Structural Geology Along the Nainital–Pangot Road (Kilbari Section), Nainital Lesser Himalaya (Uttarakhand, India): Focus on Back-Structures

Mohit Kumar Puniya and Soumyajit Mukherjee

Abstract This chapter presents an interesting track in the Lesser Himalaya aimed for structural geological fieldwork. We report back-structures, mainly back-faults, from the Nainital–Pangot road. We expect geological trainers will find this track interesting and will conduct tectonic fieldwork here. The Department of Geology (Kumaun University) is located close to this study area, and it will be very easy to bring the B.Sc. and M.Sc. students from this department in a say three day fieldtrip to demonstrate and explain these structures.

1 Introduction

The Himalayan mountain belt is an example of continent–continent collision, started 50–55 Ma and resulted in 60–75-km-thick lithosphere (Hauck et al. 1998; Nelson et al. 1996; Yin and Harrison 2000). This orogenic belt is characterized by compressional thrusts that generally dip toward N, NNE, or NNW directions. Crustal shortening and tectonic uplift of the Himalaya is mostly controlled by major thrusts such as the Main Central Thrust (MCT), the Main Boundary Thrust (MBT), the Himalayan Frontal Thrust (HFT), or the Main Frontal Thrust (MFT) and other associated structures within the Indian continental crust (Yin 2006; Mukherjee 2015; Goswami et al. 2020).

Recently, back-structures, back-folds and back-faults have been documented from several parts of the Himalaya (Mukherjee 2013; Bose and Mukherjee 2019a, b; Mahato et al. 2019). It appears that such structures are integral parts of collisional orogens.

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2 Geology of the Study Area

Kumaun Lesser Himalaya has been studied by several workers since long (e.g., Auden 1934; Heim and Gansser 1939; Fuchs and Sinha 1974; Hukku et al. 1974; Pal and Merh 1974; Pande 1974; Valdiya 1980; Kumar et al. 2017; Sah et al. 2018). The study area lies in the Outer Lesser Himalaya Sequence (LHS) sub-vertical road section along the Nainital–Pangot road for ~18 km was studied (Fig. 1). This section is also known as the Kilbari section locally. It is the northeastern part of a strip of en-echelon basins of the Krol belt. In this traverse, one encounters rocks of the Mussoorie Group (Valdiya 1988). The Mussoorie Group can be divided into, in an upward direction in the succession, Blaini Formation, Krol Formation, and Tal Formation in the investigated area. The main rock types in the area are quartzite of the Blaini Formation, pyrite-bearing slates of the Kailakhan Member (Infra-Krol), slates of the Manora Member (calcareous slates, greyish to greenish in color), purple slates of Hanuman Garhi Member (ferruginous slates), and dolomites of the Upper Krol Formation (Valdiya 1988).

The MBT is characterized by imbricating thrusts and faults (Valdiya 1984). Other major faults in this area are the Nainital lake fault (Middlemiss 1890), Bhumiadhar

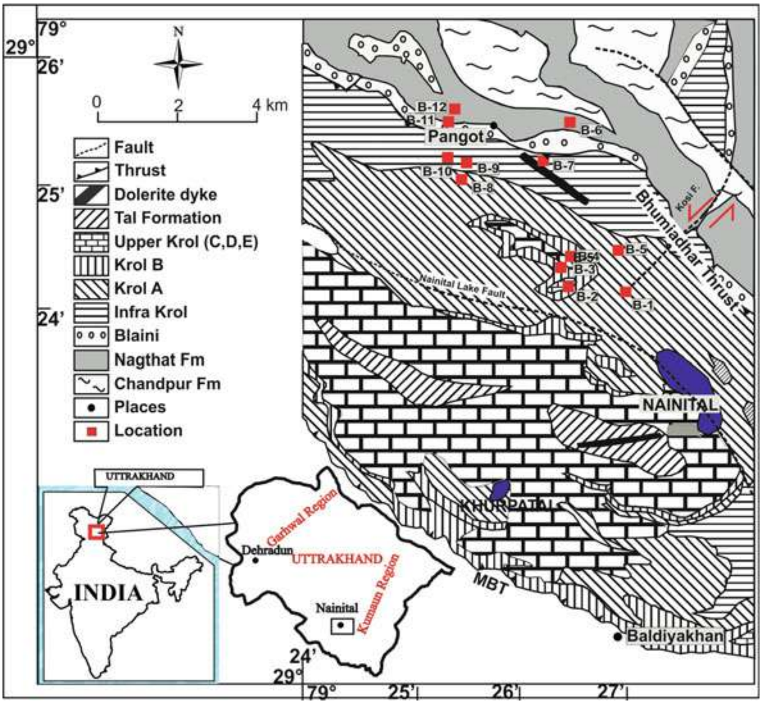

Fig. 1 Geologic map of the study area with back-structures locations. The map is reproduced from Valdiya (1980). Red boxes: back-structure locations

Thrust, Kosi Transverse Fault and the Manora Fault (Valdiya 1988) (Fig. 1). The Nainital Lake Fault passes through the Nainital Lake. This fault has dextrally offset the MBT near Beluwakhan west of Jeolikote (Valdiya 1984) and the Manora Fault near Alukhet (Fig. 1). Bhumidhar Thrust passes through the study area near Pangot village and mark the boundary between the Infra-Krol slate at the hanging wall and the Blaini quartzite at the footwall (Fig. 1). The Bhumiadhar Thrust is intersected by the Kosi Transverse Fault and displaced it sinistrally (Fig. 1).

3 The Present Study

A fieldwork was carried out along the Nainital–Pangot road ~18 km long in the Kumaun Outer Lesser Himalaya, Uttarakhand, India. This study focuses on the field observations of back-structures (Fig. 2). Also, one can document Himalayan fore-structures in the form of ductile top-to-south/-SSW shear (Figs. 3, 4). Back-structures are identified from here based on S-C fabrics, brittle minor faults (Fig. 2a, d, h) and P- and Y-brittle shears. P-planes slightly swerve close to the Y-planes (Fig. 2c).

In the Krol group of rocks, back shears are present in the form of fault planes (Fig. 2a; Table 1) and P- and Y-planes (Fig. 2b, c, e; Table 1) with top-to-north shear. The Blaini Formation rock is brittle top-to-NE back sheared. This is deciphered from faulted veins and P- and Y-planes (Fig. 2h; Table 1). Except back- structures, top-to-S shear are also documented in the form of P- and Y-planes and even asymmetric folds (Fig. 4).

This study was confined in the NNE portion of Nainital syncline of Mussoorie Group of rocks (Figs. 1 and 3). The Nainital syncline was faulted by the Nainital Lake Fault (NLF), with NNW trend (Valdiya 1988; Kumar et al. 2017; Sah et al. 2018). The nature and the geometry of the NLF were described by Valdiya (1988); it is a pivot type fault with the swing tip is in SW of study area (Fig. 1). The locking point of the NLF is near the outlet of the Nainital Lake (near the bus stand) in SSE direction of this traverse (Valdiya 1988; Kumar et al. 2017). There is one more transverse sinistral fault that displaced the Bhumiadhar fault in SE of the investigated area (Fig. 1). Our study area lies at the hanging wall block of the Bhumiadhar Thrust and the NLF. Due to these tectonic setting, there can be an extensional regime developed. Whether the back-structures in this region developed due to the combined effect of NLF, transverse fault, and Bhumiadhar Thrust needs to be studied.

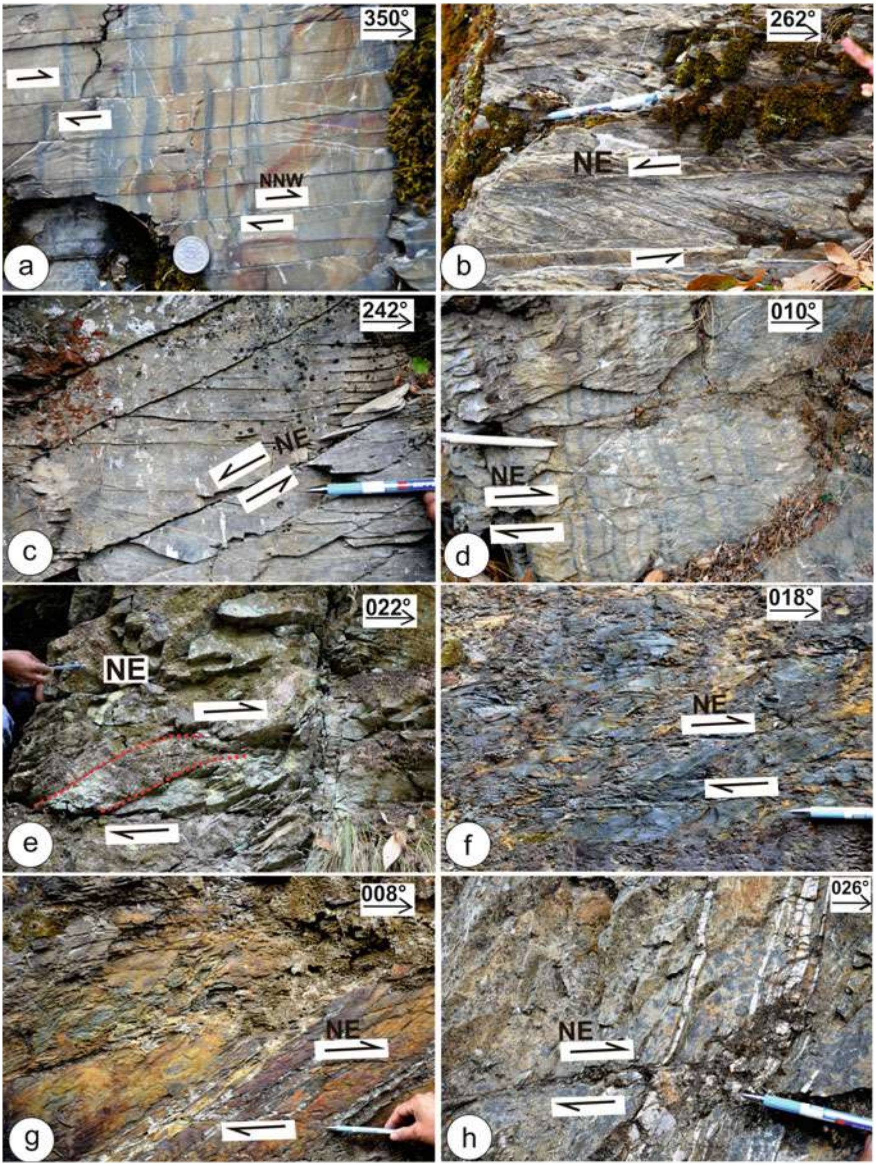

Fig. 2 Field photographs, **a** parallel normal faults show top-to-NNW slip. Fault plane attitude: 124°/29°-SW. Manora Slate, **b** S-C structure: top-to-NE shear. S-plane attitude: 010°/41°-NW; C-plane attitude: 340°/64°-SW. Manora Slate, **c** P- and Y-planes: Top-to-NE back-shear. P-plane attitude: 220°/21°-NW. Y-plane attitude: 170°/12°-SW. Slate, **d** parallel normal faults show top-to-NNW shear. Fault attitude: 330°/7°-SW. Slate of Krol Formation, **e** P- and Y-planes show top-to-NE back-shear. 'P'-plane orientation 330°/31°-SW and 'Y'-plane 340°/38°-SW. Slate, **f** P- and Y-planes: top-to-NE shear. P-plane attitude: 330°/45°-SW. Y-plane attitude: 340°/38°-SW. In slate, **g** P- and Y-planes show top-to-NE slip. P-plane attitude: 360°/31°-S. Y-plane attitude: 010°/30°-SW. In slate, **h** faulted veins in quartzite show top-to-NE back-slip. Normal fault plane's attitude: 285°/47°-NNE

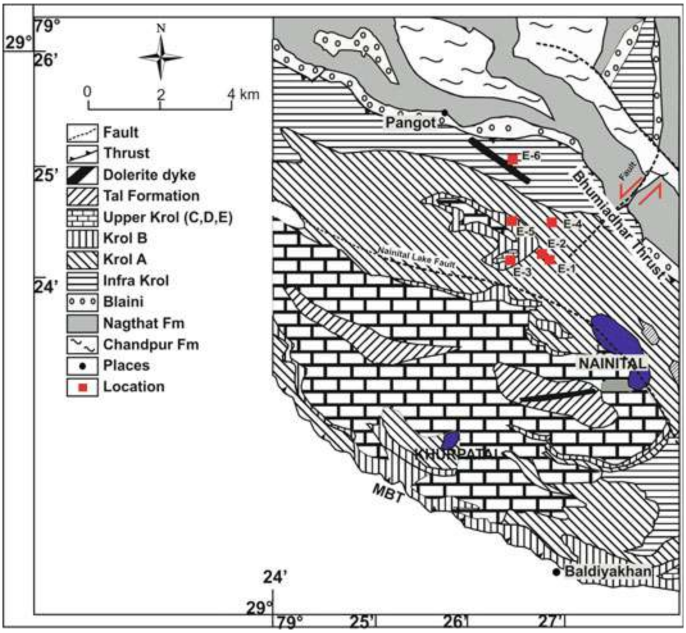

Fig. 3 Other field locations from where shear has been noted. The map is reproduced from Valdiya (1980). Red boxes: spot locations

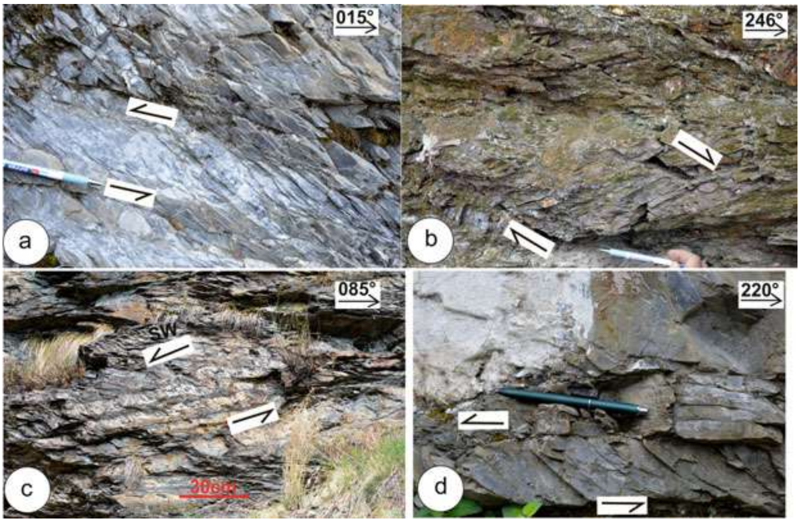

Fig. 4 Field photographs of shear senses, **a** pointed pen tip show NE shearing direction in Krol slate at location E-1, **b** brittle shearing show top-to-SW direction in Infra-Krol slate at location E-4, **c** asymmetric fold shows top-to-S slip. Location E-5, **d** P- and Y- brittle top-to-SSW shear. Location E-6

Table 1 Back-shear data table from the study area

Backthrust field data				
Location (see Fig. 1)	P-plane	Y-plane	shear sense	Location
B-1	010/41°-280°	340/64°-250°	Top-to-40°	29°24′13.3″, 79°26′54.4″
B-2	300/20°-210°	235/18°-325°	Top-to-N	29°24′19.5″, 79°26′40.7″
B-3	325/39°-235°	N-S/28°-W	Top-to-050°	29°24′33.5″, 79°26′39.6″
B-5	062/38°-SE	010/22°-100°	Top-to-N	29°24′49″, 79°26′55.6″
B-6	N/7°-W	235/30°-145°	Top-to-NNE	29°25′49″, 79°26′46.″
B-7	310/34°-220°	horizontal	Top-to-north	29°25′19.7″, 79°26′15.4.″
	290/30°-200°	horizontal	Top-to-355°	29°25′19.7″, 79°26′15.4.″
B-7	300/21°-210°	350/26°-260°	Top-to-N	29°25′19.7″, 79°26′15.4.″
B-8	330/35°-240°	340/20°-250°	Top-to-045°	29°25′03.7″, 79°25′44.2″
B-9	N/31°-S	010/30°-280°	Top-to-N	29°25′19.6″, 79°25′49.3″
B-10	260/18°-170°	245/21°-335°	Top-to-350°	29°25′28″N, 79°25′39.4″
B-11	315/26°-225°	350/34°-260°	Top-to-N	29°25′42.9″N, 79°25′23.6″
B-12	315/72°-225°	220/47°-310°	Top-to-30°	29°25′46.2″N, 79°25′23.3″

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