# Geology of Sikkim State and Darjeeling District of West Bengal

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# Introduction

## Prologue

The Himalayan range along its strike elongation is usually divided into Western Himalaya (Kashmir, Himachal Pradesh), Central Himalaya (Uttarakhand, Nepal) and Eastern Himalaya (Sikkim–Darjeeling, Bhutan, Arunachal Pradesh). There are variations in the stratigraphy and structure among subdivisions such as Sub-, Lesser-, Greater/ Higher- and Tethyan Himalaya as one traverses from south to north across the Himalaya. But there is considerable similarity of the same in different subdivisions along its strike elongation. A geological map showing the arcuate stretch of the Himalaya with position of Sikkim and Darjeeling is shown in Fig.1.

Sikkim, is a small (7,096 sq.km) state of the Indian union in the Eastern Himalaya. The geological set-up and stratigraphic positions of the rock units of the Sikkim Himalaya are the topics of academic debate, evaluation and reevaluation, because of tectonic complexity, polyphase metamorphism and unfossiliferous nature of most of the lithounits. The geological formations from south to north of the state are disposed in reverse tectonic order. The Lesser Himalaya (Peninsular Himalaya of Auden, 1935) is covering most of the outer Himalaya of Sikkim. Tethyan Himalaya, incorporating Phanerozoic formations, covers northern most parts of Sikkim. Darjeeling Himalaya is an integral geological part of Sikkim Himalaya. The major geological and physiographical aspects of Darjeeling District of the state of West Bengal and of the state of Sikkim are inextricable with many unavoidable repetitions, cross references and therefore, to provide clarity, geological homogeneity and continuity, the geology of these two sectors of Himalaya are presented together in this text book. There is a composite geological map of the Sikkim-Darjeeling Himalaya (Plate-I).

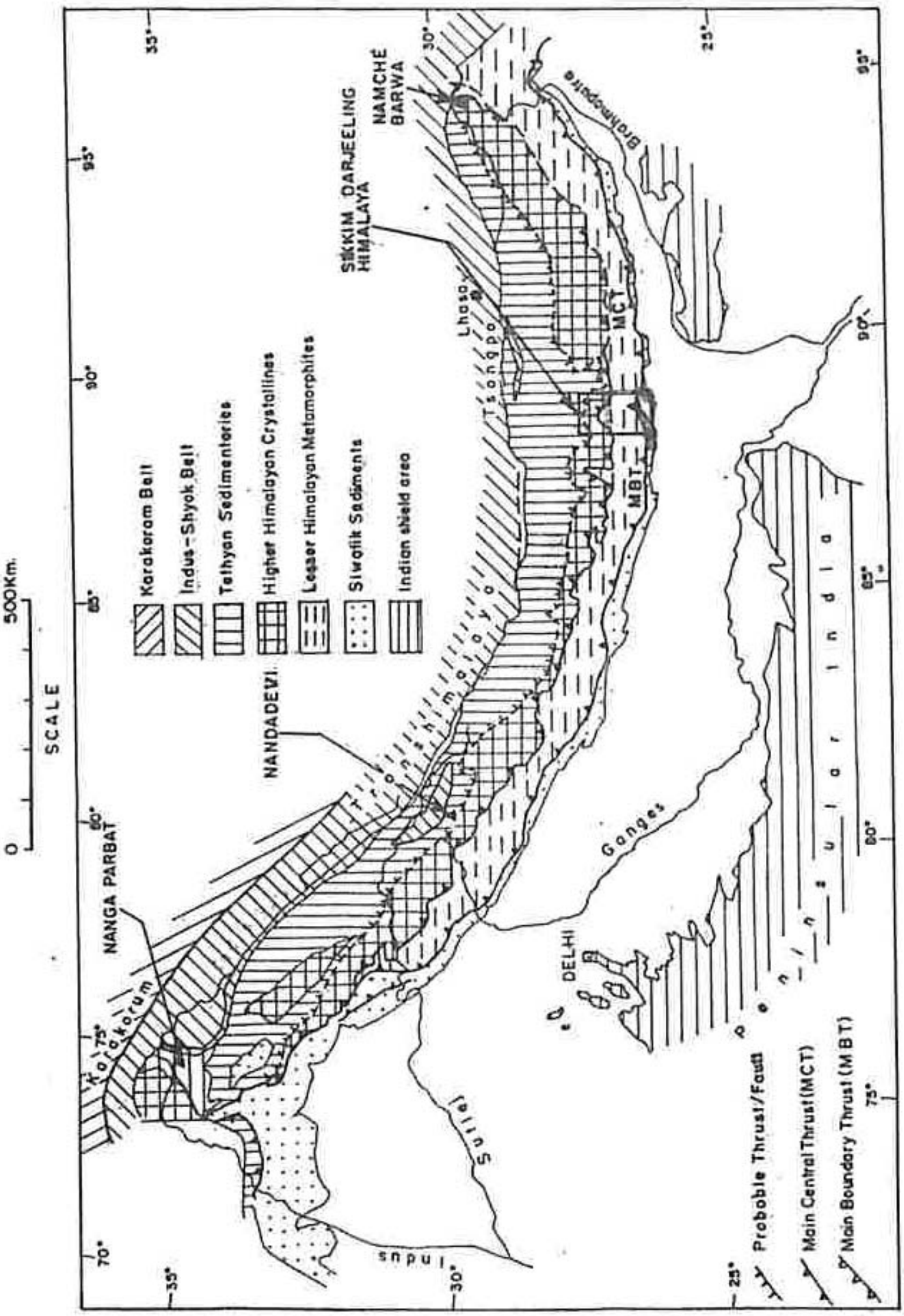


**Fig.1.** Geological Map of Himalaya showing position of Sikkim–Darjeeling major lithological and tectonic belt (Modified after Gensser, 1964)

Sikkim–Darjeeling Himalaya is mostly covered by Precambrian metapelites of low to medium grade and Baxa carbonate-quartzite association (Daling Group), high grade gneisses (Darjeeling Group) with deformed granite gneiss (Lingtse Granite Gneiss). The Palaeozoic-Mesozoic rocks include Gondwana-equivalent Rishi Group (Namchi Formation, Rangit Pebble-Slate) and Tethyan rocks (Everest Pelites, Everest Limestone, Lachi and Chho Lahmo Formations). Each of these stacks ranging in age mostly from Proterozoic to Mesozoic has distinct tectono-sedimentary, magmatic, metamorphic and structural characteristics. The major lithotypes of Sikkim-Darjeeling region belong to the eastward extension of rock types of the Nepal Himalaya which contains the complex fold-thrust tectono-stratigraphic sequences forming nappes, windows, klippen etc. In the Himalaya, the only working mine producing copper is located at Rangpo-Bhotang in East Sikkim. Genesis of sulphides within the Daling Group of rocks has been studied extensively.

The views of different workers prevail in establishing the stratigraphy of the Sikkim-Darjeeling Himalaya. Controversy exists as to what constitute 'Daling' and what is the contact between 'Daling' and 'Darjeeling' and what is the nature of tectonism these rocks have suffered. Different opinions prevail regarding stratigraphic position and genesis of Lingtse Granite Gneiss. The Main Central Thrust (MCT) is the most important tectonic zone whose location and significance are debated. The phenomenon of 'Inverted Metamorphism' is best seen in the Sikkim-Darjeeling Himalaya and satisfactory explanation of which has to be sorted out. Problem also pertains to the mechanism by which Tethyan Phanerozoic sequences escaped regional metamorphism while their substrate has been metamorphosed and migmatized in Mesozoic-Cenozoic times. All the opinions on stratigraphy, tectonics and metamorphism have been synthesized in this book and that will fulfill a long standing need. A palaeogeographic and tectonic evolution of the Sikkim-Darjeeling Himalaya has also been presented here.

The Geological Survey of India (GSI), the premier organization, has carried out geological investigation viz., mapping, mineral exploration and glaciological studies etc., for more than three decades in the Sikkim-Darjeeling Himalaya. The data in different publications

have not been integrated and synthesized into any comprehensive scientific publications. The syntheses has been attended here with the hope that this would serve as a reference book on geology of this part of the Eastern Himalaya.

## Location and Extent

Sikkim is a small mountainous state with 7096 sq.km area in the Eastern Himalaya bounded by Latitudes 27°05'N-28°08'N and Longitudes 88° 01'E-88° 55'E. The small state extend about 113 km from north to south and about 64 km from east to west. The state is bounded in the north and northeast by the Tibetan autonomous region of the People's Republic of China, in the south by the state of West Bengal of India, and by independent Himalayan Kingdom of Nepal in the west and Bhutan in the east.

Darjeeling District is the northernmost district of West Bengal state in Eastern India. The district is bounded by Latitudes 26°27'N-27°13'N and Longitudes 87°59'E-88°53'E and covers an area of 3149 sq.km. The district is bordered by Sikkim, Nepal and Bhutan in the north, west and east respectively. On the south lies the Purnea district of Bihar and West Dinajpur district of West Bengal.

## Early History

As a small but independent country, Sikkim struggled for a long time to maintain its territorial integrity. In the eighteenth and nineteenth centuries, it fought prolonged wars with Bhutan and Nepal. British penetration began in 1839 and although the British took over part of the area, the Sikkim remained an independent buffer between British India and Tibet. Under the formal feudal system, the Chogyal was the Head of the state of Sikkim. The period following Indian independence in 1947 was one of political uncertainity in Sikkim. Later by the terms of a 1950 treaty, Sikkim was deemed to be an Indian protectorate; but in 1975 more than ninety seven percent of the electorate voted for merger of Sikkim with India and a month later on 16th May 1975 Sikkim became a state of the Indian union. Elections

to the legislative assembly of the Sikkim were held in 1979. In 1935, the British East India Company took possession of Darjeeling. Prior to that Darjeeling formed a part of the Sikkim and for a brief period of Nepal.

## People

Almost all the people in Sikkim-Darjeeling are Buddhists and Hindus, although there are adherents of Christianity and Islam. Population density in Sikkim is around 80 per sq.km. Most of Sikkim's inhabitants live in the central, eastern, western and southern parts of the state. In the far north, the land is rugged, snow bound, inaccessible and uninhabitable. As there is little flat land, villages are few and each consisting of many hamlets of small homesteads scattered over the slope of the hills.

Majority of the people in Sikkim and in the hills of Darjeeling district are Gorkhas. Amongst the population are also the Newars, Sherpas and Bhutias. The original inhabitant of Sikkim-Darjeeling hills are Lepcha or Rongpa. The Lepchas are now predominantly Buddhists but many of them are also Christians having been converted to this faith by the missionaries.

## Administrative Division and Communication

A map of Sikkim-Darjeeling showing district division and important locations is shown in Fig.2. The Sikkim state has four districts viz., North, South, East and West with headquarters at Mangan, Namchi, Gangtok and Geysing respectively. Gangtok is the capital of the state. Each district is headed by a district officer, who is also a district collector. Road transport is the primary mode of travel and the state has around 1600 km of roads. Ropeways have also been provided at some points. Capital Gangtok is nearly 120 km from the nearest airport at Bagdogra in Darjeeling district of West Bengal. Siliguri of West Bengal at 110 km from Gangtok is the nearest Railway station.

Four Administrative Subdivisions viz., Darjeeling, Kalimpong,

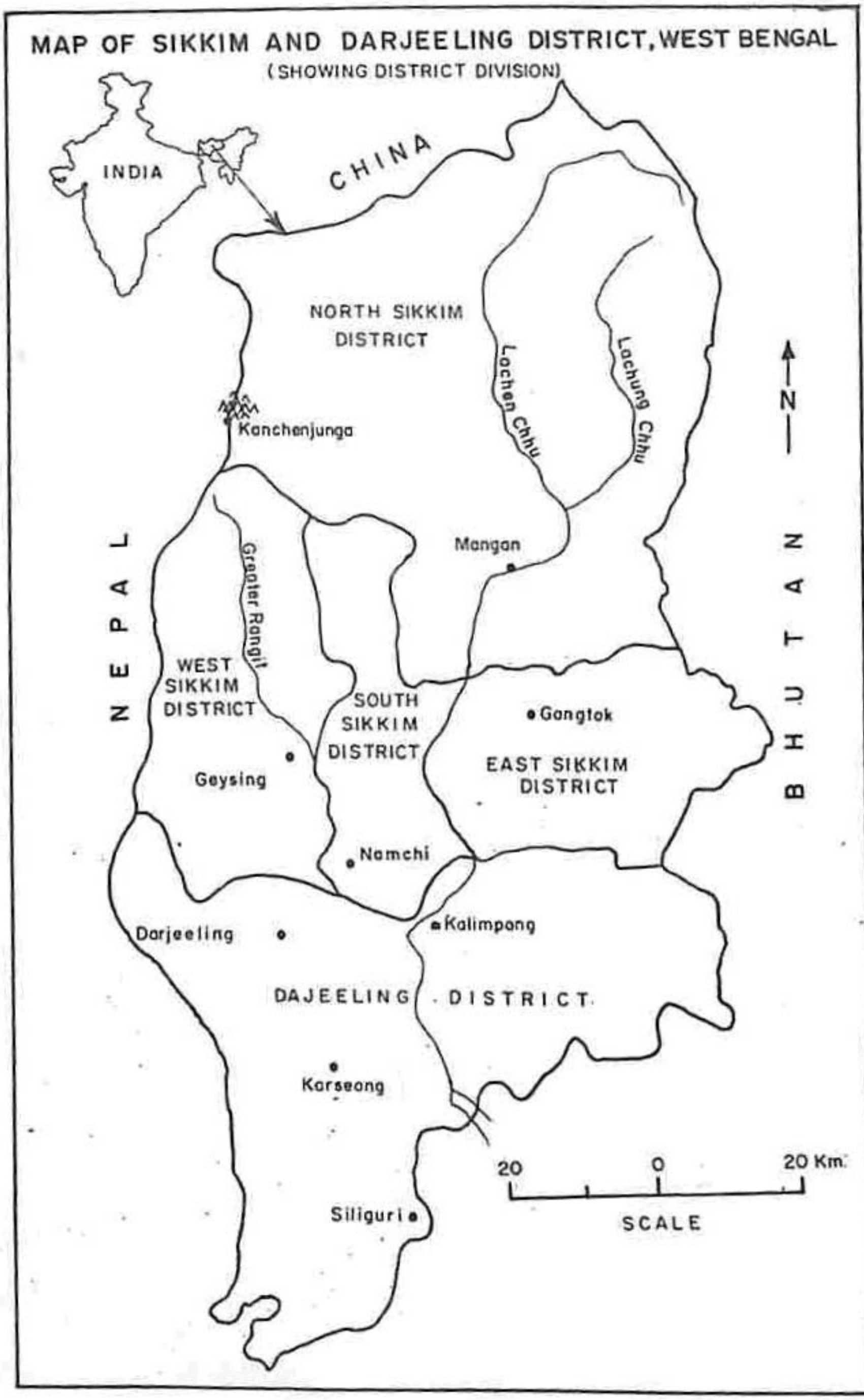


**Fig.2.** Map of Sikkim and Darjeeling district, West Bengal showing district division (after Students' Reference Atlas, NATMO, 1998).

Karseong and Siliguri comprise the Darjeeling district of West Bengal with its headquarters at Darjeeling town. The district has been divided into two broad divisions, the hills of the Darjeeling Himalaya and the plains of the adjacent southern terrain. The entire hilly region of the district comes under Darjeeling Gorkha Autonomous Hill Council, an autonomous body under Government of West Bengal. The Council covers the three hill subdivisions of Darjeeling, Karseong, and Kalimpong. The National Highway-55 connects Darjeeling town in the hills to Siliguri in the plains. It is the land of world heritage Darjeeling Himalayan Railway where the century old Miniature Train still runs uphills.

## Climate

Varied climatic conditions of Sikkim-Darjeeling are mainly due to variations in altitude. The climate varies from the tropical heat of low valley bottoms to the alpine cold of higher reaches. The moist tropical climate is experienced upto an average altitude of 600 m. Beyond that, a subtropical climate prevails upto an elevation of about 1500 m. Thereafter, the cold temperate climate conditions are found upto an altitude of around 3000 m. Further up, it becomes progressively cooler. Depending upon elevation, the annual rainfall varies from 1250 to 5000 mm. Because of the proximity of the Bay of Bengal and exposure to the effects of summer monsoon, Sikkim-Darjeeling region is one of the most humid areas in the Himalaya. Most of the annual rainfall is received during the months of May through October. The abundant rainfall results in frequent landslides that interrupt traffic and sometimes cause loss of human life. The higher reaches during winter are covered with snow and that in many places attains a thickness of 30 to 40 m. The heavy snow mass frequently brings in avalanches which often cause human and material destructions.

The temperature of a particular place in Sikkim varies considerably with altitudes. At places of low altitudes in Lesser Himalayan part, the temperatures vary between 4° C and 35°C. Places like capital Gangtok with moderate altitudes of about 1800 m experience temperature in between 1°C and 25°C. In places at altitudes above 4000 m, the temperature never rises above 15°C and it remains much below the

freezing point during winters and greater part of the spring and autumn. The mean annual temperature of Darjeeling district fluctuates from 24° C in the plains and drops below 12° C on the hills. During summer, the temperature in the hills reaches 16°-17° C and during winter drops at 5°-6° C. The mountainous terrain in the Darjeeling Himalaya is exposed to heavy rainfall. The southern slopes of the ridges receive much higher annual precipitation (4000-5000 mm) than the leeward sides (2000-2500 mm).

## Flora and Fauna

Sikkim-Darjeeling region contains luxuriant seemingly endless forests with about 4000 species of plants making it a botanist's paradise. The subtropical type vegetation extending upto altitude of around 1500 m includes varieties of bamboos, ferns, tree ferns, canes, palms, sats, pandanus and orchids. The temperate forests existing at altitudes from 1500 to 4000 m include oak, laurel, maple, chestnut, magnolia, alder, birch, rhododendron, hemlock, and fir. The alpine forests characterized by flowering plants as primulus gentians, blue poppies, aconites, and Himalayan rhubarb are found to occur at elevations of 4000 m to above 5000 m.

Sikkim-Darjeeling has a rich animal life including about 80 species of mammals, 600 species of birds, 630 species of butterflies and 200 variants of other insects and creatures. Notable animals include the black bear, brown bear, musk deer, sambar, barking deer, Tibetan antelope, tiger, leopard, leopard cat, marbled cat, goral, wild sheep, wild goat, wild bear and the wild ass.

## Early Pioneers

The chief geological work in Sikkim-Darjeeling was carried out by F.R. Mallet (1875) and P.N. Bose (1891). Important observations on Geology of Sikkim have been made by J.D. Hooker (1854), Garwood (1903), Loczy, L. Von (1907) observed in 1878, H. H. Hayden (1907), L. L. Fermor (1912), A.M. Heron (1922), Dyhrenfurth (1931), L. R. Wager (1934), J. B. Auden (1935) and A. Heim and A.

Gansser (1939) till the early part of last century. Geological investigation in Sikkim and in the adjoining state of West Bengal commenced in the middle of the 20th century. Hooker (1854) in his well know Himalayan journal reported the geological results of his extensive two years work in many parts of Sikkim. Hooker was also able to trace the regional domal structure of the gneisses and found the overlying sedimentary rocks. He also noted crinoidal limestones at Chho Lahmo, the well known lake near the Tibetan watershed.

The Darjeeling district of West Bengal and its foothills were studied by Mallet (1875) who has given an excellent account on the geology and mineral resources of the Darjeeling district and western Duars. Bose (1891) stated about the Gneissic group and the Daling sequence and compiled the mineral resources of Sikkim. It has been followed by Garwood's description and physical features of Sikkim, accompanied by first general map (1903). Northwestern Sikkim was included in Hayden's traverse (1907) to Lhasa and Loczy, L. Von (1907) published a geological section from Darjeeling to Kanchenjunga which he observed in 1878. Later followed investigation in connection with the climbing expeditions, such as Dyhrenfurth (1931) in northwest Sikkim and Wager (1934, 1939) in northern Sikkim and adjoining southern Tibet while traveling to and from Everest. Auden (1935) stated about the problems of Daling sequence and Darjeeling gneisses and geology of the Chho Lahmo region on the Tibetan frontier in the Record on his traverses in Himalaya. In 1936, A. Gansser and A. Heim visited the Tista region, Darjeeling district and attended a traverse to Gangtok of Sikkim (Heim and Gansser, 1939). Later geological mapping and related investigation by different workers on detailed scale and newer themes have been carried out by Geological Survey of India (GSI) and other organizations during last fifty years and that has generated valuable geoscientific information on Geology of Sikkim and Darjeeling Himalaya.

## Geological Contributions by the GSI and other Organizations

The main contribution to the geology of the Sikkim-Darjeeling Himalaya is by the GSI as part of its progamme of systematic geological mapping and resource development. The status of knowledge

on various aspects of the geology of Himalaya including many observations on the geology of the Sikkim-Darjeeling Himalaya has been reviewed, evaluated and well documented in the Proceedings of Himalayan Geology Seminar held in New Delhi during September 1976 (1979-1986, Misc. Publn., GSI., no.41, pt.1 to 7). A seminar on geological studies in the Himalaya was held in Calcutta during October 1971 and the papers presented were published (1976, Misc. Publn., GSI., no.24, pt. 1,2) which bear many geoscientific information on the Sikkim–Darjeeling Himalaya. The Daling symposium was held in Calcutta in 1981 and some selected papers including those from the Sikkim–Darjeeling Himalaya were published (1989, Sp. Publn. GSI., no.22). In response to multi-institutional call for evaluating the constrains for tectonic modeling in the Himalaya, the GSI carried out various exercises on stratigraphy, sedimentation, structure and tectonics, metamorphism and magmatism, metallogeny, and neotectonics etc. of Himalaya with a publication (1989, Sp. Publn., GSI., no.26). The Regional Geological Map of Himalaya published along with this special publication may considerably help in any write- up on Geology of Himalayan Terrain. Other organizations like Wadia Institute of Himalayan Geology, Oil and Natural Gas Corporation and Universities have made significant contribution in the geology of the Sikkim–Darjeeling Himalaya.

From the time of early pioneer work till present the geology, stratigraphy and tectonics of the rock units of the Sikkim-Darjeeling Himalaya have been subjects of many academic discussion, evaluation and reevaluation. Mallet (1875) classified the Precambrian supracrustal rocks of Eastern Himalaya into two broad units. He noted a very marked lithological change between what he called the units viz., the Daling series and the Darjeeling gneiss. Bose (1891) broadly classified the rock types of Sikkim Himalaya into the older Gneissic group and the younger Daling series comprising the submetamorphics with a gradual passage in between the gneisses and Daling series. Mallet (1875), however, considered the gneiss as younger than the Daling. Auden (1935) preferred to use the term 'Daling' and 'Darjeeling gneiss' as the lower and upper portions of a great sedimentary sequence, the terms representing to some extent metamorphic grades rather than stratigraphic series. Wager (1939) used the term 'Daling

series' in the stratigraphic sense for the whole pelitic sedimentary sequence and implied its correlation with his 'Mt. Everest pelitic series' whereas the upper part of his 'Daling series' being converted into a migmatitic gneiss (Darjeeling gneiss) through lit-par-lit injection. Later, Ray (1947) from the stratigraphic point of view grouped 'Daling series' and 'Darjeeling gneiss' into a single unit called the 'Senchal series' from the name of the highest peak in the Darjeeling Himalaya. The 'Senchal series' seems to comprise two lithologically distinct portions, the lower characterized by dominance of graywacke schists with pelitic schists and the upper by prevalence of pelitic schists and gneisses with less dominating calcareous and carbonaceous materials. Ghosh (1956) introduced a new unit between 'Daling series' and 'Darjeeling gneiss' and called it as 'Rangli schist'; but he retained more or less the classification of Mallet (1875). The term 'Rangli schist' was proposed for the mica schist with well developed garnet and staurolite which are extensively exposed in the Rangli valley, west of Rangli in southeast Sikkim. Its underlying 'Daling series' and overlying 'Darjeeling gneiss' comprise rocks of chlorite-biotite and kyanite-sillimanite zones respectively. Ghosh (1956) also suggested for discontinuing the usage of the term 'Daling series' and instead referred those rocks as Daling phyllite. However, the rocks of Mallet (1875), Auden (1935), Wager (1939), Ray (1947) and Ghosh (1956) have led to the conclusion that the Daling and Darjeeling rocks belong to one great metasedimentary, essentially argillaceous sequence with varying degrees of metamorphism being responsible for strong difference in their petrological characters. Gansser (1964) followed the classification of Mallet (1875); but he introduced a thrust plane (MCT) in between 'Daling' and 'Darjeeling'. Ray (1976) on the basis of his thrust-tectonic concept grouped the rocks of Sikkim into the Sikkim Group (Darjeeling gneiss and Chungthang metasediments) and the Daling Group (Gorubathan, Reyong and Baxa subgroups) which underlies the younger Gondwana-equivalent and Siwalik sediments. Auden (1935) opined that there is a transition between Daling and overlying Darjeeling gneisses with an inverted metamorphic sequence. However, a greater part of North Sikkim has still remained unmapped due to inaccessibility and presence of perpetual snow clad terrain and so the classification of gneissic complex is not complete.

Over the last thirty years numerous models have been proposed to explain the stratigraphy and sedimentation, structure and tectonics, metamorphism, magmatism and metallogeny etc. of Eastern Himalaya and those theories have been widely explored to explain related aspects of other mountain belts. Publications of Sinha-Roy (1973ab, 1982, 1987) on Sikkim Himalaya are very significant in the context of sedimentation, magmatism and tectonic history of the region. Acharyya and Sastry (1979) stated a general account of the stratigraphy of the Eastern Himalaya. Raina and Bhattacharyya (1975), Raina and Srivastava (1980), Raina and Srivastava (1981) and Raina (1982) have stated in detail about the sedimentaries and tectonic evolution of the Sikkim Himalaya. Different views on position and genesis of Lingtse Granite Gneiss have been summarized by Paul et al. (1982, 1996). In recent years, different institutions have worked out the tectonics and metamorphic history of the Sikkim-Darjeeling Himalaya on the basis of geochemistry, geothermo-barometry and geochronological studies (Mohan et al. 1989; Neogi et al. 1998; Ganguly et al. 2000; Dasgupta et al. 2004; Catlos et al. 2004) which provide enough information for further researches in the tectogene.

In the context of metallogeny, Piddington (1854) mentioned about copper occurrences of Sikkim. Mallet (1875) was the first to describe the sulphide occurrences from different parts of the Sikkim-Darjeeling Himalaya. Bose (1891) gave a detailed account of the mineral resources of Sikkim. Exploration and other details of Rangpo-Bhotang sulphide deposit have been stated by Mukherjee and Dhruva Rao (1974). In a recent National seminar held during 2006 on geology, mineral and water resources of the Sikkim Himalaya, the different salient aspects of geology and mineralization of Sikkim region have been discussed (2006, Abstracts Volume, Sikkim unit, GSI, ER) which may serve as a guide to take up further geological investigation in Sikkim.