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Review Article

DISCREPANCIES AND RESEARCH GAPS ON THE LITHOSTRATIGRAPHY OF THE JAJARKOT THRUST SHEET, WESTERN NEPAL HIMALAYA

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ABSTRACT

The interaction between the Indian and Asian plates has led to the formation of imbricated thrust sheets in the Himalayas. This study focuses on a segment of the Jajarkot Thrust Sheet characterized by metamorphic rocks, including garnet-biotite schist, biotite schist, quartzite interlayers, and marbles. The upper stratigraphic sequence of this thrust sheet contains fossiliferous rocks from the Paleozoic era. Prior classifications have identified three main units: Chaurjhari Formation, the Thabang Formation, and the Jaljala Formation. However, the Department of Mines and Geology recognizes two units: the Siuri Formation and the Surbang Formation. This discrepancy, along with inconsistent terminologies like "Jajarkot Nappe" and "Jajarkot Klippe", highlights the need for a unified stratigraphic framework. Such clarity is crucial for assessing mineralization potentials, particularly for iron and copper, in western Nepal and understanding the thrust sheet's tectonic history within the broader Himalayan context.

Keywords: Jajarkot Thrust Sheet, lesser Himalaya, stratigraphy, western Nepal

INTRODUCTION

As a result of the continent-continent collision between India and Asia, the Himalaya is believed to have originated forming the world's highest mountain range, stretching from east to west for about 2,400 km with a width of 230 to 350 km in a massive arc (Dewey & Bird, 1970; Powell & Conaghan, 1973). The collision occurred between 55 and 40 million years ago (Dewey et al., 1989; Searle et al., 1987).

Penetration of India beneath Asia (Karakoram-Tibet) resulted in crustal shortening and splitting of the Indian continent's northern boundary into slices along three major thrusts from north to south, which represents South-propagated thrusts. These major intra-crustal thrusts are the Main Central Thrust (MCT), the Main Boundary Thrust (MBT), and the Main Frontal (or Himalayan Frontal) Thrust (MFT or HFT). These substantial intra-crustal thrusts have separated the Himalaya into four tectonic zones: the Sub-Himalaya, Lesser Himalaya, Higher Himalaya, and the Tibetan-Tethys Himalaya from south to north, respectively (Gansser, 1964; Thakur, 1981, 1992; Valdiya, 1980).

The Lesser Himalaya, which stretches over 1,500 km from Himachal Pradesh to Bhutan, is situated between the Higher and Sub-Himalayan ranges. It is tectonically bound to the north by the MCT and to the south by the MBT. The MBT is a low-angle reverse fault that has carried the older, Lower Himalayan rocks over the younger Sub-Himalayan rocks. Likewise, the MCT has carried the older high-grade metamorphic crystalline rocks of the Higher Himalaya to the Lesser Himalaya. The regional geology of the Lesser Himalaya in Nepal is well-mapped (Figure), and its east-west extent is well documented (Stöcklin & Bhattarai, 1977; Dhital & Kizaki, 1987; Amatya & Jnawali, 1994; Paudel & Arita, 1998; Paudyal & Paudel, 2013; Dhital, 2015).

The Lesser Himalayan rocks are severely folded and faulted, with complex stratigraphy and structures. In the eastern Nepal Himalaya, large tectonic windows expose low-grade metamorphic rocks of the Lesser Himalaya surrounded by high-grade metamorphic crystalline rocks of the Higher Himalaya (Upreti, 1999). A massive thrust sheet covers a large area in central Nepal near Kathmandu (Stöcklin & Bhattarai, 1977; Stöcklin, 1980). A thrust sheet has been mapped in the Mugling-Damauli section, and the rocks of this thrust sheet have been correlated with the nearby nappes and klippes (Paudyal & Paudel, 2013; Paudyal, 2014). The Jajarkot Thrust Sheet is a large thrust sheet in western Nepal (Sharma, 1980; Frank & Fuchs, 1970; Kansakar, 1991, 1992; Dhital, 2015; Soucy La Roche, 2018). A huge area is free of crystalline thrust sheets between the Kahun Klippe in the east and the Jajarkot Thrust in the west, where low-grade metasedimentary rocks of the Lesser Himalaya are found. Thrust sheets like the Karnali nappe, the Dadeldhura nappe, and other smaller thrust sheets are being studied further west of the Jajarkot Thrust Sheet (Bashyal, 1981, 1986; Næraa et al., 2007; Upreti, 1990).

The Karnali Nappe is developed along the Karnali River and its tributaries in far western Nepal. This nappe is comprised of kyanite-sillimanite gneiss, calc-silicate gneiss, migmatitic gneiss, and augen gneiss (Hayashi et al., 1984). In the southern part, calc-silicate gneiss forms a thick interband within the garnet-biotite gneiss. The migmatitic gneiss and augen gneiss dominate the top of the succession. The rocks of the Karnali Nappe are comparable with the rock succession of the Higher Himalaya (Le Fort, 1975).

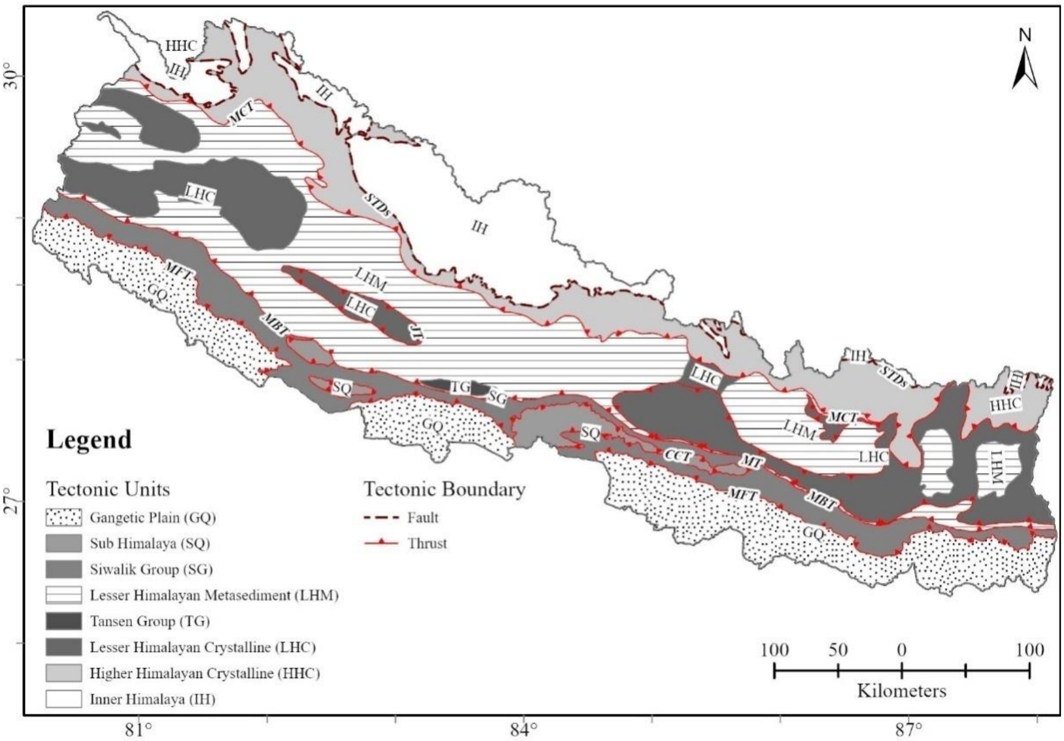

Figure 1. Generalized geological map of Nepal (modified after Amatya & Jnawali, 1994).

The Dadeldhura Nappe is a massive synformal crystalline nappe in far western Nepal that is a direct eastward extension of the Kumaon Almora Nappe or Klippe (Gansser, 1964; Valdiya, 1980; Fuchs, 1977; Arita et al., 1984). The Gaira Formation is the base portion of the nappe and is composed of garnet-mica schist, carbonaceous schist, quartzite, metabasic rock, and granitic gneiss (Bashyal, 1986; Upreti, 1990). The Dadeldhura Granite is a granitic mass 4-5 km wide, surrounded by granitic orthogneiss. The core of the Dadeldhura Synform is composed of lead-grey to black carbonaceous phyllite with small quartzite strata cut by coarse pegmatitic veins.

The rocks of the Jajarkot Thrust Sheet are the least studied section in the Nepal Himalaya. Moreover, the studies made by the previous researchers seem fragmentary. There are controversies in lithostratigraphic classification and nomenclature from researchers to researchers (Fuchs & Frank, 1970; Sharma et al., 1984; Kansakar, 1991; Dhital, 1992, 2015). The present study has tried to find the controversies and research gaps in the stratigraphy of the rocks of the Jajarkot Thrust Sheet.

The primary objective of this review is to identify and elucidate the geological challenges and research voids pertinent to the Jajarkot Thrust Sheet. Specifically, the focus is directed towards discerning discrepancies within the lithostratigraphic classification of this geological unit. Additionally, this study endeavours to propose methodologies to address the observed inconsistencies in stratigraphic interpretations, geological structures, and correlation techniques. This stage of work provides a structured introduction to the research goals and sets the stage for the subsequent discussion and findings.

METHODOLOGY

This paper reviews the geological work carried out by previous researchers in the Jajarkot Thrust Sheet. For this, the literature on geological mapping, stratigraphy, structural setting, metamorphic evolution, depositional environment, and other related publications was thoroughly reviewed, including published and unpublished research papers, reports, books, and book chapters. Discussions were made with senior professors, professionals, and research committee members of the Central Department of Geology, who were involved in geological mapping in Nepal Himalaya for a long time. Finally, the authors' views have been provided as suggestions for further research to address the discrepancies and fulfil the existing research gaps (Figure).

SYNOPSIS OF REVIEW

Stratigraphic Review

The Lesser Himalayan Crystalline of western Nepal is defined as a separate unit, so it is referred to the Lower Crystalline Nappe. The Lower Crystalline Nappe is also known as the Jajarkot crystalline zones, or simply the MCT zone (Fuchs & Frank, 1970) as shown in Figure. The thickness of this zone varies by hundreds to thousands of meters and has a long and narrow body with an approximate dimension of 140 km × 28 km (DeCelles et al., 2001). This narrow elongate body of a crystalline thrust sheet with a Cambro-Ordovician carbonate rock cover named as the Jajarkot nappe (Hagen, 1969). The allochthonous Paleozoic rock succession from the Lesser Himalaya is overlying the low-grade metamorphic autochthonous rock strata. Sharma et al. (1984) named this allochthonous unit the Jaljala Group after the Jaljala Nappe in midwestern Nepal, a part of the Jaljala thrust sheet. Arita et al. (1984) defined it as the Jajarkot crystalline zone, which appears to be a type of klippe derived from the MCT zone to the north.

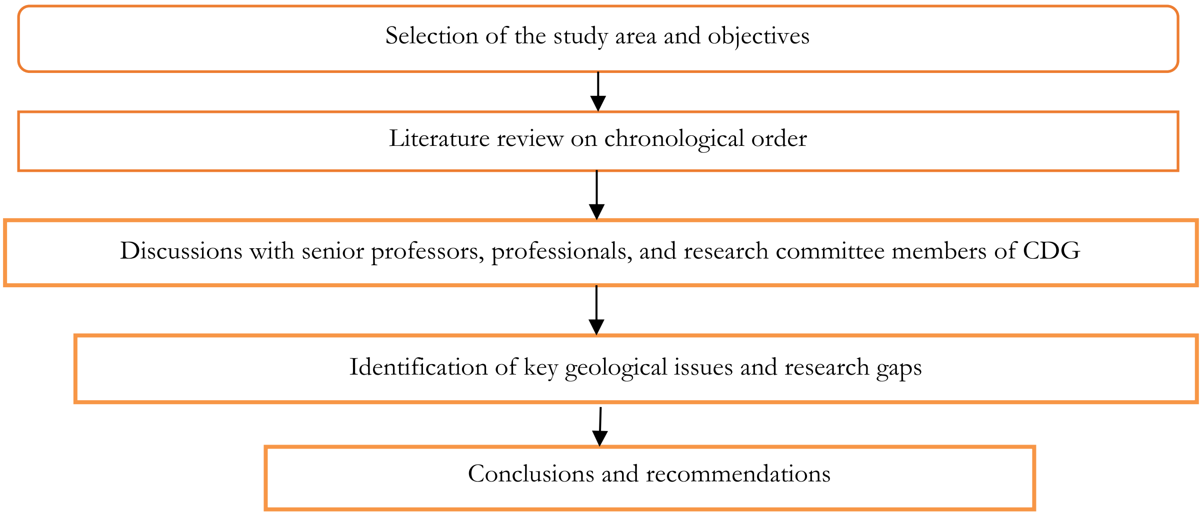

Figure 2. Flow chart showing the methodological scheme for the study.

According to Arita et al. (1984), the MCT zone or the Lower Crystalline Nappe zone (Fuchs & Frank, 1970), is composed of a pile of mica-chlorite schist with or without rotated garnet porphyroblast, green schist, green and black phyllite, quartzite, and amphibolite with abundant graphitic phyllite. The rocks are sheared. The Jajarkot crystalline zone also contains blastomylonitic augen gneiss, which is common in the MCT zone of central and eastern Nepal Himalaya (Hashimoto et al., 1973). This blastomylonite augen reveals cataclastic microcline perthite with a diameter of 0.5-1 cm. According to Pêcher and Le Fort (1986), the Lesser Himalayan Crystalline rocks, such as the Almora and Kathmandu nappes, are pushed outliers of the Higher Himalayan Crystalline (HHC). Sharma et al. (1984) and Sharma & Kizaki, (1989) investigated the rocks of the Jaljala area and classified the Higher Himalayan rocks of the klippe into three geological units; the Chaurjhari Formation, the Thabang Formation, and the Jaljala Formation from stratigraphically older to younger age, respectively.

The Jajarkot Thrust Sheet sequence is possibly Precambrian in age based on lithological comparison with similar rocks from India. The lithological description of the Jajarkot sheet has been given by several researchers (Fuchs & Frank, 1970; Sharma et al., 1984; Kansakar, 1991) in the past. The lithological descriptions and unit names purposed by the authors are mainly based on few traverses, especially from the Bheri River basin, i.e., the western closure of the thrust sheet. One of the widely adopted stratigraphic classification for the Jajarkot Thrust Sheet is three-fold classifications (Frank & Fuchs, 1970; Fuchs & Frank, 1970; Sharma, 1980; Shrestha et al., 1987) which is briefly described in the following section:

Chaurjhari Formation

The Chaurjhari Formation, the Jajarkot Thrust Sheet's lower rock units, are composed of muscovite-biotite schist and garnet-biotite-muscovite schist, as well as subordinate micaceous quartzite, garnetiferous graphitic schist, feldspathic schist, and augen gneiss (Sharma et al., 1984; Sharma & Kizaki, 1989) (Fig. 3). The mica schist is interbedded with grey graphitic schist that are tens of meters thick and contain garnet. K-feldspar and plagioclase are found as sporadic bands in feldspathic schist. Interbands of white micaceous quartzite frequently fracture into slabs of about a few centimetres thick. However, these quartzites get larger towards the eastern part. Additionally, this unit has some incredibly rare marble bands. The sequence's metamorphism decreases upwards, giving way to carbonate rocks.

Thabang Formation

The Thabang Formation gradationally overlies the Chaurjhari Formation and is represented by an alternating sequence of coarse crystalline impure marbles interbedded with mica schist (Fig. 3). Calcite is the most abundant mineral in marble, but quartz, muscovite, biotite, hornblende, and garnet are also present in trace amounts. In the higher stages, the metamorphic grade declines and eventually disappears in the overlying Jaljala Formation.

Jaljala Formation

The Jaljala Formation is composed of a series of interbedded, medium- to fine-grained, calcareous sandstone and calcareous siltstone. Silver to greenish grey phyllite is also prevalent. The top portion is interbedded with grey silty limestone and grey-green slate (Fig. 3).

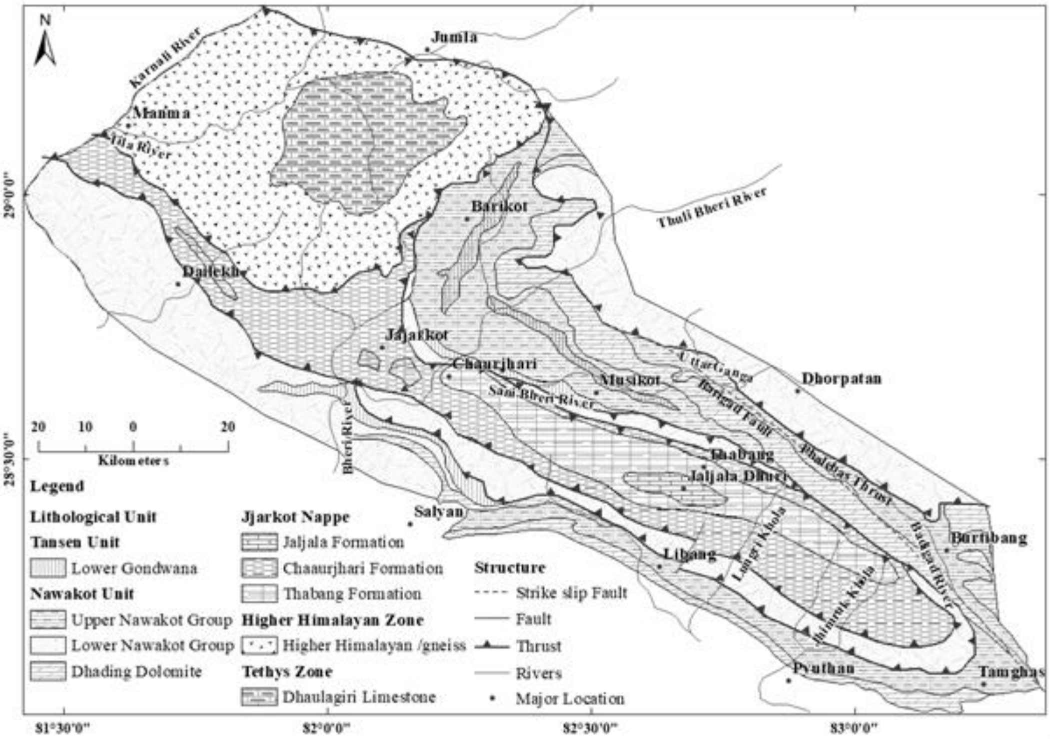

Figure 3. Geological map of the western Nepal Lesser Himalaya (Fuchs & Frank, 1970; Sharma et al., 1984; Amatya & Jnawali, 1994; Upreti, 1997).

The **Jaljala Subgroup** within the Midland Group (Tater et al., 1984), as identified on the geological map published by DMG (2020), is made up of two Precambrian rock units. The Siuri Formation with the Balbang Quartzite member and the younger Surbang Formation. The Siuri Formation is composed of garnet-bearing schist, quartzite, and intrusions of basic rocks and granite. The Balbang Schist member is a mixture of quartz-mica-schist and calcareous quartzite with thinly laminated crystalline limestone. The Surbang Formation is made up of grey to brown crystalline limestone interbedded with calcareous schist, calcareous quartzite, and biotite-quartz-schist. But the overlying Cambro-Ordovician fossiliferous carbonate succession is not reported on the map (Fuchs & Frank, 1970; Sharma et al., 1984).

The **Sharda Group** (Dhital & Kizaki, 1987), bounded by the Kapurkot Thrust in the south and the MCT in the north, is another thrust sheet, represented by the Dangri Formation and Raira Quartzite member (Fig. 4). The lower part of the Dangri Formation consists of alternating layers of light to dark grey phyllite and white to light grey quartzite. The quartzite bands have parallel laminae and planar cross-laminae. The unit transitions to grey to green-grey biotite schist, yellow quartzite, and psammitic schist. In some areas, there are also thin pegmatite veins and microgranite dikes (Sharma & Kizaki, 1988). The Raira Quartzite member (Adhikari & Sharma, 1983), which is about 200-400 m thick, appears in the upper part of the Dangri Formation and is made up of a pale yellow to white or light grey-green variety with parting, grey-green phyllite, black graphitic schist, and biotite schist.

The Dangri Formation continues with grey-green biotite schist containing tiny garnets and white quartzite. The uppermost schist-predominating band abruptly gives way to a 100 m thick zone of grey mylonitic banded gneiss, followed by a thick succession of garnet schist or graphitic schist with thin marble bands, kyanite schist, and gneiss alternations. This sequence is called the Chaurjhari Formation (Sharma et al., 1984) of the Higher Himalaya, and the Main Central Thrust is located at the base of the mylonitic gneiss.

The **Dailekh Group** (Dhital, 2015), bounded by the Budar Thrust, and the Chaklighat Thrust, is of crystalline sequence and begins with the Ranimatta Formation, a unit that is found in a wide area of the Bheri River valley (Fig. 4). The main components of this unit are parallel-laminated, infrequently plane cross-laminated, pale grey, yellow, or white quartzite, as well as sporadic green to light blue-green bands. Some quartzite beds are granular to pebbly, and metabasic rocks (mainly amphibolites) make up about 30% of the formation's total thickness. The rocks in the upper reach of the Chhera Khola consist of an alternating sequence of blue-green phyllite or garnet schist and light grey to green-grey quartzite. The Simta Phyllite is a distinct member within the Ranimatta Formation, consisting mainly of blue green phyllite and lacking in quartzites and amphibolite.

The Chhera Diamictite is found farther north in the Chhera Khola and is calcareous and metamorphosed to a garnet grade. It contains angular to subrounded clasts of grey dolomite, pale yellow quartzite, grey gneiss, and black schist. The boundary between the Chhera

Diamictite and the Ranimatta Formation is distinct and believed to be a disconformity. The boundary between the Chhera Diamictite and the overlying Marka Formation is gradual. The Marka Formation is mainly composed of light grey to pale quartzite with grey to blue-grey garnet schist or phyllite intercalates.

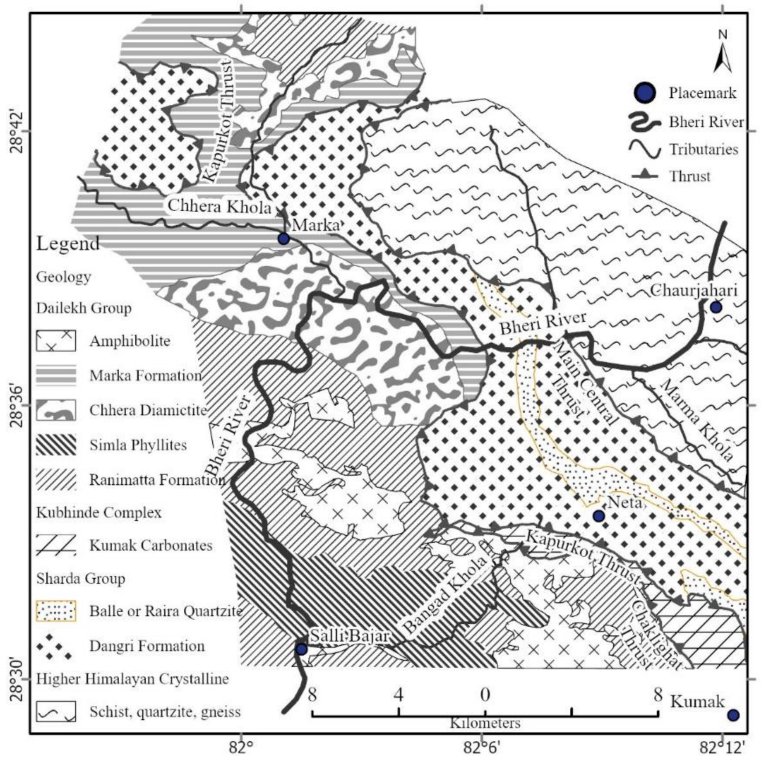

Figure 4. Geological map of the Bheri River section modified after Dhital (2015).

Geological structures and tectonics

The Jajarkot crystalline zone, which Arita et al. (1984) classified as a klippe, developed from the MCT zone to the north. The MCT zone also contains the rock association of sheared phyllite, schist, and blastomylonitic augen gneiss, despite being bounded on both the north and south sides by steep faults. The Barigad Kaligandaki Fault (BKF) divides the Jajarkot Thrust Sheet into inner (north) and outer (south) belts (Arita et al., 1984; Sakai, 1985). The outer belt is an overlapping para-autochthonous unit of the Palpa Klippe that runs mostly along the MBT in the south. The rocks of the MCT zone (including Ulleri gneiss) are thrust over the Para-autochthon in the Piuthan area, forming a klippe (Jajarkot Thrust Sheet) (Arita et al., 1984).

The MCT zone, also known as the Lower Crystalline Nappe (Fuchs & Frank, 1970), occurs beneath the Himalayan gneisses of the Himalayan gneiss zone and the Chakhure-Mabu crystalline klippe zone (Arita et al., 1984). The thickness of this zone varies from place to place, ranging from hundreds to thousands of meters. The mineral lineation and micro folding axis in the NNE-SSW direction predominate in the Jajarkot crystalline zone, whereas mineral lineation in the E-W direction is uncommon, though some synform and antiform axes are in the ENE-WSW direction. This zone is separated from the Midland meta-sediments by steep faults on both the north and south sides, though it appears to have been thrust over the latter at some point.

DISCUSSION

Stratigraphy

Stratigraphic classification of thrust sheets like the Kathmandu Nappe, Kahun Klippe and Jajarkot Thrust Sheet have been assigned by various researchers (Fuchs & Frank, 1970; Ohta et al., 1973; Hirayama et al., 1988; Amatya & Jnawali, 1994; Dhital et al., 2002; Paudyal & Paudel, 2011, 2013; Paudyal, 2014; Sah, 1999, 2007). Correlating the stratigraphic units of one author with those of another is challenging.

Two types of nappes are considered within the Lesser Himalaya of Nepal. Among which the Kathmandu Nappe, the Kahun Klippe, and the Jajarkot Thrust Sheet are thrust sheets with low- to medium-grade rock strata, whereas the Karnali Nappe, the Dadeldhura Nappe continued with the Almora Nappe (India) are medium- to high-grade rock sequences. Nappes with high-grade metamorphic rocks are not correlable with medium-grade nappes like the Jajarkot Thrust Sheet. Hence, the rocks of the Jajarkot Thrust Sheet can be correlated with other Lesser Himalayan crystalline thrust sheets, including the Kathmandu Nappe and the Kahun Klippe (Stöcklin & Bhattarai, 1977; Paudyal & Paudel, 2013). The rock succession of Kathmandu Nappe has been extensively studied by several researchers (Stöcklin &

Bhattarai, 1977; Stöcklin, 1980; Sah 2015; Acharya and Paudyal, 2019). The Bhimphedi Group or equivalent rocks are reported from the Jajarkot Thrust Sheet (Shrestha et al., 1987). The crystalline unit of the Jajarkot Thrust Sheet has been covered by fossiliferous carbonate succession like the Phulchauki Group of the Kathmandu nappe (Stöcklin and Bhattarai, 1977; Stöcklin, 1989). There is a report of an unconformity between the Jaljala Formation and the Thabang Formation in the Jajarkot Thrust Sheet.

The Raduwa Formation (Stöcklin & Bhattarai, 1977) of central Nepal is correlated with the Shivapur Schist of Kahun Klippe (Paudyal & Paudel, 2013). The Shivapur Schist is underlain by the Musimarang Formation, which is composed of an intercalation of quartzite and schist in various proportions. Quartzite dominates at the base of the succession, while the upper part has an abundance of schist. The oldest unit in the Kahun Klippe is the Gwaslung Formation consisting of grey marble and white calcareous quartzite. The Shivapur Schist from the Tanahun Group is considered equivalent to the Raduwa Formation in central Nepal (Paudyal & Paudel, 2013). The Gwaslung Formation and Musimarang Formation are considered as the older units than the Shivapur Schist. However, there are no reports of rocks equivalent to the Musimarang Formation and the Gwaslung Formation in the Jajarkot Thrust Sheet. Similarly, Paudyal & Paudel, (2013) have not recorded Tethyan affinity rocks in the Kahun area. Interestingly, there are reports of such fossiliferous rocks in both the Kathmandu Nappe and Jajarkot Thrust Sheet. The Kahun Klippe lying between the Kathmandu Nappe in the east and the Jajarkot Thrust Sheet in the west is devoid of fossiliferous succession. Unlike other researchers, the geological map prepared by DMG (2020) has not mentioned the existence of Cambro-Ordovician fossiliferous calc-silicate rock at the top of the Jajarkot Thrust Sheet. Similarly, Dhital and Kizaki (1987); Dhital (1992, 2015) mentioned that the rocks of the Jajarkot Thrust Sheet are equivalent to the Higher Himalayan crystalline units bounded by the MCT. However, there are no rocks like gneiss and marbles as found in the Higher Himalaya zone. This clearly shows that there is much variation in stratigraphy of the Jajarkot Thrust Sheet (Table 1).

Table 1. Correlation between lithological units of various Lesser Himalayan thrust sheet with Jajarkot Thrust Sheet.

Kathmandu Complex (Stöcklin & Bhattarai, 1977; Stöcklin, 1980)	Kahun Klippe (Paudyal & Paudel, 2013; Paudyal, 2014)	Jajarkot Thrust Sheet (Fuchs & Frank, 1970; Sharma et al., 1984)	Jajarkot Thrust Sheet (DMG, 2020)
--	--	Jaljala Formation	Not mentioned
Bhaisedovan Marble	--	Thabang Formation	Surbang Formation
Raduwa Formation	Shivapur Schist	Chaurjhari Formation	Siuri Formation
--	Musimarang Formation	--	--
--	Gwaslung Formation	--	--

Geological structures and tectonics

A vast area of the Jajarkot Thrust Sheet remains unexplored till the date. Studying adjacent nappes and klippes, the concept of structure and tectonics in this region can be understood to some extent. (Arita, 1983) mapped the MCT zone along the Modi Khola section of the Annapurna region with high bendable strain up to 2–3 km thick, bounded by an upper thrust, MCT-2 (Vaikrita Thrust), and a lower thrust, MCT-1 (Munsiari Thrust). The prior, upper MCT-2 corresponds to the MCT (Colchen et al., 1986) though the lower, afterward MCT-1 corresponds to the MCT brittle thrust fault (Searle et al., 2008) and roof thrust for the less-metamorphosed sediments of the Midland meta-sediment zone in the south and carried the MCT thrust zone as "klippen", e.g., the Jajarkot crystalline zone (Arita et al., 1984) and the Arkha Crystalline Zone (Arita et al., 1982) in western Nepal. The entire inverted metamorphic sequence is mapped as part of the Greater Himalayan sequence, and the MCT brittle fault is placed along the base of the inverted metamorphic sequence (Searle & Godin, 2003).

There are great controversies about the root zone of the Lesser Himalayan thrust sheets (Stöcklin, 1980; Rai et al., 1998; Upreti & Le Fort, 1999; Johnson et al., 2001; Paudyal & Paudel, 2013). Some thrust sheets are made up of medium-grade metamorphic rocks such as garnet-schist and marbles, while others are made up of kyanite-grade gneiss and marble.

In central Nepal, the Mahabharat Thrust (MT) has brought garnet-grade schist (Raduwa Formation) (Stöcklin & Bhattarai, 1977) over the low-grade metamorphic rocks of the Nawakot Group. An equivalent Dubung Thrust (DT) has carried the rocks of the Kahun Klippe (Paudyal & Paudel, 2013). This shows the equivalent thrust has extended further westward from the Kahun region. But the depth of thrust propagation westward from the Kahun regions has yet to be observed.

The crystalline nappes and klippes of the Lesser Himalaya have been interpreted as peculiar slices (Upreti & Le Fort, 1999). To understand the origin of the thrusts, Upreti & Le Fort (1999) proposed two thrust models. Alexander et al., (2011) found the southern extension of the South Tibetan Detachment System (STDS) at the northern part of Kathmandu Nappe. They concluded that the Lesser Himalayan Crystalline Nappe's right-way-up metamorphic sequence is continuous throughout the South Tibet Detachment System and the MCT hanging walls. According to Gehrels et al., (2003), the Himalayan orogenic belt originated as an Early Paleozoic thin-skinned thrust belt. They gave evidence for early Paleozoic tectonism in the rocks of the Kathmandu Nappe.

Pearson (2002) studied several areas of central Nepal and with a few exceptions, discovered that the Ramgarh Thrust (RT) has brought the rocks of the Robang, Kushma, and Ranimata Formations, or their equivalents, over the younger units. However, this concept has been in great debate till the date. They also noted that structures contained within the Lesser Himalaya accommodated tectonic shortening after movement on the MCT halted in the middle Miocene and before moving on the MBT resumed in the Pliocene. The Ramgarh Thrust was active in western Nepal between 15 and 11 Ma, but it could have been active later in central Nepal.

The higher Dadeldhura and lower Ramgarh thrust sheets were structurally mapped below the MCT in western Nepal (DeCelles et al., 2001; Robinson et al., 2003, 2006). They were unable to locate a distinct thrust at the MCT location and inferred its presence from extrapolation along the strike in the Karnali valley. The Dadeldhura thrust sheet contains garnet-muscovite-biotite schists, augen gneiss, and Cambrian-Ordovician granites. The Kushma and Ranimata Formations of greenschist-facies metasedimentary rocks make up the Ramgarh thrust sheet. Both the Dadeldhura and Ramgarh thrust sheets occur in a synformal klippe, which is structurally similar to the Almoraklippe to the west and the Kathmandu nappe to the east (Searle et al., 2008). The Ramgarh Thrust forms the roof thrust through a series of imbricated thrust slices of unmetamorphosed Lesser Himalayan Late Archaean, Proterozoic, and Cambrian rocks (DeCelles et al., 2001; Robinson et al., 2006).

The possible origin of the Lesser Himalayan crystalline thrust sheets has been explained by conceptual models by different researchers. There are four explanations proposed for the origin of the Lesser Himalayan crystalline thrust sheets.

1. The root zone of the Lesser Himalayan crystalline thrust sheets considered as the Higher Himalayan rocks delivered by the MCT (Heim & Gansser, 1939; Hagen, 1969; Le Fort, 1975; Stöcklin, 1980).
2. The Lesser Himalayan crystalline thrust sheets are thrust sheets of the MCT zone performed by the Lower MCT (or Munsiari Thrust) in India (Valdiya, 1980; Arita et al., 1984; Fuchs & Frank, 1970; Srivastava & Mitra, 1994).
3. The Lesser Himalayan crystalline thrust sheets are the distinct thrust sheets with missing roots carried by the Mahabharat Thrust (MT) (Upreti & Le Fort, 1999). The MCT is interpreted by Upreti & Le Fort (1999) as the contact between the higher-grade Sheopuri Gneiss and the lower-grade Bhimphedi Group, and they proposed that the Sheopuri Gneiss will outcompete the Kathmandu Complex along the MCT. The thrust sheet was split into two nappes: the Gosaikundnappe, composed of Higher Himalayan rocks, and the Kathmandu nappe, composed of the Kathmandu Complex.
4. Paudyal & Paudel, (2013) has concluded that the Bhimphedi Group and rocks of the Kahun Klippe are not linked to the MCT zone or the Higher Himalaya, as explained in the previous section. They suggested thrust propagation and erosion model to describe the origin and evolution of the Lesser Himalayan thrust sheets.

ISSUES AND DISCREPANCIES

The following are the issues and discrepancies in the present stratigraphic review:

1. The term Jajarkot nappe was first given by Hagen in 1969. However, he has not given the stratigraphy of the thrust sheet. The terminology nappe is also not justified.
2. Fuchs and Frank (1970) carried out mapping of the Jajarkot Thrust Sheet (named as Jajarkot crystalline zone or simply the MCT zone). They have proposed three mappable geological units. Out of which, the two older units consists of garnet-grade metamorphic rocks and the younger topmost unit consist of sedimentary rocks of the Tethyan affinity with Silurian crinoids. They have marked disconformity between these two distinct successions.
3. Sharma (1984) mapped the rocks of the Jajarkot Thrust Sheet into two groups: the Chaurjhari Group (older succession) and the Jaljala Group (younger succession). He has reported two thrusts at the base of the Chaurjhari Group. He has correlated the Chaurjhari Group with the Bhimphedi Group and the Jaljala Group with the Phulchauki Group of central Nepal, as proposed by (Stöcklin & Bhattarai, 1977).
4. Kansakar & Chitrakar (1984) carried out the mapping of the Bheri river section, western corner of the Jajarkot Thrust Sheet. According to them, there are several thrust sheets in the area. They are mapped and named as the Chorpani nappe, Kumak nappe, Sallyan nappe, Marma-Jajarkot nappe, and Golyachaur-Chaurjhari nappe from south to north in the region. The boundary of the Jajarkot Thrust Sheet is not shown on this map.
5. Arita et al. (1984) carried out geological investigation of the Jajarkot crystalline zone and classified it as a klippe developed from the MCT zone. According to them, the Barigad Kaligandaki Fault (BKF) divides the thrust sheet into inner and outer belts.

6. Dhital and Kizaki (1987) have mapped the metamorphosed crystalline rocks of the Bheri River section under the Sharda Group. Later Dhital (1992, 2015) has shown the low- to medium-grade metamorphic crystalline rocks of the Karnali river basin under the Dailekh Group. The position of the Jajarkot Thrust Sheet is not demarcated clearly in the map.
7. DMG (2020) has shown the rocks of the Jajarkot Thrust Sheet within the Jaljala Subgroup, which contains two Precambrian rock units. They have not reported the fossiliferous succession in the Jaljala region.

The above points show that there is no consistency in the stratigraphy of the rocks in the Jajarkot Thrust Sheet.

CONCLUSIONS

The Jajarkot Thrust Sheet exhibits a lack of consistent stratigraphy. Existing research on the topic remains fragmented, offering incomplete coverage of the entire region. Discrepancies in the identification of the primary thrust boundary are evident in the geological map of Nepal, with variations observed among different authors. Furthermore, there exists a significant absence of stratigraphic correlation between different sectors of the thrust sheet, both in the east-west and north-south orientations. To address these inconsistencies and gaps, a comprehensive geological study adhering to established stratigraphic principles is imperative. Such an investigation will not only facilitate a more accurate stratigraphic framework for the thrust sheet but also enhance the interpretations concerning its underlying structures and the root zone of the thrust sheet.

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AUTHOR CONTRIBUTIONS

The concept of the manuscript writing was provided by Kabi Raj Paudyal and Ram Bahadur Sah. The literature collection and the first draft of the manuscript were prepared by Sunil Lamsal. The review was carried out by Kabi Raj Paudyal, and final discussion was made by all the authors of this manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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