Introduction

The Mussoorie and Garhwal Synclines have been studied for the purpose of this thesis with special reference to petrography, stratigraphy and palaeontology of the Tal Formation and a contribution is also made to the stratigraphy and palaeontology of the "Boulder Slate Member" of the "Bijni Tectonic Unit" of the Garhwal nappe. A study of petrography of the fossils and the oolites of the Nilkanth Formation (Singh, 1979 b) has also been made. The age of the Tal Formation and the "Bijni Tectonic Unit" has a direct bearing on the geological history of the Lesser Himalaya, because these are the only Pre-Tertiary sedimentary horizons in the Lesser Himalaya which have yielded definite mega and micro fauna. Long after, the discovery of Jurassic fossils from the Upper Tal of Garhwal Himalaya by Middlemiss (1885) many reports of contradictory ages ranging from Precambrian to Cretaceous have come from different units of the Tal Formation and the associated underlying sequences. The structure and tectonic position of the "Bijni Tectonic Unit" is also controversial. The Lower Member of the "Bijni Tectonic Unit" has yielded well preserved megafossils of Upper Carboniferous and Lower Permian ages near the village Jogira in Garhwal Syncline. In the present work, an attempt
was made to corroborate more evidences for the exact stratigraphic position of the Tal Formation and "Bijni Tectonic Unit". About 500 thin sections were studied for working out the petrographic details of these horizons.

The systematic descriptions were made of the various fossil groups viz. conodonts, small shelly fossils, trace fossils, inarticulate brachiopods from the Tal Formation and articulate brachiopods, bryozoans, lamellibranchs from the "Bijni Tectonic Unit" and the associated horizons of the Mussoorie and Garhwal Synclines.

1.1 LOCATION

The area under study lies on the Survey of India topographic sheets (1:50,000), nos. 53J/3 and 58K/9 and is confined between the latitudes 30° 19' and 30° 30' north and the longitudes 78° 04' and 78° 15' east in Mussoorie Syncline and between the longitudes 78° 34'-78° 42' and latitudes 29° 46'-29° 51' in the Garhwal Syncline. The areas forming the subject matter of the present thesis are mostly approachable by motor-roads. The Maldeota phosphorite mine is located about 14 km from the Dehradun and is connected by bus upto the Maldeota village figure 1.1.

The road bifurcates from the Kumalda bridge for Satengal via Dubra, Dhaulagiri, Loarka and Gopi Chand Ka Mahal. A complete sequence of Tal Formation is along this road and this succession is unconformably overlain by the
Nilkanth Formation near Satengal village. The Krol-Tal contact is well exposed on the road near Landour bazar, Jabarkhet, Batagad, Kaplani, Masrana and Durmala phosphorite mine, located on the northern limb of the Mussoorie Syncline and approachable by bus.

The Dogadda village lies on the Subathu Formation exposed in the Garhwal Syncline and is located 25 km. north of Kotdwar. The fossiliferous locality yielding megafossils lies near the village Jogira, 9 km from Dogadda town (Figure 1.2). This locality is approachable by unmetalled road. The Bansi, Gajwar and Dhaliyan-ka-danda from where Nilkanth Formation (Shell Limestone) was sampled can be approached by mule tract or foot tract. A complete sequence of the Tal Formation is exposed on the Rishikesh-Deoprayag road to the right of the river Ganga and is located on the northern limb of the Garhwal Syncline between Singtali and Kauriyala near 42 km. stone. The Garhwal thrust (Auden, 1937) lies near the Singtali village. A number of traverses were taken along the roads, nallas, foot paths and thickly forested areas in both the Mussoorie and Garhwal Synclines, to collect systematic samples for detailed investigation.

1.2 PHYSIOGRAPHY

The Mussoorie and Garhwal Synclines lie in the Garhwal Lesser Himalaya. Geographically it constitutes the
central part of the 2500 km. long and 200 km. wide Himalayan belt which runs in an arcuate shape along the northern limit of the country. The topography of the area is typically mountainous, varying in height from 600 m. to 3000 m. above m.s.l. The rivers Yamuna and Ganga demarcate more or less the western and eastern boundaries of the Garhwal Himalaya.

The Ganga in its upper reaches is known as Alaknanda before its confluence at Deoprayag with Bhagirathi. The main physiographic feature of the area is an imposing ridge, trending roughly NW-SE to NNW-SSE. Numerous spurs branch off in diverse directions from this ridge, standing to the north of the broad Dehradun Valley. The spurs and ridges are separated by the deep ravines. The valleys are mainly anticlinal and the spurs and hills are synclinal and these constitute major topographic features of the region, forming the subject matter of the present work.

1.3 DRAINAGE PATTERN

The area encompassing the Mussoorie Syncline is drained by the Chipalih nadi, the Bandal nadi, the Bhusti nadi, the Kali gadd, the Kholdi gadd, the Pathal gadd and their tributaries. The Patal gadd and its tributaries flow in north-westerly direction whereas other streams and streamlets follow southwesterly and/or southerly course. The east-west trending Mussoorie-Masrana ridge acts as the
main water-divide between the northwesterly and southwesterly drainage systems. The streams and streamlets are fed by springs and the surface run-off; subsurface water also adds to the flow in the lower reaches. The Chiphaldi nadi drains the southeastern sector of the area. The river originates near Marora and flows in a southwesterly direction. The Bandal nadi starts north of Bhusti and also flows in a southwesterly direction. The Bandal nadi joins the Song nadi, south of Maldeota. The topography of the Garhwal Syncline is also mountainous. The deep valleys are separated by high and sharp crests. The area has a relief of about 1140.6 m., the maximum height (1847 m.) is marked by Lansdowne peak. The township of Dogadda is placed at a junction of four prominent ridges. The Qodibari Gauntaili ridge towards the north, the Jua-charekh ridge towards the southwest, the Aidaba-Jhawanu ridge in the south and the Basyur gad ridge towards the east. The point of highest elevation (1150.9) near Dogadda is the village of the Jua. The area is drained by the Sila gad and the Bhairam. Numerous tributaries flow into them, from the easterly direction and then the Silagad flows due west. It is joined by Mukara gad close to the village of Sirsa. After changing its course close to Fatehpur it flows in a southerly direction. Bhairam and Sila gad join at Dogadda and then flow in the northwesterly direction as the Khoh river. The lithology has played a major role in the
development of the drainage pattern of the area. The river at first flows parallel to the phyllite of the Amri Formation and is deflected at Fatehpur by the sharp contact in lithology.

1.4 CLIMATE

There is a wide contrast in the climate of the area during different seasons of the year, the winter is fairly severe with occasional snow falls, during the months from December to March. In the months of summer the temperature goes up to 41°C. The monsoon breaks out towards the end of June and continues up to the September. Only pleasant months left for outdoor activities are the months of April, May, October and November. The area receives mean annual rainfall around 218 cm with relative humidity varying from 54% to 63%.

1.5 FAUNA AND FLORA

Garhwal is world famous for its wild animals such as Tiger, Panther, Civetcat, Leopard-Cat and jungle-cat (cat-family). Silver fox and jackal (Dog family) musk deer and barking deer, Sambhur, goralbeer and monkeys are quite common. Birds are represented by about 400 varieties which are encountered in this part of the Lesser Himalaya. The major part of the area is thickly forested. Valleys have a rich cover of Fern, Oak, Deodar, Pine, Fir, Rhododendron
and Tun. Apple and Cherry trees are encountered in the higher reaches whereas Acacia and shrubs are met with at the lower height.

1.6 PREVIOUS WORK

The name "Tal" in the stratigraphy of Himalaya was introduced by Medlicott (1864), while doing mapping between the Rivers Ravi and Ganga for a sequence of black shales followed predominantly by sandy facies in the Tal Valley, east of the river Ganga. Oldham (1884) took the traverse between the Simla hills and Chakrata and he was concerned chiefly with the Blaini and Infra-Blaini rocks. King (1885) had reported the presence of phosphatic nodules in the shales, a six inches thick bed of phosphatic nodules occurring over the limestone and below the chert. The Tal rocks specifically, were described by Middlemiss (1887) from the Tal valley and he was the first to report the occurrence of probably Jurassic fossils from the so-called Tal Formation in the Garhwal Himalaya exposed near Gajwar village. Auden (1934) mapped the Krol belt in the Simla Himalaya and stated that the synformal Krol belt is bound by Krol and Tons thrusts, and the Krol belt rests as an allochthon over the Lower Tertiary rocks in the south and the Morar-Chakrata beds (=Simla Slate) in north.

Auden (1934) divided the Tal sequence into Lower and Upper Tals. According to him the Lower Tal varies in thickness from 550 m in the west to 1006 m in the east
and the Upper Tal measures about 610 m. in the "eastern" basin. Auden (1934) considered the Upper Tal to have been deposited in fluvio-deltaic conditions in proximity of sea. On the basis of the presence of the arkose in the Tal beds, he suggested the existence of a Pre-Tertiary Himalayan granite, which contributed the potash feldspars found in the Upper Tal. Auden (1937) also proposed existence of unconformites between the Krol and Tal Formations, and between the Quartzite Member and Shell Limestone (=Nilkanth Formation of Singh, 1979 b).

Bhargava (1972, 1976) extended the mapping of Krol belt of Auden (1934) into the Nigalidhar and Korgai Synclines of Himachal Pradesh. Shanker (1971) mapped the Mussoorie Syncline of Uttar Pradesh. Bhargava (1972) separated the Krol belt into the Outer and Inner Krol belts. According to him, the Simla Group formed the base for Outer Krol belt whereas Nagthat Formation provided the base for the Inner Krol belt. Prior to the work of Bhargava (1976) it was generally believed that both the Lower and Upper Tals of Middlemiss (1887) roughly correspond to the Upper Tal of Auden (1934). It was also believed that the Lower Tal of Auden (1934) is probably not developed in that area. However, Ghosh (1975) established a complete sequence of Lower Tal comprising black chert and phosphorite at the base and this continued over a strike length of more than 10 km between Kiurki and Mohanchatti in
Pauri Garhwal district.

Mussoorie phosphorite deposit being the first discovery of its kind in the country attracted considerable attention from geoscientists. Ahluwalia (1970, 1980, 1988a) studied the phosphorite horizons in Pari Tibba, Chamasari, Maaran, Durmala, Bhusti Jalikhal, Bagi-Mathiangaon and Maldeota. The phosphorite deposits have also been investigated in the Mussoorie Syncline by Chaterji (1967), Ghosh (1968, 1975), Saraswat et al. (1970), Raha (1979 a, b; 1973), Patwardhan and Ahluwalia (1973, 1975), Pareek (1973, 1976, 1978 a, b), Chaudhri (1977), Sharma (1974) and Joshi and Srivastava (1979) discussed the petrography, geochemistry and genesis of the Tal phosphorite. Ganesan (1975), Chaudhri and Ramanujam (1983) carried out the clay mineral study from different stratigraphic horizons of the Tal Formation. The various sedimentological aspects of the Tal Formation were worked out in detail by Singh (1979 b, c; 1980), Chaudhri and Ramanujam (1982).


Trace fossils from the upper Argillaceous and
Arenaceous Member of the Tal Formation have been described by Banerjee and Narain (1976), Singh and Rai (1983), Rai and Singh (1983), Singh et al. (1984) and Mathur et al. (1988). Inarticulate brachiopods and trilobites collected from the shaly horizon of the lower part of the Quartzite Member have been recorded and illustrated by Kumar et al. (1983, 1987, 1988), Tripathi et al. (1984, 1986). However, detailed systematic description of this fauna was not attempted by these workers. The fossils from the Nilkanth Formation have been described by Tewari and Kumar (1967), Tewari and Gupta (1978), Singh (1980), Singh and Singh (1988), Raiverman and Singh (1985), Saklani et al. (1977), Bhatia (1980), Kalia (1972, 1976), Mehrotra et al. (1976).

The study of the oolites from the Nilkanth Formation was carried out by Bassi and Vasta (1971), Qureshy and Anantharaman (1984) and Srivastava (1984). The stromatolites from different stratigraphic units of the Tal Formation have been described by Raha and Gururaja (1970), Patwardhan and Ahluwalia (1975), Sharma (1976), Bhargava and Ahluwalia (1978), Banerjee (1978), Patwardhan (1979), Tewari (1984, 1988) and Ahluwalia (1988 b).

In addition to the above, there are several other recordings of fossils of different types from the Tal Formation. Shrivastava (1973, 1975), Srivastava and Mehrotra (1974), Tripathi (1976), Bhargava (1980), Saxena (1985) and Singh (1981). The fossils from the "Bijni


Gupta (1978), Brasier and Singh (1987). The details of above works would be discussed in the stratigraphy chapter. A general review of the geology of Mussoorie-Dehradun has been recently given in a guide book brought out by Geological Society of India (Tandon et al., 1988).
GEOLOGICAL MAP OF GARHWAL SYNCLINE
(AFTER RAVI SHANKAR AND GANESAN 1973 AND RUPKE 1974)

INDEX

- Chakrata
- Chandpur
- Nagthat
- Blaini
- Krol Thrust
- Tal
- Subathu
- Siwalik
- Bijni
- Amri

Fig. 1-2