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Occurrence of pseudotachylites in the vicinity of South Almora Thrust zone, Kumaun Lesser Himalaya

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Thin veins of pseudotachylites are observed within the South Almora Thrust (SAT) zone of the Almora crystallines, Kumaun Lesser Himalaya. The SAT zone presents a relatively wide variety of mylonite types. Within this zone thin, dark-coloured veins of pseudotachylites are found. Folded veins of irregular thickness are also observed. The pseudotachylites are formed by rapid crystallization of melts. Intense deformation and friction-related heating is generated during the thrust sheet movement, which is responsible for producing the melts. Small amount of melts generated during the frictional heating cool rapidly in association of the wall rock and form thin veins, which have sharp boundaries (or folded) within the wall rock. Quartz, K-feldspar and plagioclase occur as porphyroclasts in the host rocks.

Keywords: Frictional heating, melts, mylonite, pseudotachylites, veins.

THE Almora Crystalline Zone (ACZ) is one of the largest and better-studied crystalline outcrops of the Lesser Himalaya, extending almost WNW-ESE and tectonically bounded on both the sides by sedimentary rocks. These are believed to be the remnants of a large thrust sheet that has moved from the Higher Himalayan Crystalline Zone along the Main Central Thrust (MCT) to rest over the Lesser Himalayan Sedimentary Belt. ACZ is basically characterized by asymmetrical synformal structure. The unit is delineated along the two flanks by the South Almora Thrust (SAT) and the North Almora Thrust (NAT)[1–7] (Figure 1). ACZ is characterized by the typical occurrence of a variety of mylonite types along its southern boundary (SAT) and is marked by a high degree of shearing, pulverization and recrystallization of rocks[8,9].

Mylonites are a special kind of metamorphic rocks that form in both ductile and ductile–brittle shear zones, and accommodate intense strain dominantly through ductile processes[10]. Mylonites have two types of constituents, i.e. matrix and porphyroclasts[11]; the matrix is composed of the more ductile elements of the rock. A true mylonite is composed of 10–50% porphyroclasts[12]. The heat transfer during thrusting has left signatures in rocks deformed during this process and show changes in the textural and chemical composition in the rocks of ACZ, which exhibit intense shearing and deformation along the northern and southern margins and are highly mylonitized[8]. Though mylonites from ACZ have earlier been described by many workers[5,6,13,14], a detailed study of them in the vicinity of the SAT zone (both the footwall block rocks as well as the hanging wall block rocks) has revealed interesting occurrence of pseudotachylites, which are reported here and would help in understanding the tectonic evolutionary history of ACZ.

In the present study the mylonite zone has been traced all along the southern boundary of the Almora unit, i.e. SAT. The hanging wall along the SAT has typically mylonitic rocks exposed, whereas to the south the footwall block has massive (north-dipping) Nagthat quartzites with their constituents showing prominent deformation (mylonitization), with a well-developed stretching lineation. The mylonitic rocks, in general, show a prominent schistosity as defined by the alignment of ellipsoidal quartz and sometimes by feldspar grains and their aggregates (Figure 2).

A zone of intense deformation was observed during the course of the present study (Figure 3) and the samples were subjected to detailed petrographic studies. It is interesting to note that the samples were collected from within the ultramylonites[6]. This zone shows occurrences of pseudotachylites[15,16] in the form of veins, which have either produced within the host rock. They are formed by rapid crystallization, and are chemically and mineralogically layered. The veins of pseudotachylite also occur as pairs of parallel surfaces, connected by injection veins (Figure 4 *c*). Injection veins are more conspicuous and allow recognition of pseudotachylites within the outcrop. The veins of pseudotachylites have distinct, sharp, straight boundaries with the wall rock. K-feldspar and

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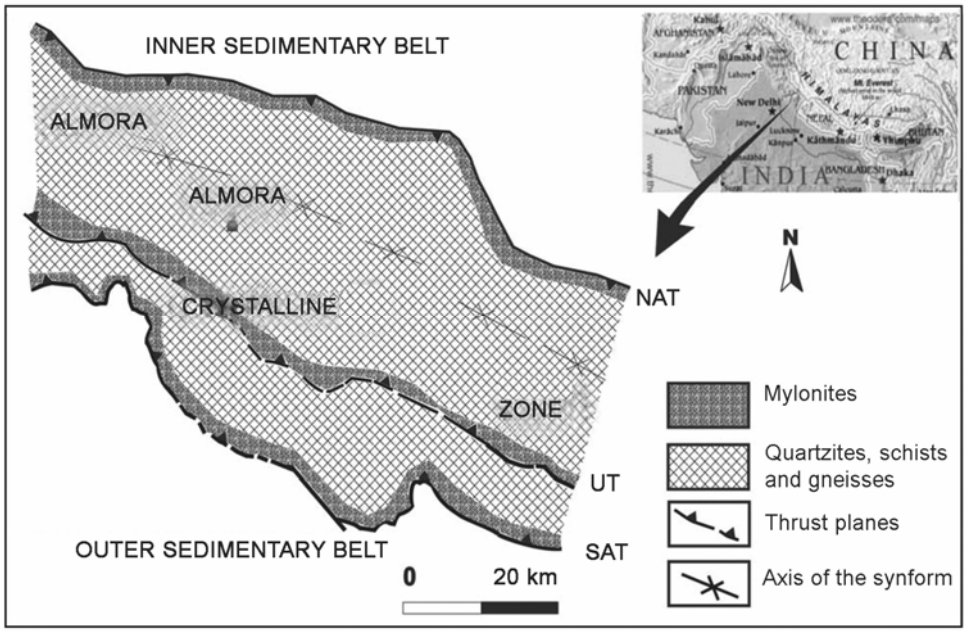

Figure 1. Schematic map of Almora Crystalline Zone (ACZ; modified after Valdiya[7]). SAT, South Almora Thrust and UT, Uprari Thrust.

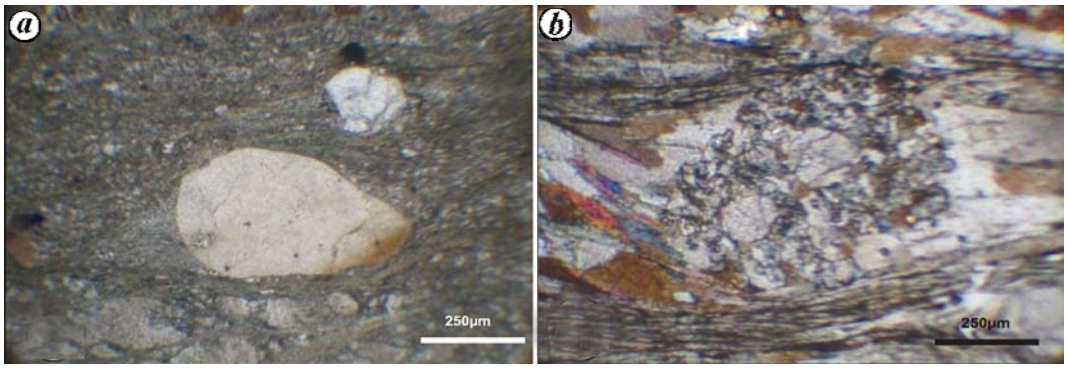

Figure 2. Photomicrographs of mylonites from the SAT zone showing (***a***) ellipsoidal quartz porphyroclast wrapped within the mylonitic foliation and (***b***) rotated feldspar porphyroclast.

quatrz commonly occur as clasts in pseudotachylites. The quenching of melts into glass (or a fine-grained, aphanitic material) occurs along the SAT zone (Figure 3). At places, the layerings are folded (Figure 3 *d*) and are interpreted to have formed by fluid flow in the melt. This layering is commonly of a different colour along the vein wall in the interior and is interpreted to result from selective melting of the wall rock. The mineral composition of inclusions in pseudotachylytes is commonly disproportional to the mineral composition of the wall rock; quartz and to the lesser extent, feldspar are common as inclusions, whereas Fe–Mg-rich silicates are rare.

The continuous northward push of the Indian plate during the Eocene resulted into several increments of compressional forces along its northern edge. The major amount of deformation progressed southward resulting in a time sequence into the formation of a deep crustal thrust system. With continued process of convergence of two continental plates, a branch of MCT moved southward, which was once covering the whole Lesser Himalayan sedimentaries (Figure 4). This thrust movement brought about the maximum amount of shear deformation and also the shortening of the crust in the Himalayan region, which is also evident by the presence of highly sheared, deformed and shattered rocks at the upper levels of the Lesser Himalaya sedimentary sequences. A number of smaller thrusts popped up from the sole thrust, all these smaller branches are characterized by the presence of thin mylonitic bands. Thus, the mylonite zone appears to be the product of heterogeneous deformation caused mainly due to lithological variations[8,17–19] existing in the various rocks in the SAT zone. Though mylonitization is broadly

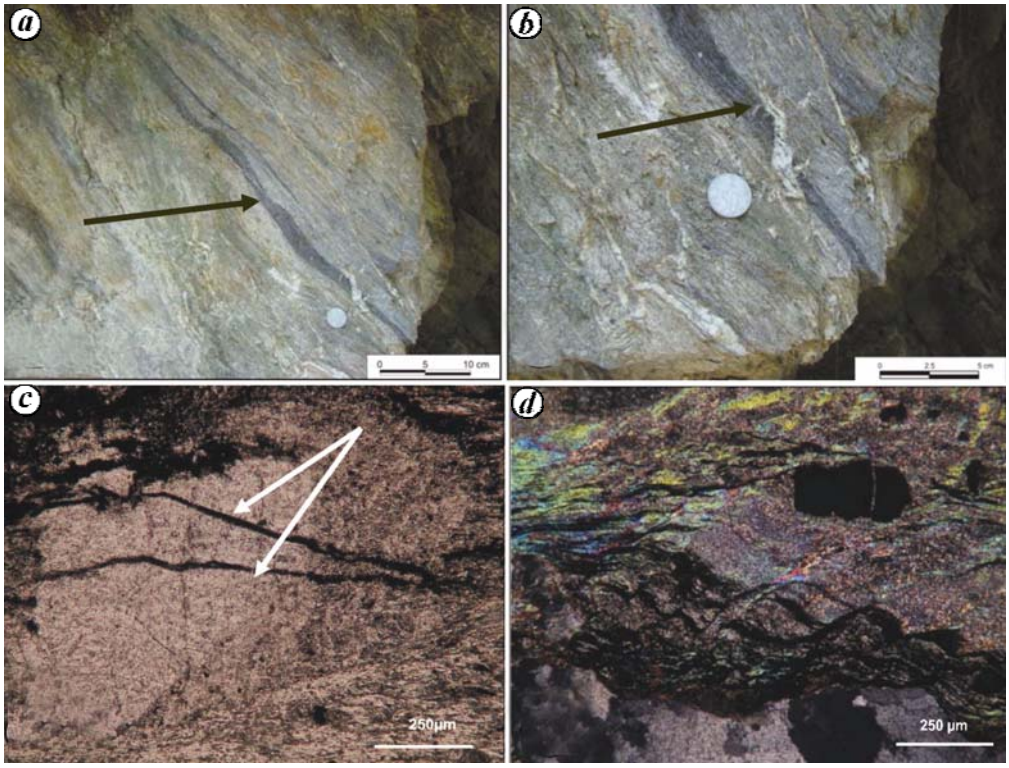

Figure 3. ***a***, Field photograph showing rocks of the footwall block along the SAT; arrow indicates the vein of pseudotachylite. ***b***, Close-up view of the same outcrop. ***c***, Photomicrograph showing thin pseudotachylite vein injecting into feldspar porphyroclast. ***d***, Photomicrograph showing thin, folded vein of irregular thickness.

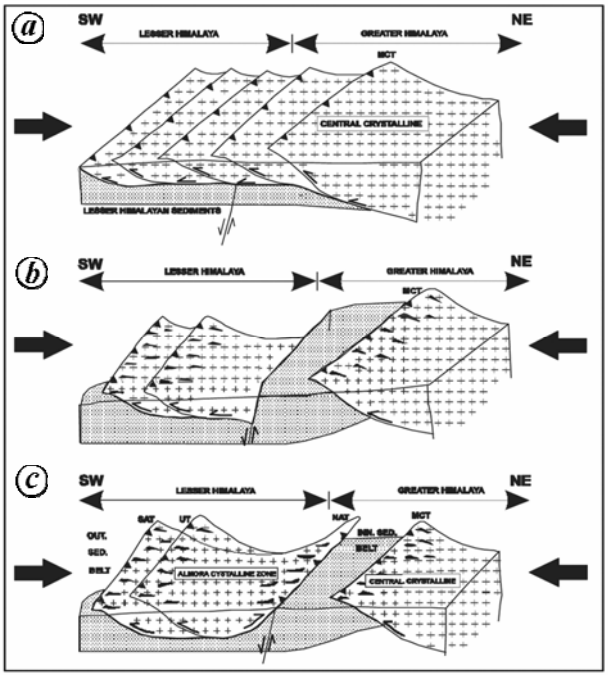

Figure 4. Schematic diagram showing the proposed model for tectonic disposition of the ACZ. ***a***, Emergence of crystalline thrust sheets from the MCT zone, overriding the Lesser Himalayan sediments. ***b***, Movement along pre-existing fault and subsequent erosion of a part of the crystalline sheet. ***c***, Development of back-thrust, giving rise to the south-dipping NAT exposing and further compressing the inner sedimentary belt in between. Thick lines indicate the stretching lineations (after Agarwal[4]). MCT, Main Central Thrust; NAT, North Almora Thrust.

controlled by thrusting (since the mylonite zone typically fringes the thrust plane), the process, in its details, appears to be lithologically (or mineralogically) controlled. The ductile deformation of quartz might have played an important role in controlling the process of mylonitization. Rapid frictional sliding during the thrust sheet movement would have generated heat at the base, resulting into the formation of melts locally. Rapid crystallization of this melt has resulted in thin veins of pseudotachylites[15,16,20–26].

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Decline of suitable habitats and conservation of the endangered lion-tailed macaque: land-cover change at a proposed protected area in Sirsi–Honnavara, Western Ghats, India

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Habitat fragmentation, loss of habitat and other anthropogenic activities have caused a population decline in many species, caused restriction in their distribution or even led to their local extinction. We attempted to understand the impact of such pressures on the newly identified and possibly the largest population of the endangered lion-tailed macaque, *Macaca silenus* in the Reserve Forests of Sirsi and Honnavara, Karnataka, using a temporal series of satellite images. Classified images showed a major increase in open area with a rapid decline in vegetation cover of about 11.5% in the wet evergreen forests over the last decade, amounting to a loss at the rate of 1.9% per year. We thus consider habitat protection and restoration of evergreen forest as the top priority along with the enforcement of conservation steps, including legal action against encroachment, extraction of timber and further fragmentation, to protect this critically important habitat of the lion-tailed macaque.

Keywords: Habitat loss, fragmentation, *Macaca silenus*, satellite imagery, wet evergreen forest.

THE primary forests of Asia, particularly those of the Western Ghats in southwestern peninsular India, are disappearing at an alarming rate due to anthropogenic activities and are undergoing a change in land-use patterns, including being replaced by forests comprising inferior secondary species[1]. The hill ranges of the Western Ghats are rich in biodiversity and display high endemism, and have thus been considered as one of the biodiversity hotspots of the world[2]. The Western Ghats, however, also has a high human density[3]. Although these hills have been inhabited for several thousands of years[4], the forests of the Western Ghats are declining drastically and have undergone severe fragmentation in recent years due to a

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