Lithological and Structural Analysis in the Lansdowne, Pauri Garhwal district Uttarakhand, India

Abstract: The present study deals with geology in and around Lansdowne town, Uttarakhand. The Garhwal Himalayan forms a part of Lesser Himalayas. Rocks of different types, from "Precambrian" to "Recent", are found in the region. The Garhwal Himalayan forms a part of Lesser Himalayas. The Lansdowne region showcases intricate geological features, encompassing various stages of deformation, faulting, and notable compositional changes from augen gneiss to granite as one approaches the town's core. The thorough examinations of the rock formations and geological structures suggest significant tectonic movements which are marked by the presence of fault lines, joint sets, and gouge zones. There is a shift from highly distorted augen gneiss to a more uniform granite. This lithological variation helps to understand the different tectonic and metamorphic conditions in the area. The research suggests that the central part of Lansdowne, known for its uniform granite composition, undergoes less severe deformation and metamorphism compared to the surrounding areas dominated by augen gneiss. The relative stability and lower deformation intensity in the granitic core suggest a potentially safer and more stable environment for settlements. As a result, from a geological standpoint, the core of Lansdowne town is more suitable for development and habitation compared to the surrounding regions.

Keywords: Lesser Himalaya; Lansdowne; Granite; Gneiss, Fault

1. Introduction

The Himalayas, located on the southern fringe of the Tibetan Plateau, are the youngest mountain range and stretches from west to east [1]. The mountain range is arc-shaped, convex southwards with syntaxial bends at the western and eastern ends [2]. They are formed as a result of the collision between the Indian and Eurasian plates [3]. Due to ongoing continental collision, the Himalayas stand as the Earth's highest mountain range undergoing active uplift. Himalaya stretches about 2500km in length from Nanga Parbat (8138m) in the northwest to Namcha Barwa (7756m) in the northeast [4]. The width varies from 350 km in the west (Kashmir) to 150 km in the east (Arunachal Pradesh) [5]. During the convergence, the large scale crustal shortening was accommodated by south directed deformation related tectonic transport of thrust sheets all along the length of Himalaya [6, 7]. As a result of the subduction of sediments due to the collision between the plates, this mountain range shows an agreement among various dating methods indicating that the older segments originated during the late Cretaceous period (82-113 million years ago), while the newer areas were formed in the early Eocene epoch (40-60 million years ago). During the convergence, the large scale crustal shortening was accommodated by south directed deformation related tectonic transport of thrust sheets all along the length of Himalaya [3, 6].

The Himalayan Mountain range is subdivided into four principal tectonic zones, from south to north: the Sub-Himalaya, the Lesser Himalaya, the Higher Himalayan Crystallines, and the Tethyan Himalaya. The generalized geological succession of the Himalayas is shown in Table 1.

Table 1. Generalized geological succession of the Himalayas

Indus Tsangpo Suture Zone (ITSZ)	
Late Precambrian- Cenozoic	Trans Himalaya
South Tibetan Detachment Zone (STDZ) or Tethys Thrust	
Precambrian	Greater Himalaya
Main Central Thrust (MCT)	
Precambrian	Lesser Himalaya
Main Boundary Thrust (MBT)	
Tertiary	Siwalik Himalaya
Main Frontal Thrust (MFT)/ Himalayan Frontal Thrust (HFT)	
Quaternary	Indo-Gangetic Plain

• **Sub-Himalaya (Siwalik range or Outer Himalaya):** It has an average altitude of 500m above sea level. The Main Frontal Thrust (MFT) or Himalayan Frontal Fault (HFT), separates the outer Himalaya from the Ganga plains [8]. It consists predominantly of Tertiary and Quaternary sediments [2]. It is bounded to the north by northward dipping Main Boundary Thrust (MBT), separating it from the overlying Lesser Himalaya [8].

• **Lesser Himalaya (Lower or Middle Himalaya):** It is higher than 2500 m, however, in the Kashmir Valley, the Pir Panjal Range rises to heights greater than 3500 m [2]. It consists of Precambrian and Cambrian sequences of the Damtha, Tejam, Jaunsar-Garhwal, and Mussoorie Groups in the Garhwal region of the western Himalaya [9]. The ranges of the lower Himalaya are i) Pir Panjal range, ii) Dhaola Dhar range, iii) Mussoorie and Nag Tibba range, and iv) Mahabharat Lekh range [10].

• **Higher Himalaya (Greater or Inner or Central Crystalline Himalaya):** It is separated from the Lesser Himalaya along the Main Central Thrust (MCT). It has an average elevation of 6000 m above mean sea level [8]. The Higher Himalayan Crystallines in the western Himalaya is represented by the Chail, Jutogh, and Vaikrita groups of rocks [2]. It is incredibly rugged with perennial snow and glacier-capped peaks [11].

• **Trans Himalaya (Tethys or Tethyan Himalaya):** It is rugged terrain with an average elevation of 3000 m above mean sea level [8]. The Tethyan Himalayan sequence is separated from the Higher Himalayan Crystalline sequence by South Tibetan Detachment System (STDS) [12]. The high ranges of the Higher Himalayan Crystalline act as a barrier for the wet Monsoon cloud to go further north, the Tethyan Himalayan Range has developed into a cold and dry desert with sparse vegetation and naked rocks [2].

Figure 1 shows the divisions of Himalayas and Figure 2 shows the cross section of Himalayas.

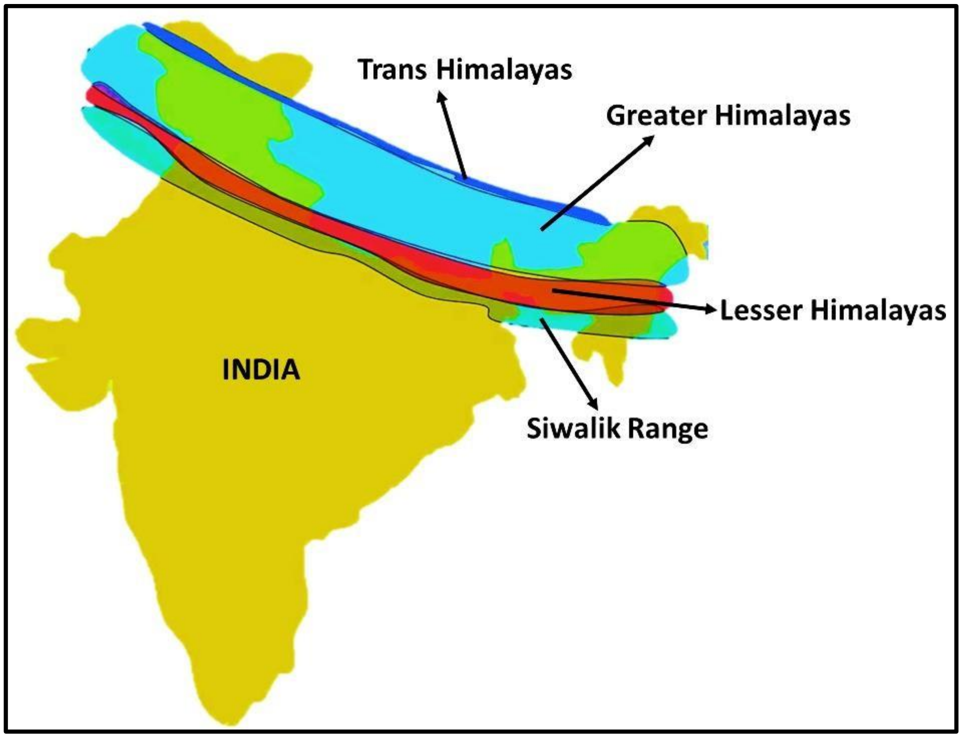

Figure 1. The divisions of Himalayas

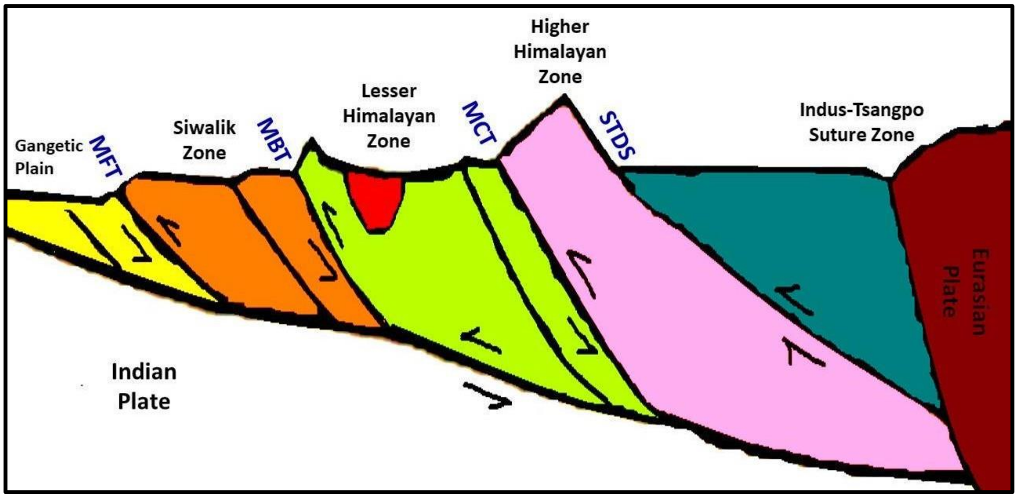

Figure 2. Cross section of Himalayas

Geological Setting

The Garhwal Himalayan forms a part of Lesser Himalayas, bounded between Main Boundary Thrust (MBT) in south and Main Central Thrust (MCT) in north [13]. Lansdowne town is situated in the Pauri Garhwal district of Uttarakhand state. The Lansdowne granitic gneisses form a part of the Amri tectonic unit of Garhwal nappe [14]. The area is characterized by a tectonic contact between the Lansdowne granite gneiss and the underlying Lansdowne metamorphites [15]. These metamorphites have undergone polyphase progressive regional metamorphism, as evidenced by three distinct deformational and folding events [16]. A unique assemblage of minerals including chloritoid, staurolite, kyanite, andalusite, and quartz is present within the region. The granitic rocks themselves have been metamorphosed into augen gneiss, mylonites, and phyllonites, indicating significant deformation [15]. Additionally, geochemical alteration of the granitic rocks is evident by processes like muscovitization, tourmalinization, and greisenization. These textural and geochemical features within the rocks can be directly linked to the deformational and folding events that have shaped the Lansdowne area. The granitic gneisses are well foliated. In the northwest they extend up to Bhayansu on the steep slopes of Lansdowne hill. They occupy the core of the Lansdowne synform. Litho-tectonic succession in the Lansdowne area is shown in Table 2 and the geological map of the Lansdowne area is shown in Figure 3.

Table 2. Litho-tectonic succession in the Lansdowne area [17]

Geology	Formation	Lithology
Almora	Lansdowne Granitic Gneiss	Granite, Mylonitised Gneiss, Augen gneiss
	LANSDOWNE THRUST	
	Lansdowne Metamorphite	Schist, Phyllite, Quartzite, quartz rich phyllite
	AMRI THRUST	
Ramgarh	Bijni	Quartzite alternating with schist and phyllite
	GARHWAL THRUST	
Tal	Dhaulagiri	Sandstone, Calcareous siltstone

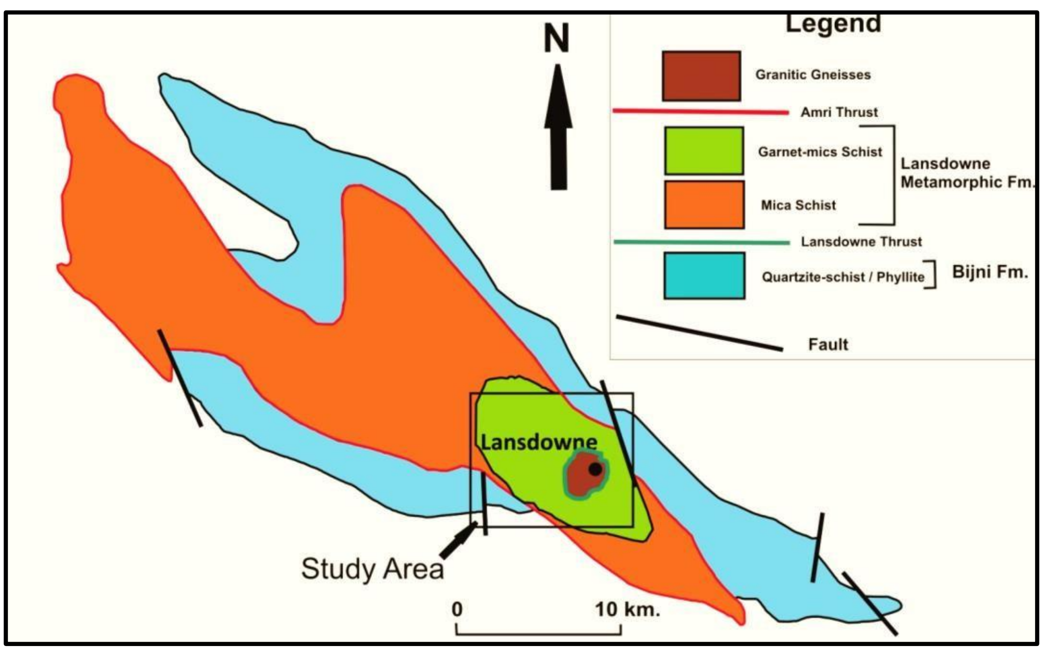

Figure 3. Geological Map of Lansdowne Area (after Fuchs and Sinha, 1978)

2. Materials and Methods

The research involved conducting thorough fieldwork to collect data on geological structures, compositional variations, and lithological changes in the Lansdowne area. Initially, potential sites were identified using topographic and geological maps, with a focus on accessibility and geological significance. At every location, a Global Positioning System (GPS) was used to accurately determine the latitude and longitude, with the coordinates recorded in a notebook alongside the site identification numbers. The foliation trends of rock outcrops were assessed using a Brunton compass, and several measurements were taken to ensure precision. A 10x hand lens was employed to analyze the mineral compositions, pinpointing significant minerals and their interrelationships. Geological maps were consulted to identify representative outcrops, and the locations of these outcrops were marked using GPS coordinates. Rock samples were then collected from these specific locations. Detailed notes were made on the changes in rock types, and photographs were captured of significant geological features. Finally, the gathered data were incorporated into a Geographic Information System (GIS) for spatial analysis, enabling precise mapping of geological features.

3. Result and Discussion

Through the field investigations and petrographic analyses, we have discovered notable differences in the structural and lithological characteristics of the Lansdowne region within the Garhwal Himalayas. The key findings are as follows:

• **Lithological Variation:** Towards the center of Lansdowne town particularly noteworthy, there is a noticeable shift in the type of rock from augen gneiss to granite. This transitional area is characterized by a gradual change in the rock's structure, with the foliated layers of gneiss gradually fading away, and the composition shifting towards a more granitic nature. Augen gneiss, characterized by its prominent large feldspar crystals, suggests a significant level of metamorphism and deformation. The shift to granite, may reflect a decrease in the intensity of deformation and metamorphism towards the core of the area, or it could indicate different stages of intrusion and cooling of magmatic bodies. The granite is composed of quartz, alkali feldspar, plagioclase, muscovite, biotite, and tourmaline. Figure 4 (a-b) shows the augen gneiss and the granite found in the study area and Figure 5 shows the traversing map.

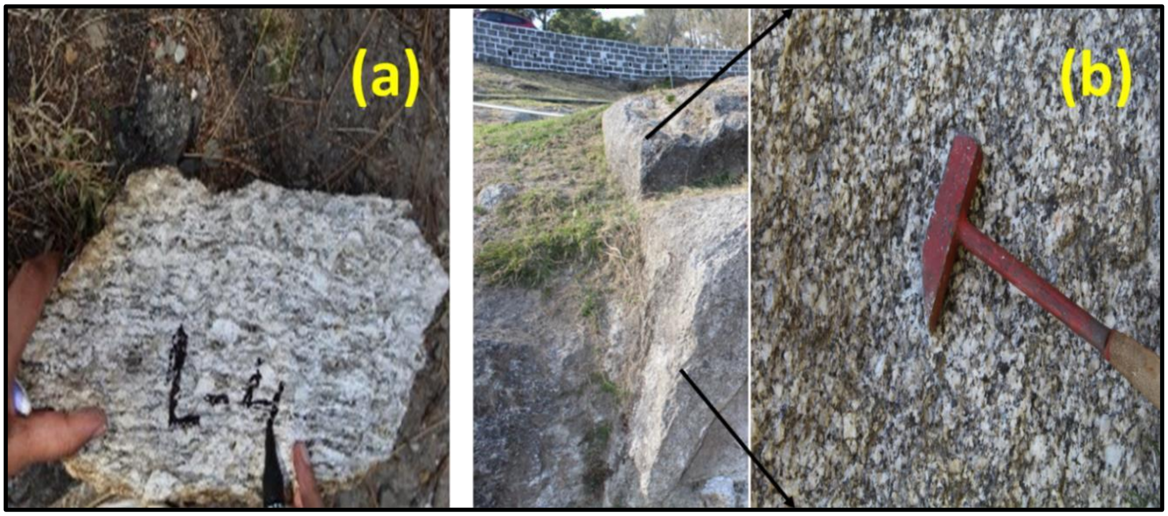

Figure 4. (a) Augen gneiss, **(b)** Granite

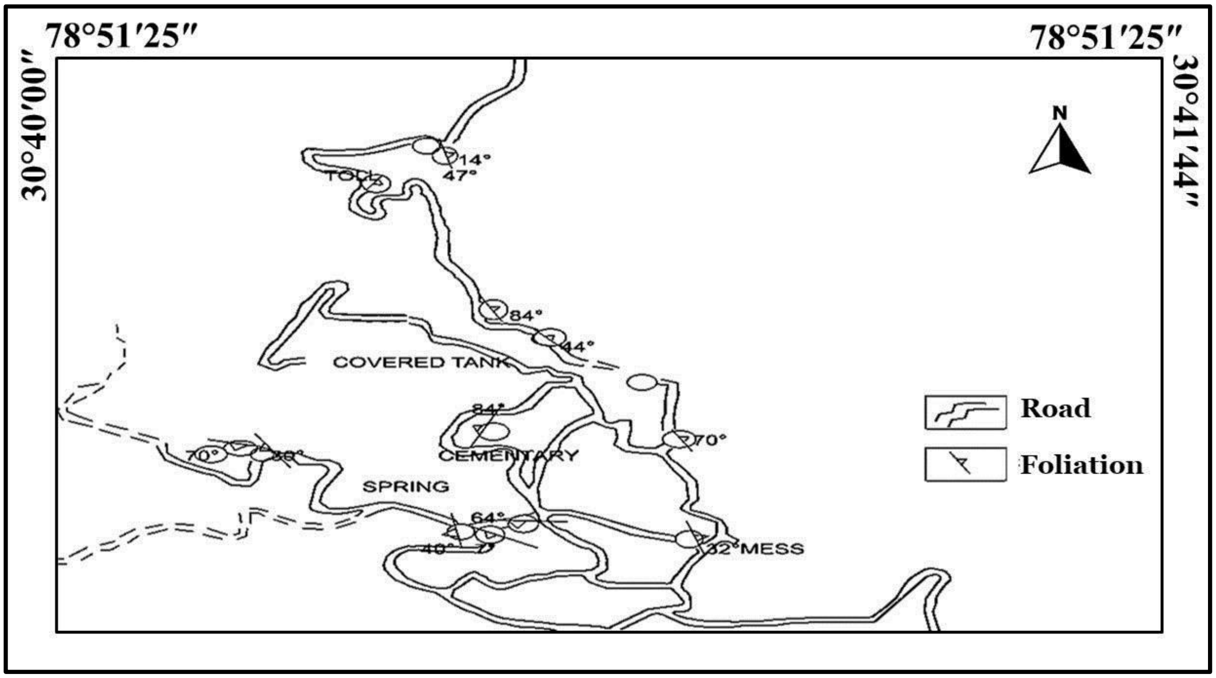

Figure 5. Traversing Map

• **Faults:** A fault is a fracture with appreciable displacement parallel to the fracture plane or fault surface. A fracture occurs when a rock breaks in response to stress and divides it into two or more pieces [18]. Locally quartz vein show small scale faulting. Reverse fault is observed in the study area in which the hanging wall block moves up relative to the footwall block (Figure 5). The presence of faults that the Himalayas have experienced multiple periods of deformation, indicating a dynamic tectonic environment.

Figure 6. Reverse Fault

• **Gouges:** A fault gouge is the fine-grained substance near the surface, which is essentially the rock powder formed during faulting [19]. Fragments of finely crushed rock and clay minerals were discovered along the fault planes, indicating the presence of gouge material (Figure 6). The presence of gouges along the fault planes is indicative of significant brittle deformation and substantial movement. It also suggests the occurrence of fluid-assisted alteration processes during faulting.

Figure 7. Fault Gouge

• **Joint Sets:** Joints are the fractures or cracks along which no displacement occurs [18]. A joint set is a group of parallel fractures with a common origin [20]. Three different sets of joints were identified (Figure 7). The orientation of the joint sets suggests that the area has been subjected to varying stress regimes, which is consistent with the ongoing tectonic activity in the region.

Figure 8. Three sets of joints

4. Conclusion

This geological study conducted in the Lansdowne region of the Garhwal Himalayas has uncovered the intricate geological complexities, encompassing the various phases of the deformation, faulting, and compositional changes from the augen gneiss to granite. The area has a tectonic contact between the Lansdowne granite gneiss and the underlying Lansdowne metamorphites. The presence of the faults, joint sets, and gouge zones suggests significant tectonic activity, while the transition from highly deformed augen gneiss to the more uniform granite towards core of Lansdowne indicates different tectonic and metamorphic conditions in the region. The research indicates that the central part of Lansdowne area which is known for its uniform granite composition, has experienced less intense deformation and metamorphism compared to the surrounding regions dominated by augen gneiss. The relative stability and lower deformation intensity in the granitic core suggest a potentially safer and more stable environment for the establishment of settlements.

Abbreviations

MFT	The Main Frontal Thrust
HFT	Himalayan Frontal Fault
MBT	Main Boundary Thrust
MCT	Main Central Thrust
STDS	South Tibetan Detachment System
GPS	Global Positioning System
GIS	Geographic Information System

Data availability

All data analyzed during this study are included in this article. The raw data that support the finding of this study are available on request from the corresponding authors.

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