Stöcklin et al. 1980). About 500 m thick band of impure marble and siliceous crystalline limestone is seen to the north of Harmi Bhanjyang. It is just on top of the nepheline syenite. Rare, thin alternation of impure marble with green phyllite as well as large (more than 10 m) boulders of crystalline limestone and marble are seen

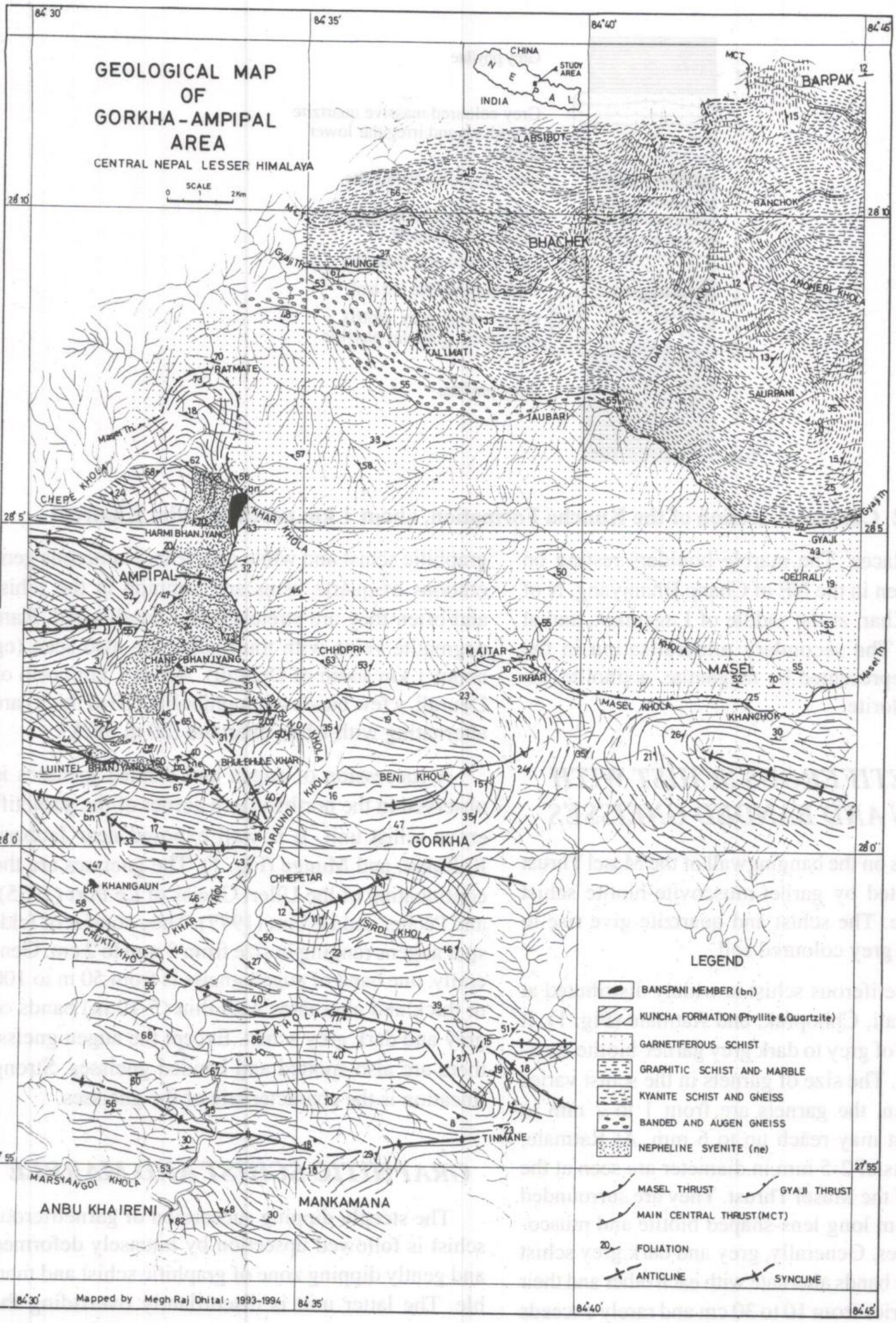

Fig. 1 Geological map of the Gorkha-Ampipal area, Central Nepal Lesser Himalaya

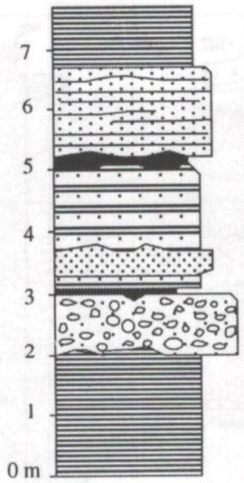

Fig. 2 Columnar section of the Kuncha Formation, about 1 km north of Anbu Khaireni

in several places. The marble boulders resting on slopes are seen in the NE of Chanp Bhanjyang, N of Bhulbhule Khar, at the saddle of Lagamkot, and at Khanigaon. The secondary mineralisation in the marbles is represented by magnetite, actinolite, biotite, and chlorite.

GARNETIFEROUS SCHIST WITH AUGEN AND BANDED GNEISSES

The rocks on the hangingwall of the Masel Thrust are represented by garnet-muscovite-biotite schist and quartzite. The schist and quartzite give rise to light grey to grey coloured soil.

The garnetiferous schist is widely distributed at Masel, Deurali, Chhoprak, and Ratmate (Fig. 1). It is composed of grey to dark grey garnet-biotite-muscovite schist. The size of garnets in the schist varies widely. Often, the garnets are from 1 to 2 mm in diameter, but may reach up to 6 mm. At Ratmate, rolled garnets of 2-5 mm in diameter are seen at the proximity of the Masel Thrust. They are surrounded by about 1 cm long lens-shaped biotite and muscovite envelopes. Generally, grey and dark grey schist and quartzite bands alternate with each other and their thickness varies from 10 to 30 cm and rarely exceeds 5 m. There are also a few bands (1-2 m thick) of graphitic schist and white quartzite. Numerous generations of quartz veins are common in the schist and often they are stretched and boudinaged. Rare pegmatite veins with tourmaline are also seen (eg about 1 km south of Deurali). About 1 km north of Deurali, a few bands of amphibolite (10 m thick) are alternating with white quartzite (20 m thick).

A succession of augen and banded gneisses is observed in the northwestern corner of the garnetiferous schist unit. It is well exposed near Jaubari, Kalimati, and Munge (Fig. 1). The gneisses are the continuation of the Ulleri Gneiss of Le Fort (1975), and Pêcher and Le Fort (1977). They consist of feldspar augens ranging in size from 2 mm to 2 cm. Generally, one band of augen gneiss is from 50 m to 100 m thick and alternates with thin (5-10 m) bands of grey and dark grey schist. Except the augen gneiss, there are also spotted and banded gneisses. Strong lineation is the characteristic of the gneisses.

GRAPHITIC SCHIST AND MARBLE

The steeply dipping succession of garnetiferous schist is followed upsection by intensely deformed and gently dipping zone of graphitic schist and marble. The latter unit is discordantly overriding the garnetiferous schist unit along the Gyaji Thrust (Fig.

1). When weathered, the graphitic schist and marble give rise to orange, red, brown, and grey soil. Steep cliffs of marble are seen along the river banks.

In the graphitic schist and marble unit, grey, green-grey, light grey, and white calcareous schist is alternating with light grey, green-grey, and white calcareous quartzite, dolomitic marble, and dark grey to black graphitic schist. Quartz and calcite veins of several generations ramify the rocks. At Gyaji, the calcareous quartzite and dolomite bands are from 10 cm to 1.5 m thick and are alternating with 1 mm to 50 cm thick schist bands. Light grey, white, and cream coloured quartzite bands are up to 5 m thick and often ripple marks are observed on top of them. Generally, schist and marble bands are thinly (1-5 mm) alternating. There are also a few bands of dark grey to black graphitic schist and garnetiferous (size of the garnets: 2-5 mm) biotite schist. Around Ranchok, below Barpak, and at the confluence of the Andheri Khola with the Daraundi Khola, a prominent band of Marble is observed which continues for several km and is like a marker bed useful in observing the large-scale open folds.

The grade of metamorphism in this unit varies widely. To the west (at the Chepe Khola), dark grey slate, phyllite, and garnetiferous schist are observed alternating with crystalline dolomite, marble, and calcareous quartzite, whereas in the east (in the upper reaches of the Andheri Khola, at Ranchok, and Barpak), large (5-7 cm long) kyanite crystals are encountered together with quartz in dark grey graphitic schist. In the Andheri Khola, and on the climb of Barpak from the Daraundi Khola, purple, pink, grey-green, light grey, and cream coloured quartzite, calcareous schist, actinolite schist, spotted (K feldspar) schist, and green-grey garnetiferous schist are observed.

KYANITE SCHIST AND GNEISS

The Main Central Thrust (MCT) abruptly overrides the marble and graphitic schist unit (Fig. 1) and brings with it grey and dark grey, parallel-banded, coarse-grained, schist, banded gneiss, augen gneiss, and mylonitic gneiss containing kyanite, garnet, biotite, K-feldspar, muscovite, and quartz. There are also a few bands of quartzite. Generally, the rock is massive to blocky. Kyanite crystalloblasts range in size from less than 1 mm to 2-5 cm. There are also about 1.5 m thick pegmatite veins containing large (1-2 cm) muscovite, biotite, kyanite, and K-feldspar crystalloblasts. Within the augen and banded gneiss, several zones (20 m) richer in grey kyanite schist are also present.

STRUCTURAL FEATURES

Each of the above units is characterised by its own type of deformation style quite distinct from the adjacent units. The style is expressed in terms of folding, foliation, lineation, boudinage, and other secondary structures. The difference in deformation style in each unit is clearly discernable in megascopic as well as mesoscopic and microscopic scales.

Well developed lineation is one of the distinctive features of the rocks in the study area. The lineation is represented by tiny undulations on foliation or joint surfaces or by the parallel arrangement of minerals. The statistical analysis of the stretching and mineral lineations from the Kuncha Formation (Fig. 3a) shows that they are trending due NNE or SSW (Peak trend = N18°E) and gently plunging in either direction concordantly to folding. The observation is consistent with the regional studies made by Ohta et al. (1973) and also with the lineations measured from the anisotropy of magnetic remanence in the Ampipal massif by Gautam (1990).

In the Gorkha-Ampipal area, the rocks of the Kuncha Formation constitute doubly-plunging to dome- and basin-like, en-echelon types of noncylindrical folds. They are from 2 to 20 km long (essentially in the northwest-southeast direction) and their wavelength reaches up to a few km. The axial traces of the folds are truncated in the north by the Masel Thrust.

On the other hand, the rocks belonging to the hangingwall of the Masel Thrust (to the north of the fault) make up a steeply dipping homocline, in contrast to the footwall rocks (to the south of the fault) which are gently dipping and constitute several noncylindrical folds. A comparison of the foliation pole maxima from the Kuncha Forma-

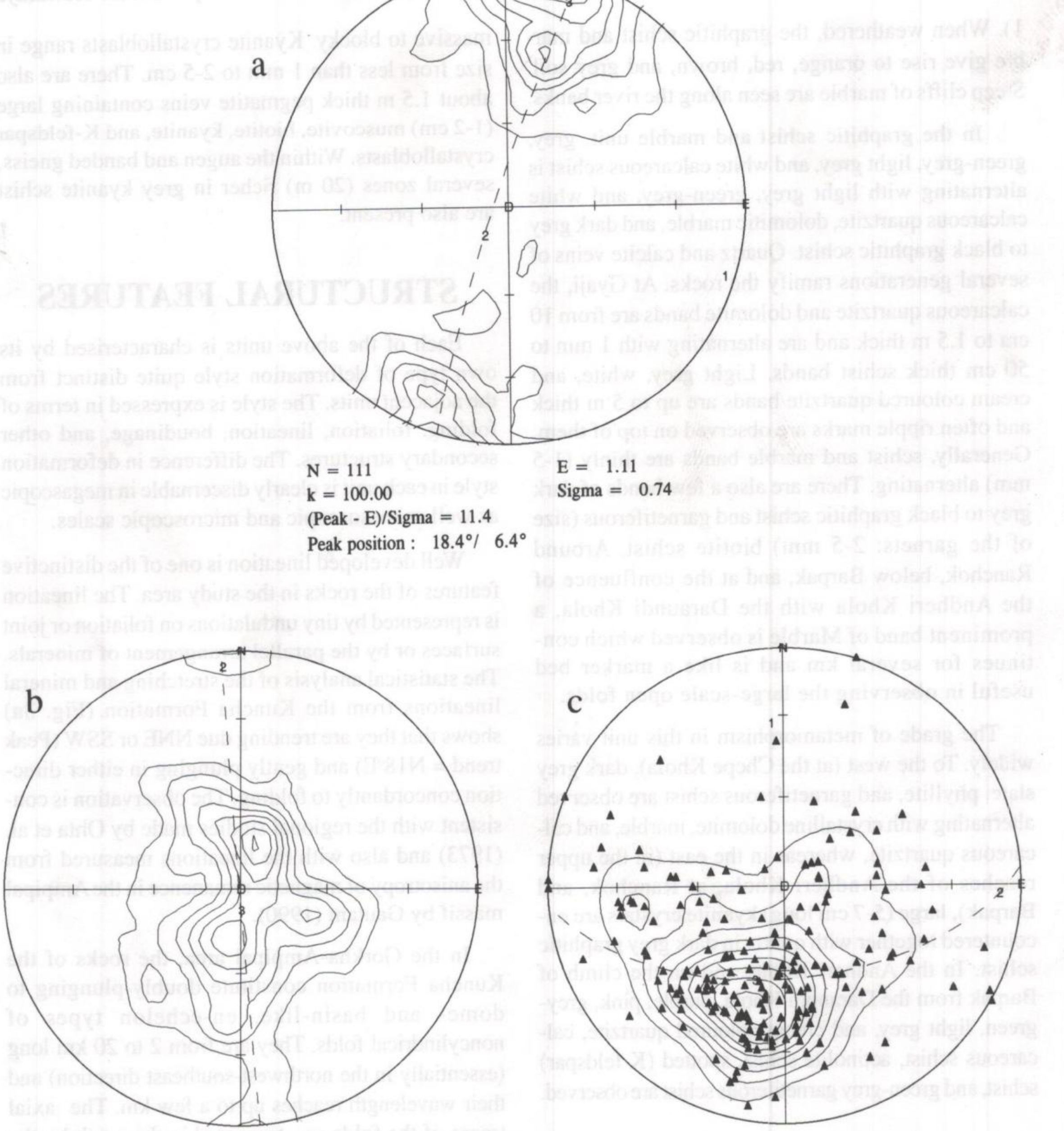

Fig. 3 Stereographic projections of lineations and foliations. a: Lineations from the Kuncha Formation; b: Foliations from the Kuncha Formation; c: Foliations from the garnetiferous schist and quartzite unit. Notice the large angular difference between the pole maxima from the Kuncha Formation and the garnetiferous schist unit. Schmidt lower hemispherical projection

tion (Fig. 3b) and the garnetiferous schist (Fig. 3c) clearly reveals the discordant relationship between the two units.

The Masel Thrust is marked by several active landslides often aligned along the fault zone or very close to it. To the north of the fault, light grey to brown soil is developed whereas to the south of it, red, light yellow to orange coloured soil prevails. These criteria are useful in locating the thrust in the field.

Further north, the garnetiferous schist unit is delimited by the Gyaji Thrust. Like the Masel Thrust, numerous active and old landslides are seen along the trace of the Gyaji Thrust. At Gyaji, copper mineralisation and old copper mine workings are seen at the proximity of the fault zone where a large (more than 1 km wide) landslide is active. The mineralisation is represented basically by quartz, calcite, chlorite, chalcopyrite, and pyrite.

The Gyaji Thrust brings with it the grey and dark grey graphitic schists, phyllites, and marbles. There are numerous small-scale disharmonic, convolute, and ptigmatic folds in the laminated calcareous quartzite and schist. Often, the marble bands exhibit more-or-less parallel and policlinal folds (Fig. 4)

The Main Central Thrust sharply overrides the graphitic schist and marble unit, and its hangingwall is represented by gently dipping kyanite schists, mylonitic gneisses, and quartzites. In the west, it covers most of the graphitic schist and marble, and a narrow band is left out in the Chepe Khola (Fig. 1). The folds in the gneisses are often completely disrupted and may be classified into intrafolial, ptigmatic, and strongly boudinaged types.

NEPHELINE SYENITE BODIES

Lasserre et al. (1975) and Pêcher (1977) reported three locations of alkaline gneisses. The largest of them was in the Ampipal area and the other two were near the confluence of the Daraundi Khola and the Masel Khola. Present study shows that there are also several other intrusive bodies in the Kuncha Formation.

The nepheline syenite intrusives are located in the vicinity of the villages Harmi Bhanjyang, Ampipal, Chanp Bhanjyang, Bhulbhule Khar, and Luintel Bhanjyang (Fig. 1 and 5). Two separate pegmatite-like bodies are also encountered in the north of Sikhar and at the confluence of the Masel Khola with the Daraundi Khola (Fig. 6).

The nepheline syenite bodies observed in the study area vary widely in their shape, size, and orientation. The largest pluton is observed in the vicinity of the villages Labsichaur, Chanp Bhanjyang, Ampipal, Harmi Bhanjyang, and the upper reaches

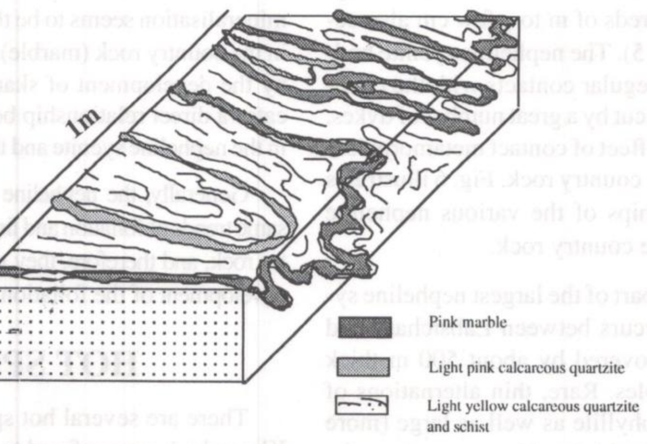

Fig. 4 Isoclinal to policlinal, disharmonic, convolute, and ptigmatic folds in the laminated calcareous quartzite and schist. On the trail from the Daraundi Khola to Barpak

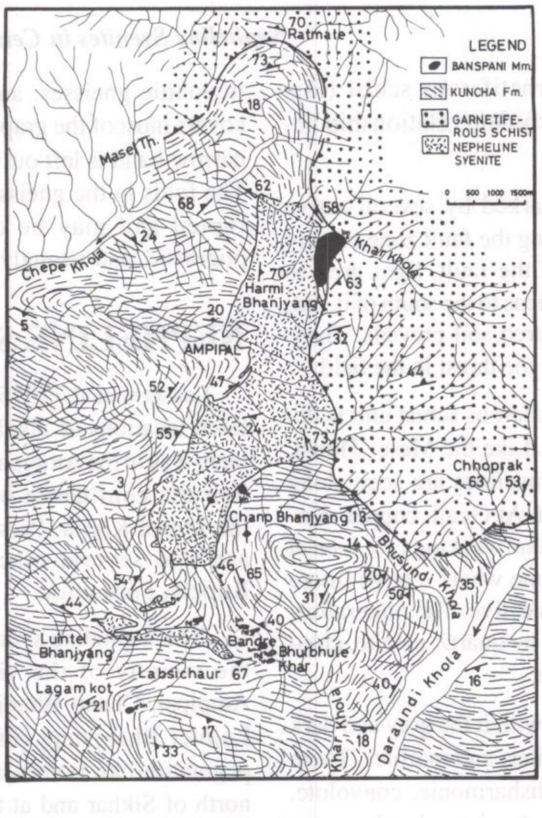

Fig. 5 Map showing the distribution of nepheline syenite bodies and the calcareous quartzite and marble in the Ampipal area.

of the Khar Khola (Fig. 1 and 5). It is about 7.5 km long in NNE-SSW direction and about 2 km wide. The second largest pluton, which occurs between the villages Bandre and Luintel Bhanjyang, is about 2.5 km long approximately in east-west direction and 300 m wide. Numerous other smaller bodies ranging in size from hundreds of m to a few cm also occur in the region (Fig. 5). The nepheline syenite bodies have sharp and irregular contacts with the country rock, they are crosscut by a great number of dykes, and occasionally the effect of contact metamorphism is also observed in the country rock. Fig. 6 illustrates the contact relationships of the various nepheline syenite bodies and the country rock.

The northeastern part of the largest nepheline syenite body (which occurs between Labsichaur and the Khar Khola) is covered by about 500 m thick band of impure marbles. Rare, thin alternations of impure marble with phyllite as well as large (more than 10 m) scattered marble boulders are seen on the slopes in the NE of Chanp Bhanjyang, N of Bhulbhule Khar, at the saddle of Lagamkot, and at Khanigaun. The secondary mineralisation in the marbles is represented by magnetite, actinolite, biotite, and chlorite. There exist a few old iron mine workings in the magnetite mineralisation zones. Similar minerals are also seen in the nepheline syenite. The mineralisation seems to be the result of metasomatism in the country rock (marble) and the nepheline syenite by the development of skarns (Fig. 7). It also indicates a direct relationship between the mineralisation in the nepheline syenite and the marbles on top of them.

Generally, the nepheline syenite bodies exhibit the same trends of foliation and lineation as those of the country rock, and therefore, they must be intruded before the development of the foliation and lineation.

HOT SPRINGS

There are several hot springs around Bhulbhule Khar which are confined to two separate places (Fig. 8). The hot springs are seen coming through the

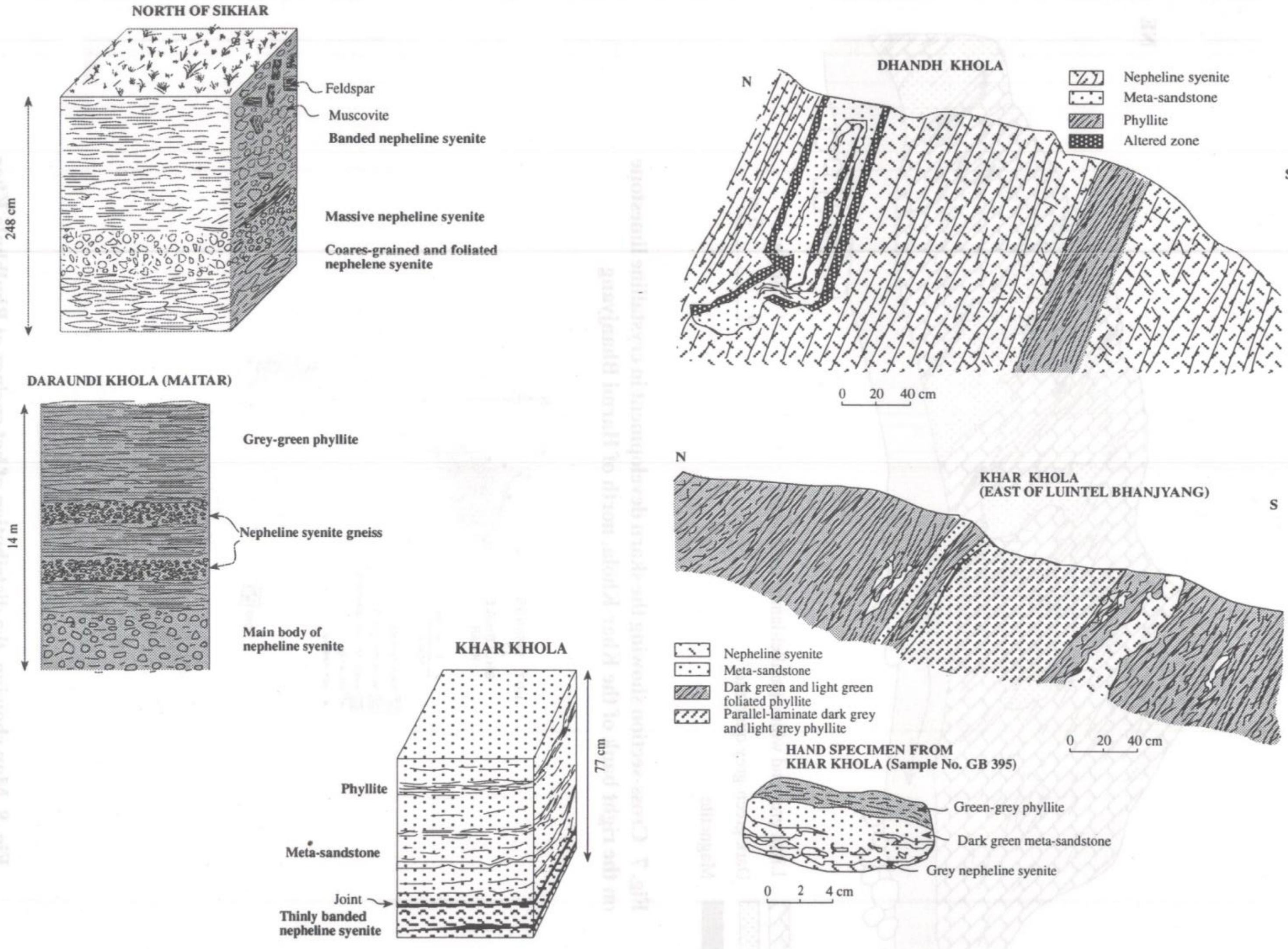

Fig. 6 Diagrams showing various relationships of nepheline syenite bodies in the Gorkha-Ampipal area

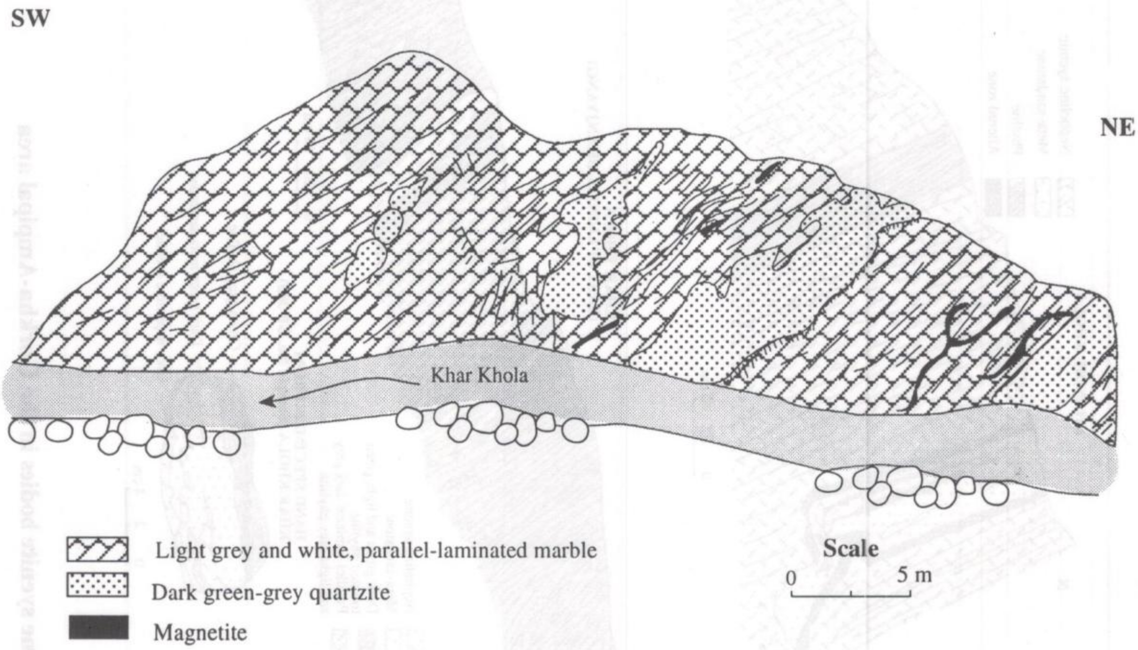

Fig. 7 Cross-section showing the skarn development in crystalline limestone on the right bank of the Khar Khola, north of Harmi Bhanjyang

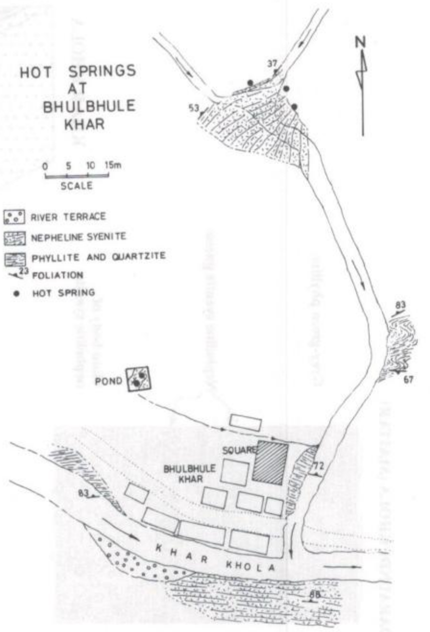

Fig. 8 Map showing the distribution of hot springs at Bhulbhule Khar

strongly altered nepheline syenite. A few isolated outcrops of grey-green phyllite and nepheline syenite are also seen around the hot springs but most of the area is covered by cultivated land. The hot springs are alkaline and contain a high amount of H_2S gas and sulphur.

CONCLUSIONS AND DISCUSSION

The rocks of the study area are divided into the following four units (from south to north, respectively): 1. Kuncha Formation (phyllite and quartzite); 2. garnetiferous schist with augen and banded gneisses; 3. graphitic schist and marble; and 4. kyanite schist and gneiss. The structural features of the four units are quite differrent from each other and every unit is characterised by its own type of deformation style which is clearly discernable in megascopic as well as mesoscopic and microscopic scales.

In the Gorkha-Ampipal area, low-grade metamorphic rocks of the Kuncha Formation constitute doubly plunging folds with dome- and basin-like structures, and are delimited in the north by the Masel Thrust which brings with it garnet-biotite schists. The rocks of the hangingwall (to the north of the fault) constitute a steeply dipping homocline which also are further discordantly overlain by grey and dark grey graphitic schists and marbles along the Gyaji Thrust. The Main Central Thrust sharply overrides the latter unit and brings with it gently dipping kyanite schists and gneiss.

The presence or absence of the Kunchha-Gorkha Anticlinorium (Ohta et al. 1973 and Pêcher 1977) in the study area depends on the structural interpretation of the rocks on either side of the Masel Thrust. Owing to sharp lithological differences and structural discordance between the rocks constituting the hangingwall and footwall of the Masel Thrust, it is difficult to reconstruct the anticlinorium. On the other hand, the MCT separates the rocks with sharp compositional and structural differences and is easily traceable. In the study area, the grade of metamorphism apparently increases form south to north, but may vary widely within the same unit (eg, the graphitic schist and marble unit contains slate and phyllite in the west and kyanite schist in the east).

The nepheline syenite bodies are intruded in the Kuncha Formation. They show sharp and irregular contacts with the country rock, are crosscut by many dykes, and occasionally the effect of contact metamorphism is also observed in the country rock. The nepheline syenites exhibit the same trends of foliation and lineation as those of the country rock, and therefore, they must have been intruded before the development of foliation and lineation in the Kuncha Formation.

The occurrence of banded and augen gneisses, pegmatites, amphibolites, and nepheline syenites with crosscutting dykes probably points out to a prolonged magmatic activity in the past, whereas the development of copper and other secondary ore mineralisation zones, several generations of quartz and calcite veins, and the presence of hot springs indicate a continued post magmatic hydrothermal activity in that area up to the recent times. Similarly, the influence of calcareous country rock in the formation of nepheline syenites is also not ruled out.

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