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Field and Petrographic Characteristics of Photang Thrust Sheet of Zanskar Tethys Himalaya, Ladakh, India

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ABSTRACT

The Photang thrust sheet is a distinct complex of rocks that lies under the Spongtang ophiolite, showing almost complete ophiolite sequences. The pre-collision tectonic setting, emplacement age, mechanism of association of diverse litho-units within Spongtang klippe, and their regional correlation is still debatable and partially known. The controversy exists as to whether the ophiolite was obducted onto the northern passive margin of the Indian plate during the Eocene or the late Cretaceous. Moreover, the fundamental question emerges whether the Photang thrust sheet is a part of the independent Spong arc, has been tectonically derived from the Ophiolitic Melange Zone in the Dras island arc, or is a representative of the accreted seamounts of the Indus suture zone. This paper presents the application of fundamentals of field geology and petrography to understand the pre-collision tectonic setting of the Photang thrust sheet, Spongtang ophiolite, and associated rock sequences in the Photoksar region of the Zanskar Himalaya.

Keywords: Photang thrust sheet, Spongtang ophiolite, Tectonic setting, Obduction, Ophiolitic Melange Zone, Indus suture zone, Himalaya

1. INTRODUCTION

The Neo Tethys Ocean closed along the Indus Suture Zone (ISZ) in the south and the Shyok Suture Zone (SSZ) in the north when the Indian and Asian plates collided (Upadhyay et al., 1999; Steck, 2003). In the Ladakh-Zanskar region of northwest Indian Himalaya, rocks of the tectonic junction of ISZ are well exposed. Two groups of ophiolites have been documented north and south of the ISZ. These are considered to have been emplaced during the Indo-Asia convergence after the Neo-Tethys Ocean closure (Maheo et al., 2004). The southern Spongtang ophiolitic complex shows an almost complete sequence of ophiolites. This complex is overlain by island arc (Spong arc) related rocks of the Late Cretaceous. Beneath the Spong arc and Spongtang ophiolite, the Photang Thrust Sheet (PTS) runs in the southeast direction and has been interpreted as an accretionary complex (Corfield et al., 2001). The PTS consists of rocks of tectonic melanges and volcanic units associated with marine sediments. Below the PTS lies the Mesozoic argillaceous continental slope deposits of the Lamayuru complex. The Lamayuru complex is further underlying by the shallow marine rocks of the Zanskar Supergroup. The studies done in this region suggest that a subduction zone must have been formed that was responsible for the formation of the Spong arc andesites (Corfield et al., 2001). This resulted in the southward transportation of the Spongtang ophiolite onto the Indian plate and the Spong arc sequence over it (Buckman et al., 2018). It was also responsible for developing the SW-directed low-angle thrust system over time. This thrust system emplaced the Photang thrust sheet and other rock sequences below it onto the north Indian passive continental margin.

Although various studies have been done so far, it is still unknown whether the Photang thrust sheet belongs to the Spong arc or has been tectonically derived from the Ophiolitic Melange Zone in the Dras island. Another possibility is that it may represent accreted seamounts of the Indus suture zone that now lies about 40 km north in the Ladakh region of the northwest Himalaya. This paper presents the outcrop relationship of the different rock units of the study area. The combined study of field geology and petrography has helped in understanding the pre-collision tectonic setting of the Photang thrust sheet, Spongtang complex, and associated sequences of the study area.

2. GEOLOGICAL SETUP AND STUDY AREA

The study area lies in the Photoskar village of the Zanskar Himalaya (Ladakh), India (Figures 1 & 2). This is part of the Tethys Himalaya, which lies between the High Himalayan Crystalline Sequence (HHCS) in the south and the ISZ in the north (Fig. 1). The ISZ is characterized by the presence of ophiolitic melanges that indicate the zone of closure of the Tethys Ocean. In the Ladakh Himalaya, two zones of ophiolite and ophiolitic melange crop out north (Dras ophiolite) and south (Ladakh ophiolite) of the ISZ which are said to have been formed due to the Late Cretaceous subduction followed by accretion of the Neo-Tethys oceanic lithosphere (Frank et al., 1977; Thakur, 1981; Searle, 1983).

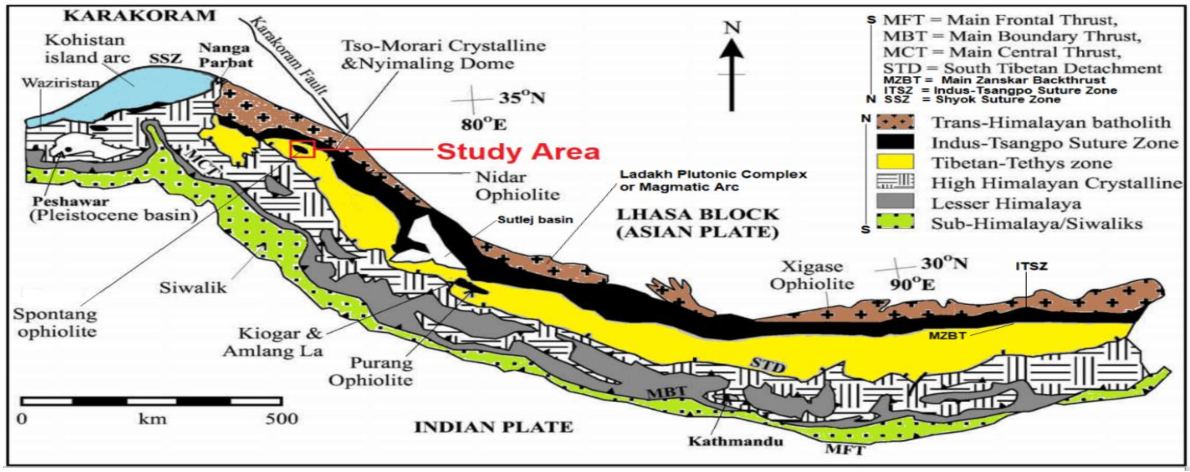


Figure 1. Litho-tectonic subdivisions of the Himalaya, show the location of the main structural features of the orogen (modified after Corfield et al., 2001).

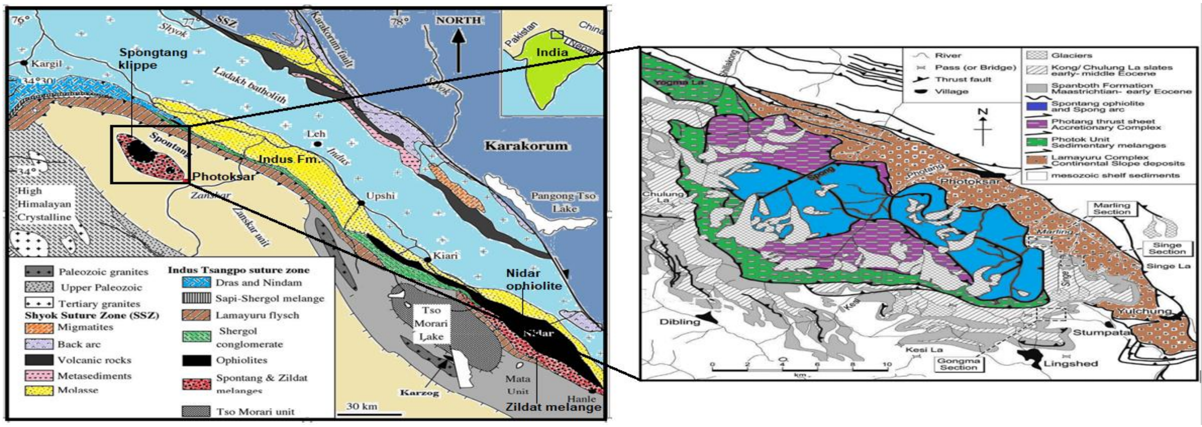


Figure 2. Geological map of Ladakh-Zanskar Himalaya (modified after Maheo et al., 2000).

In this area, the Photang Thrust Sheet (PTS) lies beneath the Spongtang klippe and overlies the Late Cretaceous-Tertiary sediments of the Zanskar Tethys Himalaya (Fig. 2). In the Photoksar region, the Spongtang complex is overlain by an island arc (Spong arc) related rock such as andesites, dacites, and volcaniclastics. These rock units crop out around the northeastern side of the Spongtang ophiolite (Fig. 2). The Spong arc is interpreted as an island arc and is formed in an island-arc setting. The Photang Thrust sheet runs continuously in the SE direction below the Spongtang ophiolite and Spong arc (Fig. 2). It comprises tectonic melanges and volcanics associated with the oceanic sediments. The thrust plane lies between the Spongtang ophiolite and the PTS and is referred to as the Spongtang thrust, which dips in the SE direction (Figures 1 & 2). The top of the thrust sheet is marked by a fuchsite-bearing mylonite, separating serpentinized harzburgites above from the lavas, carbonates, and volcanics of the PTS below. The rock sequence of the PTS in this area comprises limestone blocks surrounded by lavas and interbedded with grey shales and bedded grey fossiliferous limestone. In the SW direction of the Photoskar area, deep-water fossiliferous black-red slates lie beneath the PTS. Lamayuru Formation underlies the Photoskar Unit. This passive marginal sedimentary complex is considered pre-orogenic flysch deposited on the Indian continental slope that overlies the Mesozoic Zanskar supergroup of rocks (Bassoullet et al., 1981; Sinha and Upadhyay, 1993 b). It extends along the ISZ, from the Dras valley in the northwest to the Tso-Morari region in the southeast (Fuchs and Linner, 1996).

3. METHODOLOGY

The methodology adopted for the present work consists of a detailed field study followed by a petrographic study of the rock samples collected from the study area. Field investigations were carried out to understand the geological and structural setup of the study area, the nature and type of the various lithounits, and their mutual field relationship. During the fieldwork, the representative rock samples were collected at a height ranging from 4361 to 5016 meters and from area lies within the Latitudes: 33.97203N to 34.08123N) and Longitudes: 76.48299E to 76.90027E (Fig. 2). Thin-sections of the representative rock samples were prepared, and petrographic features at various resolutions were documented using the Leica polarizing microscope at Department of Geology, Centre for Advanced Studies, Kumaun University, Nainital, India. The photomicrographs were taken using the digital camera attached to this microscope.

4. FIELD OBSERVATIONS

During the field study, a distinct thrust sheet massif has been identified around 5 km west of Photoksar village in the Zanskar Himalaya that lies beneath the NW and SE sides of Spongtang ophiolite and above the shales of the Lamayuru complex (Fig. 2). This thrust sheet is the Photang thrust sheet (PTS) which is exposed along the of the Spongtang ophiolite (Fig. 2). It consists of tectonic melanges and volcanic rocks associated with oceanic sediments. The average thickness of this unit is approximately 500 meters, exposed along the left bank of the Photang stream in the Photoksar valley. The top of the thrust sheet is demarcated by fuchsite-mylonite. This fuchsite-bearing mylonite indicates a thrust zone known as the Spongtang thrust that separates the PTS from the overlying Spongtang ophiolite complex. The Spongtang thrust indicates a zone of imbricated thrust that separates serpentinized harzburgites (Fig. 4. A) and other ultramafic rock units of the Spongtang ophiolite above from the lavas and carbonates of the Photang thrust sheet below (Fig. 4, & Table 1&2). The basal Photang thrust separates the basaltic volcanic rocks and carbonates of the PTS above from the continental slope deposits (slates and sandstones) of the Lamayuru complex below (Fig. 2 and Table 1). The PTS in the field is characterized by alkaline volcanic rocks interbedded with exotic limestones. At the base of the PTS, sandstone and shale of the Lamayuru formation have been found, which contain dark calcareous fossil nodules (Fig. 3. A). Carbonates of the Fatula Formation underlie the Lamayuru Formation with a thrusted contact (Figures 2, 3. B & Table 1). To the north of the Bumiktse La, the hanging wall block of the Photoksar break back-thrust is exposed, which is responsible for the thickening in the Fatu La pelagic carbonates. Sheath folds within the Fatu La formation are highly non-cylindrical structures, indicating large differential flow found within thrust and shear zones (Fig. 3 B). In these folds, some axial regions may advance relative to other parts. Axes of the fold become folded, in some cases so markedly that a fold may look like the tongue or finger of a glove or knife's sheath.

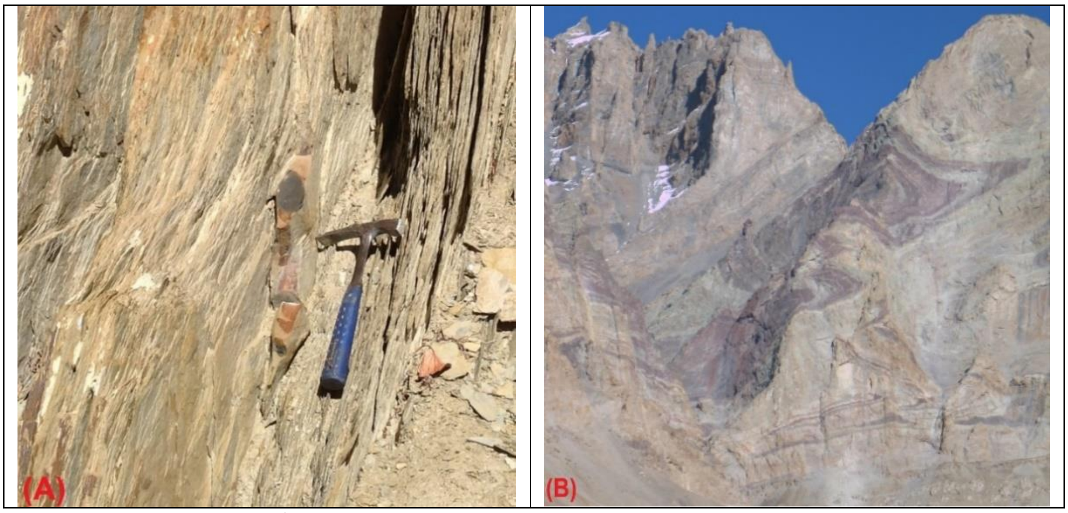


Figure 3. (A). The dark calcareous fossil nodules in the Lamayuru complex (along the Photang valley), and (B). The Fatula carbonate shows a sheath folding.

Altitude in meters	Litho-tectonic units	Lithology
5000	Spong arc	Andesites, dacites, and volcaniclastics
---Thrust---		
4730	Spongtang ophiolite	Harzburgites, dunites, and peridotites, lower crustal gabbro cumulates, upper crustal diorites and sheeted dykes, pillow lavas, and oceanic sediments
---Thrust---		
4550	Photang thrust sheet and Photok unit	Limestone, alkaline volcanics, alkali basalt, volcanic breccias, carbonate blocks, cherts, dark shales, basaltic lavas with carbonate bodies, vesicular pillow lavas, volcaniclastics, and serpentinized mylonite. Stratified black-red slates
---Thrust---		
4320	Lamayuru complex	Grey-black slates interbedded with the calcareous and weathered sandstones
---Thrust---		
3970	Fatula Formation	Carbonates

Table 1. The litho-tectonic sequence of the study area (Photoksar region of the Zanskar Himalaya).

From base to top, the whole litho-tectonic sequence of the PTS consists of bedded limestone, alkaline volcanics, alkali basalt, volcanic breccias and carbonate blocks, limestone, grey/green shales and blocks of ammonitic limestone, blocks of carbonates and breccias associated with mudstone, massive alkaline volcanic rocks with thin limestone bands, basaltic lavas with carbonate bodies, vesicular pillow lavas, sandy brown coloured limestone and marl, orange coloured weathered volcaniclastics, and fuchsite and calc serpentine mylonite (Fig. 4. A to H, & table 2). White and pink coloured limestones fill vesicles within the green/pink pillow lavas (Fig. 6. C). The green/pink pillow lavas laterally grade towards fine-grained greenish-grey sandstone. The pillow lava is about 15 m thick, followed by 20 m thick fine-grained sandstone. This sandstone has lenses of sulfide mineralization (pyrite crystals, Fig. 6. D).

Serpentinized harzburgite and other ultramafic igneous rocks
----------------------- Spongtang Thrust---------------------
Serpentine mylonite
----------------------Fault ----------------------
Orange-coloured weathered volcaniclastics
------- Erosional surface (Unconformity) --------
Sandy-brown limestone and marl
------- Erosional surface (Unconformity) --------
Vesicular pillow lavas (Pinkish limestone filled in pillow voids)
------- Erosional surface (Unconformity) -------
Basaltic lavas with carbonate bodies
------- Erosional surface (Unconformity) -------
Massive alkaline volcanic rocks with thin limestone bands
----------------------- Fault ------------------------
Limestone
------- Erosional surface (Unconformity) -------
Alkali basalt, volcanic breccias and carbonate blocks
------------------------ Photang Thrust ----------------------

Table 2. Tectono-stratigraphic sequence of the studied area (Modified after Corfield et al., 1999)

The Photang thrust characterizes the base of the PTS. In this zone, the rocks are highly deformed, sheared, and brecciated due to intense deformation along the Photang thrust (Fig. 4). Upwards from the thrust plane, the degree of deformation decreases, and a relatively undeformed succession of altered rock units are found. The Photang thrust sheet comprises a basal Photang thrust, separating brecciated and sheared volcanics, sand/carbonate bodies below, and alkali basalt, volcanic breccias and carbonate blocks above (Fig. 4. A to H). These volcanic rocks and carbonate blocks are unconformably overlain by limestone. The limestone from above is separated by a fault zone consisting of carbonates and breccias associated with mudstone, overlying grey/green shales, and blocks of ammonitic limestone (Fig. 4. F). This fault zone is overlain by massive alkaline volcanic rocks with thin limestone bands (Fig. 4. E). These massive alkaline volcanic rocks are unconformably overlying by the basaltic lavas with narrow bands of carbonate bodies. Vesicular pillow lavas unconformably overlie the basaltic lavas with carbonate bodies. This lava's vesicles or pillow voids are filled with pink-colored calcite crystals (Fig. 6. C & Table 2). The vesicular pillow lava (Fig. 4. D) is unconformably overlain by sandy-brown limestone and marl (Fig. 4. C), which is unconformably overlain by the orange-color weathered volcaniclastics at the top of the PTS (Fig. 4. B & Table 2).

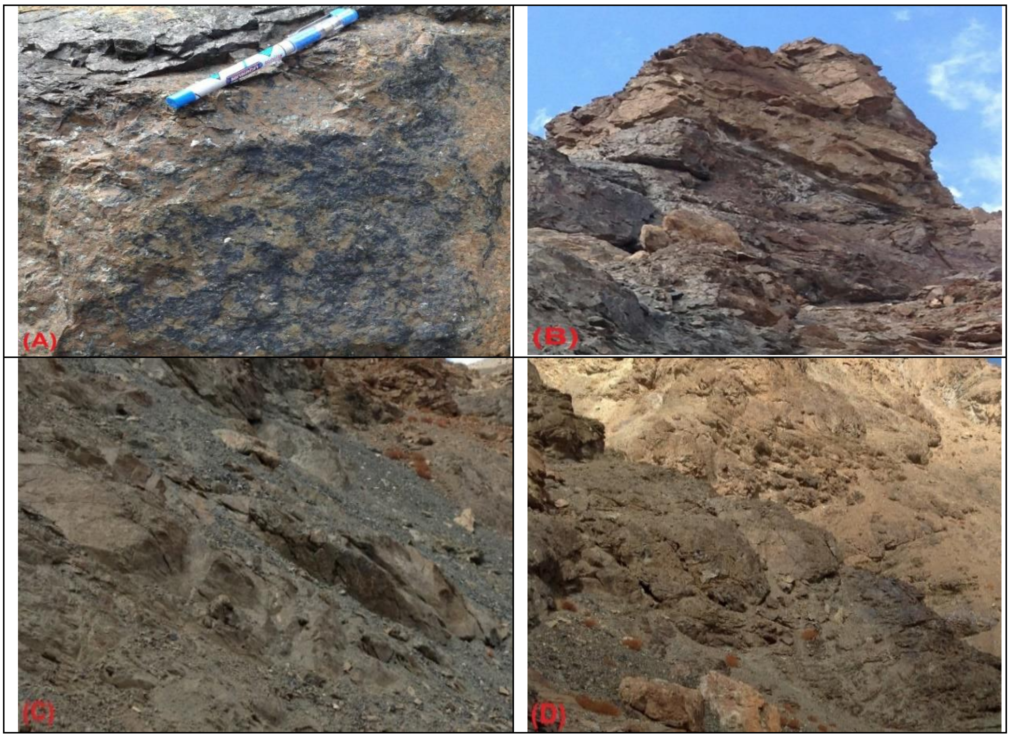
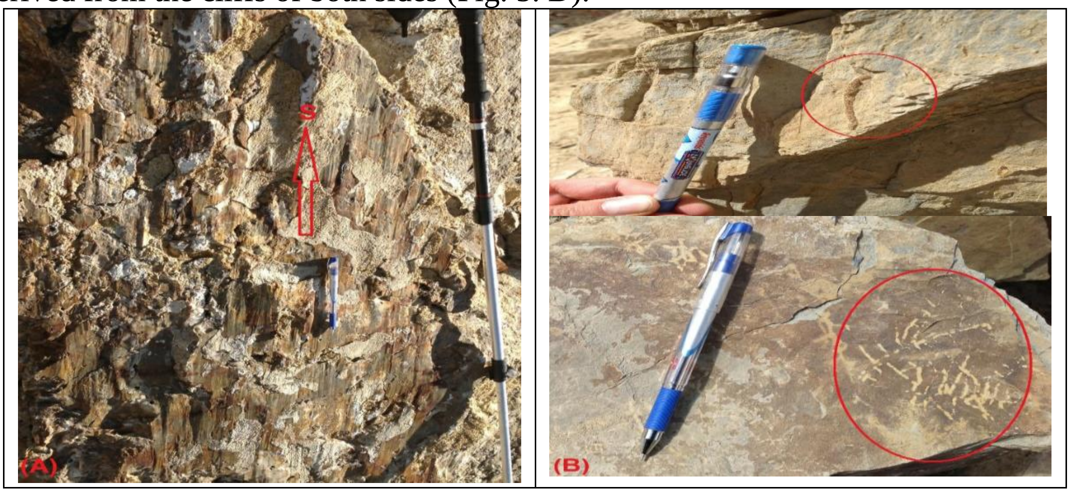


Figure 4. field photographs of the Photang thrust sheet, rock units from the base to upwards showing: (A). Serpentinized harzburgite of the Spongtang ophiolitic complex, (B). Orange-coloured weathered volcaniclastics below the Spongtang thrust, (C). Sandy-brown limestone and marl, (D). Vesicular pillow lavas, (E). Basaltic lavas with carbonate bodies, (F). Grey/Green shales and blocks of ammonitic limestone, (G). Blocks of carbonates and breccias associated with mudstone, and (H). Alkaline volcanics at the base above the Photang thrust.

On the southern cliff of the Photoksar village, the right bank of the Photang stream at an elevation of 4361 meters, we encountered a highly fractured massive greyish-brown sandstone (or quartzite). Slickensides are seen over this sandstone which shows southward movement. The fracture planes within sandstone are occupied by remobilized quartz veins which sometimes show perfect transparent quartz crystals (Fig. 5. A). This sandstone unit is tectonically emplaced over the Lamayuru unit. The tectonic juxtaposition of this unit suggests a slice may be the lower part of the ophiolitic klippe and emplaced from the north. Area left bank of the Photang stream, in the upstream direction of the Photoksar valley, calcareous slates containing marine trace fossils of *Skolithos* (Fig. 5. B). The flute casts and faint symmetrical ripple marks are seen over the bedding plane of this argillaceous unit (Fig. 5. C). On the Photoksar valley floor, boulders of chert, pillow lava, volcanics, and ultramafic rocks are derived from the cliffs of both sides (Fig. 5. D).



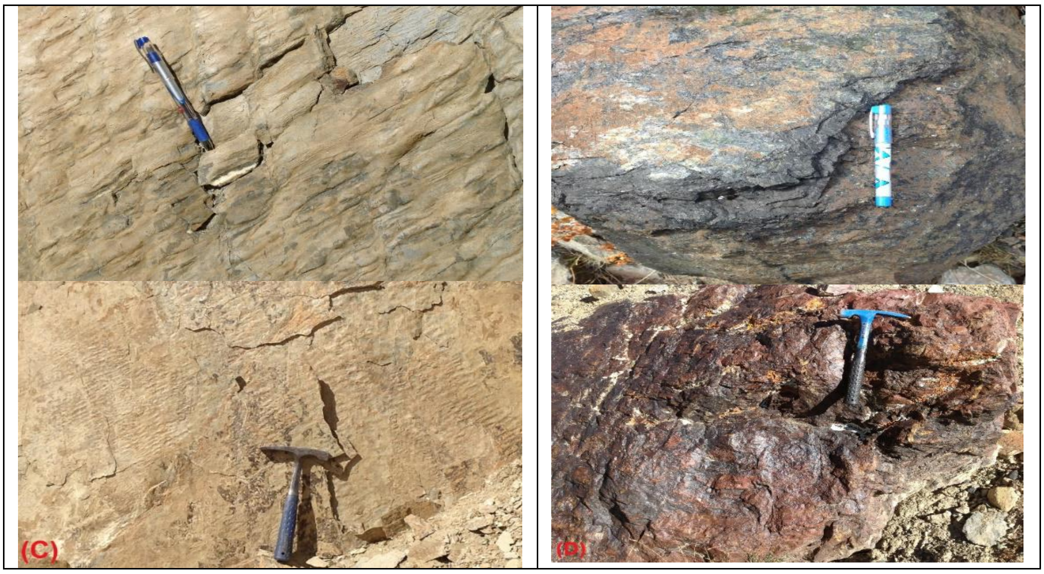
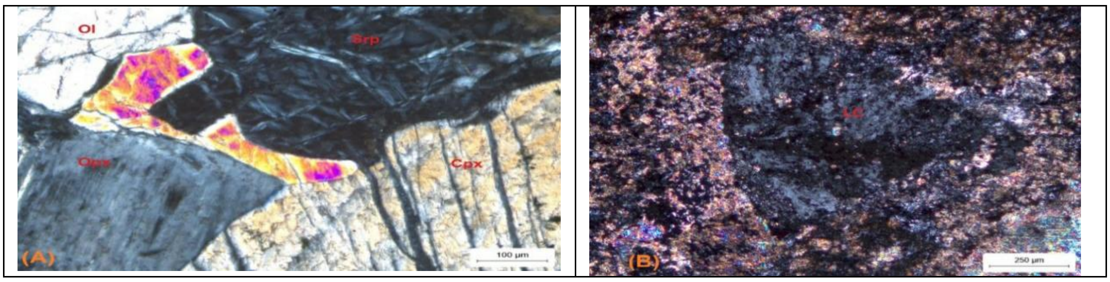


Figure 5. (A). Showing the slickensides over the surface of sandstone and fractures filled by remobilized quartz veins, the arrow indicates the southward movement direction, (B). Showing the marine trace fossils of the Skolithos ichnogenus in the Lamayuru formation, (C). The flute casts and faint symmetrical ripple marks are present over the bedding surface of the Lamayuru Formation, (D). Boulders of harzburgite and Chert on the valley floor of the Photoksar region.

5. PETROGRAPHY

Petrographic thin sections of the samples collected from study area were prepared. Some representative photomicrographs of these thin sections have been shown in Figure 8. Harzburgite of the Spongtang complex that overlies the PTS shows porphyroclastic texture (Fig. 6. A). The olivine (Ol) and serpentine (Srp) grains show undulatory extinction and kinking. Olivine has lobate margins with the orthopyroxene grains (Fig. 6. A) in a coarse-grained serpentinized harzburgite, exhibiting evidence of mantle melting. It also shows exsolution lamellae of clinopyroxene in orthopyroxene and of orthopyroxene in clinopyroxene, indicating the sub-solidus equilibration. Weathered volcaniclastic rocks that underlie the Spongtang ophiolite complex show a lithic clast in a thin section (Fig. 6. B). Underlying vesicular pillow lavas show interstices filled with calcite mineral grains (Fig. 6. C). The vesicular pillow lava grade into sandstone that show lenses of the sulphide mineralization in the form of pyrite crystals in the thin section and was also seen in the field (Fig. 6. D). The sandstone is followed by massive alkaline volcanic rock (alkali-basalt) with bands of limestone. Thin section shows successive bands of calcite (Cal) crystals within the alkali-basalt, and these calcite crystals are surrounded by the plagioclase laths (Fig. 6. E). Beneath the alkaline volcanic rock is found a reddish silica-rich mudstone associated with blocks of carbonate and breccias, shown by thin section microphotographs (Fig. 6. F). Rhombohedral cleavage of calcite crystals is quite visible in the limestone beneath the siliceous mudstone (Fig. 6. G).



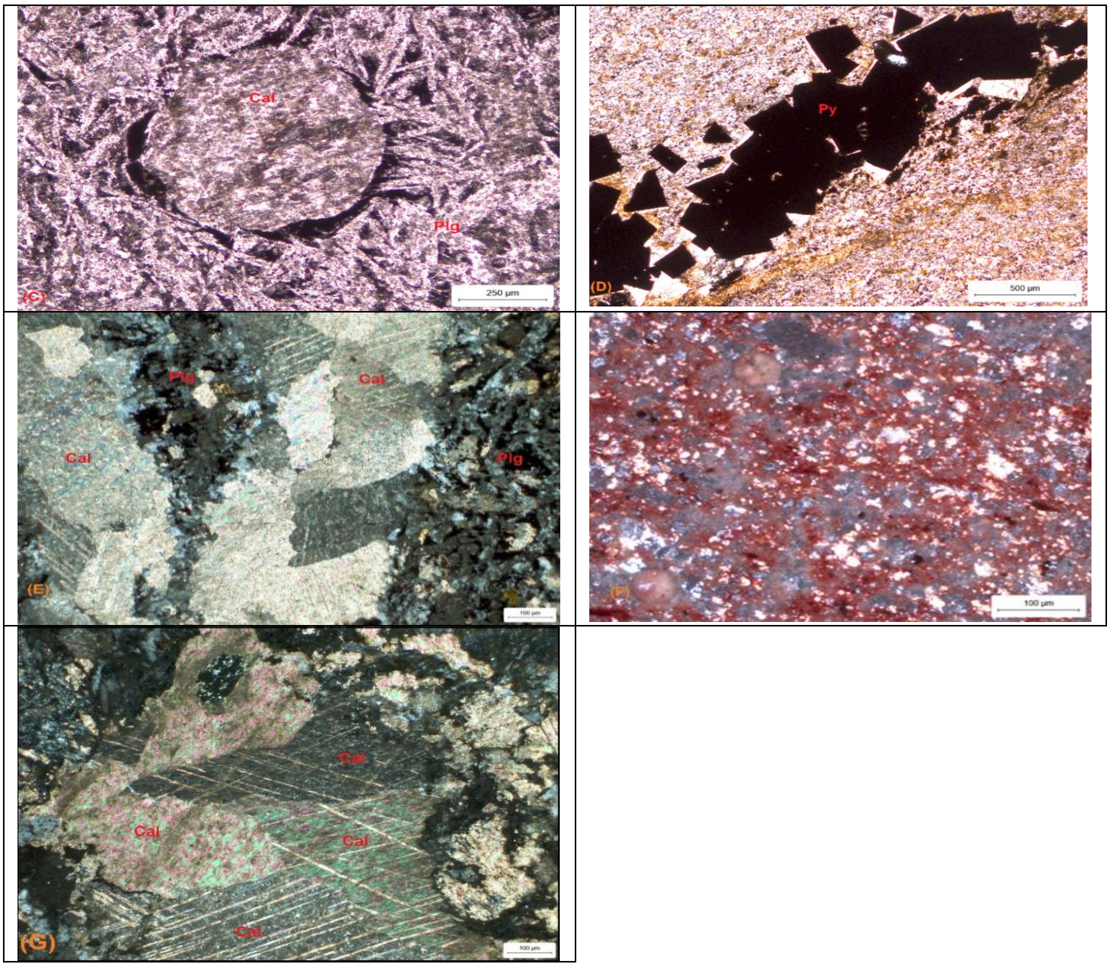


Figure 6. Some representative photomicrographs of thin sections from the Photang thrust sheet: (A). Show serpentine and clinopyroxene have lobate margins in a coarse-grained serpentinized harzburgite, (B). Weathered volcaniclastic rock showing a lithic-clast, (C). Vesicular pillow lavas showing interstices filled with calcite, (D). Showing lenses of the sulfide mineralization (pyrite crystals) in sandstone, (E). Photomicrographs of alkaline volcanic rock (alkali-basalt) with bands of limestone, (F). Photomicrographs of red coloured siliceous mudstone, and (G). Rhombohedral cleavage of calcite crystals are quite visible in the limestone

6. DISCUSSION AND CONCLUSION

The northward movement of the Indian plate and collision with the Asian continental plate resulted in the emplacement of ophiolites and ophiolite-related rocks. Ophiolitic melanges are essential constituents of several collisional zones, including the Indus Suture Zone (ISZ). Two groups of ophiolites have been documented north and south of the ISZ. The dismembered Dras and Sapi-Shergol ophiolitic melange are present towards the north, whereas the Spongtang-Nidar-Karzog ophiolitic melange is present towards the south. Previous researchers have proposed that in the ISZ, ophiolitic melanges represent the off-scraped blocks of the Tethyan oceanic lithosphere, and they reported rock blocks of the large oceanic seamounts incorporated into a chaotic accretionary prism with a sedimentary matrix (Thakur, 1981; Corfield et al., 1999, 2001; Garzanti et al., 2005; Maheo et al., 2004).

In the present study, field characteristics and petrographic details of the rocks associated with PTS from the Ladakh-Zanskar Himalaya have been studied in detail. Five major litho-tectonic units have been recognized in the present study area. These are the Fatu La Formation, Lamayuru complex, Photang thrust sheet, Spongtang ophiolite, and Spong arc from bottom to top. These litho-units are separated by thrust planes located between them. The Fatu La Formation is the Zanskar passive margin of the Indian plate and consists of carbonates. This formation is underthrusted by the continental slope deposits of the Lamayuru complex and consists of slates interbedded with calcareous and weathered sandstones. The Lamayuru complex is overlain by the Photang thrust sheet that lies beneath the Spongtang ophiolite complex. A fuchsite-bearing mylonite marks the top of the Photang thrust sheet, separating serpentinized harzburgites above from the lavas, carbonates, and volcanics of the PTS below. The Spongtang ophiolite complex consists of the upper mantle section of ultramafic igneous rocks (harzburgites, dunites, and peridotites), lower crustal gabbro cumulates, upper crustal diorites and sheeted dykes, pillow lavas, and oceanic sediments. The Spongtang ophiolite is overlain by the Spong arc consisting of andesites, dacites, and volcaniclastics. The Spong arc is interpreted as an island arc and formed in an island-arc setting.

The Spongtang complex includes all the lithological components of an ophiolite in the study area. Thus, it is concluded that the Spongtang massif is a remanent part of the oceanic lithosphere and is emplaced onto the northern passive margin of the Indian plate during the convergence of two continental landmasses, i.e., the Indian and Asian plates. The petrographic evidence indicates that the serpentinized harzburgite of the Spongtang ophiolite complex shows porphyroclastic texture. The olivine grains have lobate margins with the orthopyroxene grains, exhibiting evidence of mantle melting. The Photang thrust sheet is a litho-tectonic unit that underlies the Spongtang ophiolite complex. Based on the field and petrographic observations, it shows a chaotic mixture of varied lithologies and rock blocks from different origins. This tectonic melange consists of serpentinized mylonite, alkaline volcanic rocks, and deep-oceanic sediments and is overlain by pelagic carbonates. Thus, the Spongtang ophiolite and overlying Spong arc must have been located in the oceanic plate of the subduction zone. The Photang thrust sheet (tectonic melange) formed on this plate during the convergence of two oceanic plates located between the Indian and Asian continental plates. Over time, during the northward movement of the Indian plate, this convergence was responsible for the detachment of the oceanic lithosphere and southward transportation of the Spong arc, Songtang ophiolite, Photang thrust sheet, and the Lamayuru complex onto the north Indian passive continental margin.

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Conflict of Interest: None

REFERENCES

1. Bassoullet J P, Colchen M, Marcoux J, Mascle G. Field evidences for continental rifting in Triassic time in the Ladakh part of the Indus suture zone Geol. Ecol. Studies Qinghai-Xizang Plateau 1, Science Press, Beijing. 1981; 579-586.
2. Buckman S, Aitchison J C, Nutman A, Bennett V, Saktura W M, Walsh J, Kachovich S, Hidaka, H. The Spongtang Massif in Ladakh, NW Himalaya: An Early Cretaceous record of spontaneous, intra-oceanic subduction initiation in the Neotethys. Gondwana Res. 2018; 63:226-249.
3. Corfield R I, Searle M P, Green O R. Photang thrust sheet: an accretionary complex structurally below the Spongtang ophiolite constraining timing and tectonic environment of ophiolite obduction, Ladakh Himalaya, NW India. Journal of the

Geological Society, London. 1999; 156(5):1031-1044.
4. Corfield R I, Searle M P, Pedersen R B. Tectonic setting, origin, and obduction history of the Spongtang Ophiolite, Ladakh Himalaya, NW India. The Journal of Geology. 2001; 109(6):715-736.
5. Frank W, Thoni M, Pertscheller F. Geology and petrography of Kulu-South Lahul area. Colloques lnternationaux du Centre National de la Recherche Scientifique. 1977; 268/2:147-172.
6. Fuchs G, Linner, M. On the geology of the suture zone and Tso Morari dome in Eastern Ladakh (Himalaya). Jahrbuch Der Geologishen Bundesanstalt. 1996; 139(2):191-207.
7. Garzanti E, Sciunnach D, Gaetani, M. Discussion on subsidence history of the north Indian continental margin, Zanskar-Ladakh Himalaya, NW India. Journal of the Geological Society, London. 2005; 162:889-892.
8. Maheo G, Bertrand H, Guillot S, Mascle G, Pecher A, Picard C, De Sigoyer J. Evidence of a Tethyan immature arc within the south Ladakh ophiolites (NW Himalaya, India). C. R. Acad. Sci. Ser. II A. Sci. Terre Planetes. 2000; 330:289-295.
9. Maheo G, Bertrand H, Guillot S, Villa I M, Keller F, Capiez P. The south Ladakh ophiolites (NW Himalaya, India): an intra-oceanic tholeiitic origin with implication for the closure of the Neo-Tethys. Chemical Geology. 2004; 203(3):273-303.
10. Searle M P. Stratigraphy, structure, and evolution of the Tibetan-Tethys zone in Zanskar and the Indus suture zone in the Ladakh Himalaya. Transactions of the Royal Society of Edinburgh. Earth Sciences. 1983; 73:205-219.
11. Sinha A K, Upadhyay R. Mesozoic Neo-Tethyan pre-orogenic deep marine Sediments along the Indus-Yarlung Suture, Himalaya. Terra Nova. 1993 b; 5:271-281.
12. Steck A. Geology of the NW Indian Himalaya. Eclogae Geologicae Helvetiae. 2003; 96(2):147-196.
13. Thakur V C. Regional framework and geodynamic evolution of the Indus-Tsangpo suture zone in the Ladakh Himalayas. Trans. R. Soc. Edinb. Earth Sci. 1981; 72(02):89-97.
14. Upadhyay R, Chandra R, Sinha A K, Kar R K, Chandra S, Jha N, Rai H. Discovery of Gondwana plant fossils and palynomorphs of Late Asselian (Early Permian) age in the Karakoram block. Terra Nova. 1999; 11:278-283.

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