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Phyllonites from Attur Shear Zone and its tectonic significance in Southern Granulite Terrain, South India

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In the eastern part of the Southern Granulite Terrain, Attur Shear Zone (ASZ) is characterized by 1 to 1.5 km wide phyllonite zone which shows the maximum intensity of shearing. The foliation planes in this zone are sub-vertical ENE–WSW striking mylonitic foliation with dominant steeply plunging (70–80°) stretching lineations. The phyllonites show all gradations from protomylonite to ultramylonite and extensive biotitization of pyroxene/hornblende minerals. The microstructural studies of phyllonites indicate that ASZ has undergone extensive ductile shearing accompanied by fluid (H_2O) induced retrograde metamorphism. ASZ, probably formed at deep (10–15 km) continental crust, is exhumed at the present level of erosion by relative upliftment of adjacent blocks.

AMONG the three types of shear zones[1,2], ductile shear zone provides greater insight for deep-crustal deformation processes. At mid-crustal level, mylonites are commonly formed by ductile deformation through crystal-plastic grain size reduction and recrystallization[3–5]. The mylonites have been observed in many crystalline terrains which have deformed under greenschist to granulite facies metamorphism. In southern Peninsular India, a number of Proterozoic shear zones[6] divide the Archaean Granulite Terrain into different crustal blocks (Figure 1 *a*). Based on studies of LANDSAT images, Drury and Holt[7] inferred that northern and southern granulite blocks have been displaced along E–W trending Moyar–Bhavani–Attur lineament by dextral shearing. They estimated a strike-slip displacement of about 70 km and vertical displacement of 10 km. In contrary, the structures of Moyar–Bhavani shear zones indicate a dominant dip-slip component of shear movement resulting in extensive mylonitization[8]. The Moyar–Bhavani shear zones can be extended in the east along Attur Shear Zone (ASZ) whose tectonic status is yet to be understood[9,10]. The present study is a combined effort to characterize the ductile nature of ASZ based on meso- to micro-scale structures. It is important in the sense that many of the shear zones and in particular Cauvery Shear Zone (CSZ) appear to be ductile in nature on outcrop scale but micro-structural features were not studied to support the same. Hence, the microstructural behaviour of phyllonites from ASZ and its tectonic significance is presented here.

Within Southern Granulite Terrain (SGT), the ASZ separates northern charnockite hill ranges of Sheveroy, Chaiteri and Kalrayan from the charnockitic massifs of Kollimalai and Pachaimalai hills in the south. ASZ extends along E–W direction between Salem and Attur towns for about 100 km length. The rock types in the area are charnockite, quartzo-feldspathic gneiss, pyroxene granulite, hornblende-biotite gneiss, banded magnetite quartzite, calc-granulites and younger granitoids. Among these rock types, charnockite is widely distributed and appears to be medium-grained, dark bluish-grey and well-foliated rocks showing alternate bands of mafic and felsic minerals. The charnockite shows granoblastic texture and is dominantly composed of quartz, plagioclase, orthopyroxene and minor amounts of biotite and hornblende. Within the granulite facies rocks, a thick (1 to 1.5 km) phyllonite zone trending ENE–WSW is well exposed between Karipatti and Belur for a stretch of about 20 km (Figure 1 *b*). A few mylonite zones of narrow width trending NE–SW are also observed parallel to Tenmalai Shear Zone[11]. The occurrence of a number of undeformed charnockite pods within the phyllonite zone reveals that, the phyllonites are possibly the sheared and retrograde products of charnockites. In the southern part of this phyllonite zone, the charnockite and other lithologies show widespread carbonate alteration[12].

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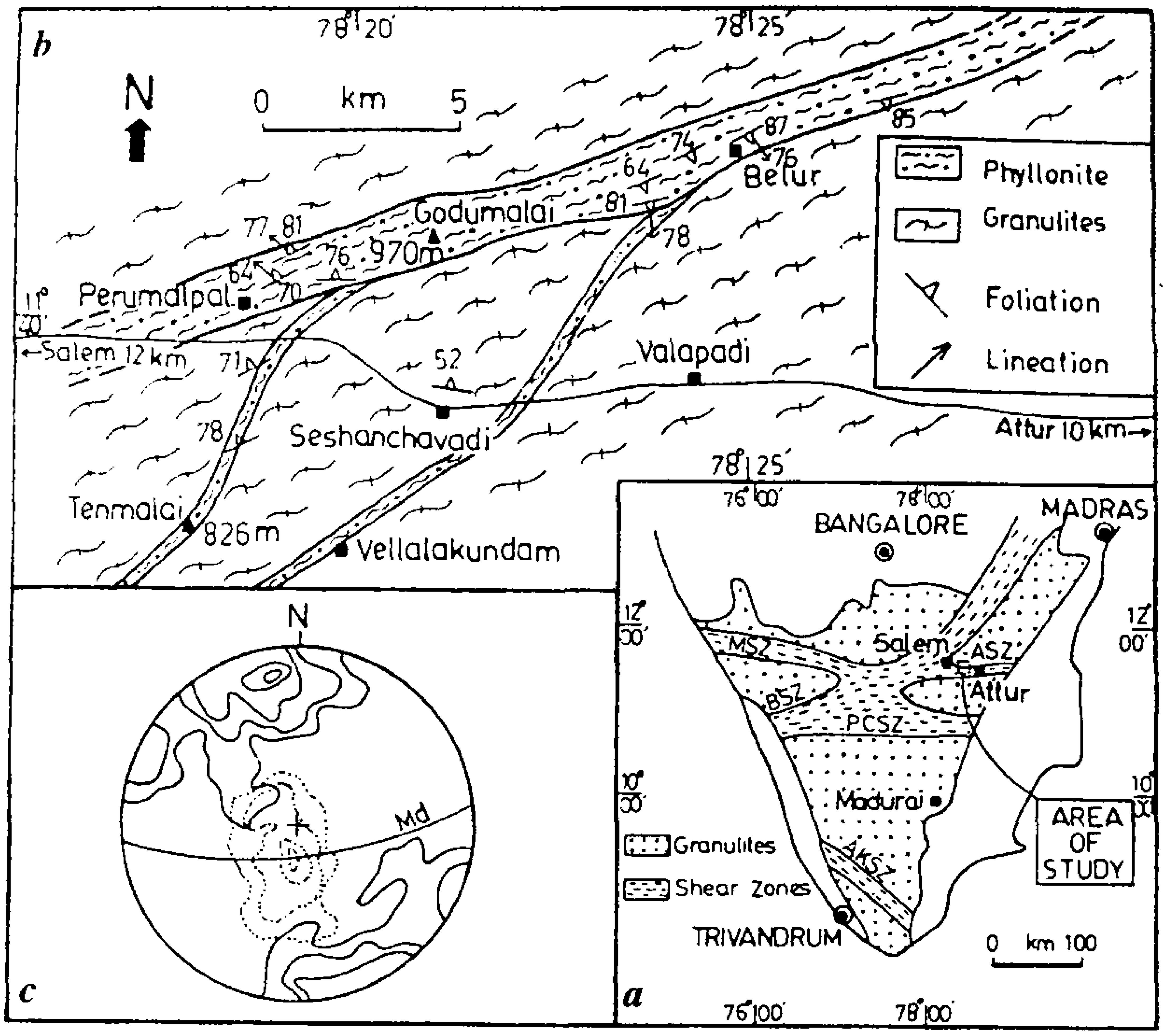

Figure 1. *a*, Simplified geological map of Southern India showing the different granulite blocks and study area in ASZ (after Wickham *et al.*[12]); MSZ, Moyar Shear Zone; BSZ, Bhavani Shear Zone; ASZ, Attur Shear Zone; PCSZ, Palghat–Cauvery Shear Zone; AKSZ, Achankovil Shear Zone; *b*, Geological map of ASZ showing the disposition of phyllonite band around Godumalai, west of Attur; *c*, Contour diagram for structural data from ASZ. Continuous contours: 81 poles to foliation; 1–3–5–9–11% per 1% area and dashed contours: 45 lineations; 1–5–15–24% per 1% area; Md, Modal foliation plane.

Generally, the term 'phyllonite' is used for schist-derived mylonite[13] which is enriched with phyllosilicate minerals such as sericite/muscovite, biotite, chlorite, etc. Due to its fine-grained mineral constituents, phyllonite sometimes resembles slate or phyllite. In ASZ, the phyllonites are medium- to fine-grained, grey to pale green, dominantly composed of feldspar, quartz and phyllosilicate minerals. They often show spotty appearance given by circular to elliptical feldspar porphyroclasts embedded within fine-grained matrix and resemble typical mylonites. The foliation planes within the phyllonite zone are essentially mylonitic foliation which are moderate to steeply dipping either north or south with steeply plunging (70–80°) mineral/stretching lineation. Stereoplotting of foliation and lineation data shows that the lineation maxima falls on the modal foliation plane (N78°/82°S) which indicates a dominant dip-slip shear movement (Figure 1 *c*). The kinematic analysis of shear sense indicators such as S-C fabric, asymmetric folds, asymmetric augens, fractured and displaced grains, etc. indicates a dextral shearing event from west to east (communicated elsewhere).

Microstructural studies from phyllonites of ASZ show all gradations from protomylonite to ultramylonite via the orthomylonite stage[14,15]. At the initial stage of mylonitization, the rock is deformed by intracrystalline strain associated with elongation of grains and grain size reduction. Plagioclase and K-feldspar show deformation twinning, strongly undulant extinction and at places they are fractured and displaced. Quartz grains also get flattened showing undulose extinction with serrated boundaries and peripheral grain refinement. At this stage the protomylonite shows mortar texture. Among the quartz and feldspar porphyroclasts, quartz grains get more elongated than feldspar. Sometimes the development of sub-grains within elongated quartz may result in a crude banding structure. As the strained quartz grains begin recovery/recrystallize with the pace of increasing strain rate, the porphyroclasts ratio decreases less than 50% w.r.t. the matrix and the rock appears as orthomylonite (Figure 2). Here the rock has developed microscopic banding given by the quartz ribbons anastomosing the highly strained feldspar porphyroclasts. With increase in the shear strain the orthomylonite passes over to ultramylonite when most of the porphyroclasts diminished to equant grains of finer size. Quartz grains are completely recrystallized with the development of finer quartz ribbon.

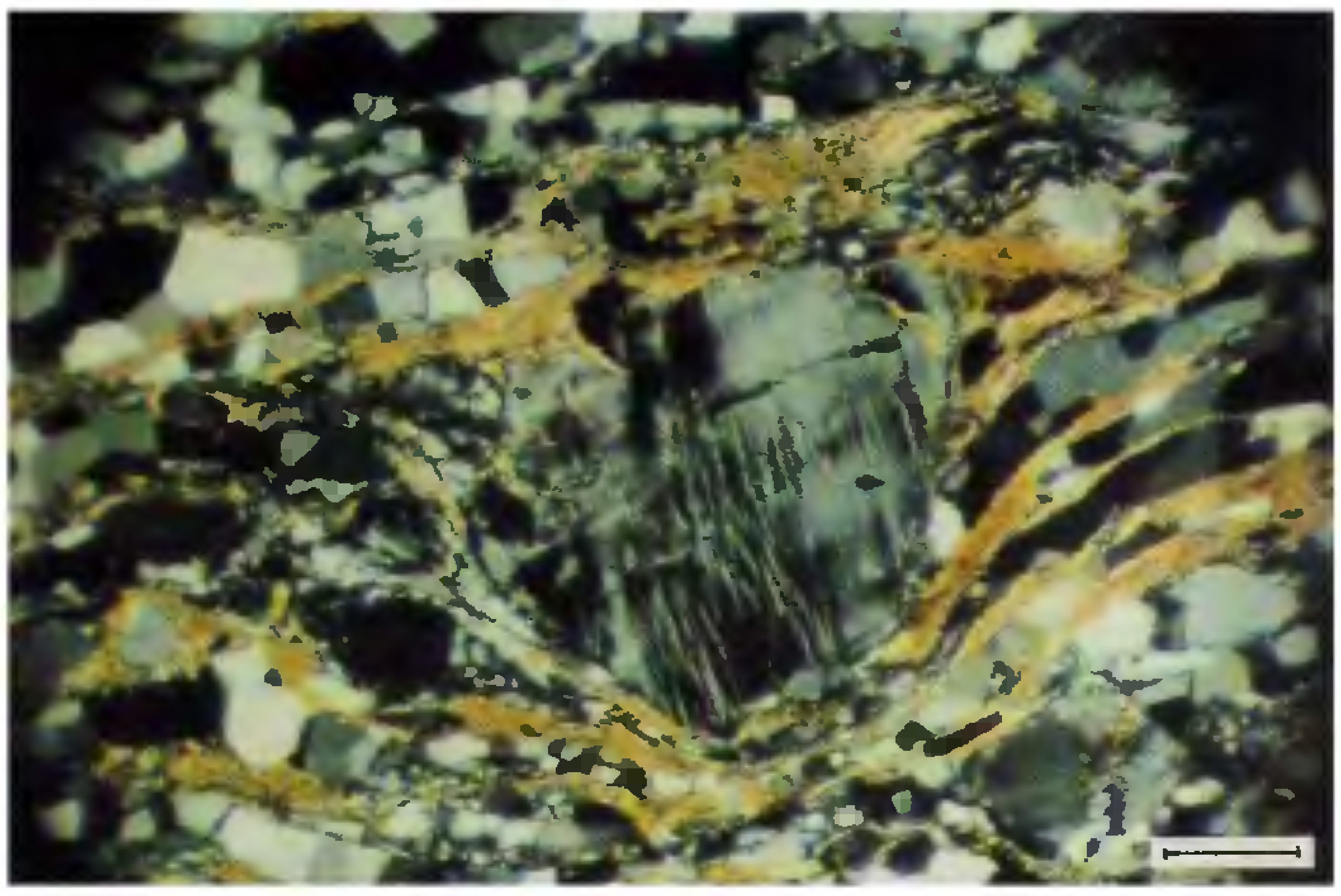

Figure 2. Photomicrograph of a typical mylonite 'orthomylonite' microstructure. Perthite porphyroclast, exhibiting deformation twinning, is swerved by quartz ribbons. Crossed nicols; bar length = 0.15 mm.

Figure 3. Photomicrograph of phyllonite showing floating hinges defined by thin quartz ribbons. The rock is rich in biotite with very few tiny feldspar porphyroclasts. Crossed nicols; bar length = 0.3 mm.

Apart from this textural change, the phyllonites have undergone extensive retrogression and neomineralization due to alteration of feldspathic and pyroxene minerals into sericite and biotite. A typical phyllonite (Figure 3) shows enrichment of very fine-grained phyllosilicate minerals such as sericite/muscovite, biotite, chlorite etc. with a few tiny quartz/feldspar clasts. The effect of ductile shearing has also been observed in a few sections of garnetiferous feldspathic gneiss in which the garnet porphyroblasts get pulverized and strewn along the mylonitic foliation. The fractured garnet grains show development of biotite/chlorite along the grain boundaries as well as along the fractures. The occurrence of hydroxyl-bearing minerals in phyllonites indicates that they might have formed by the retrogression of non-hydrous minerals of granulite facies by absorption of H_2O molecules. The mineral assemblages of chlorite, biotite, hornblende, epidote along with quartz and feldspar indicate that high-grade gneisses of granulite facies have undergone lower amphibolite facies metamorphism.

In the fault zone model, Sibson[16,17] has shown that brittle deformation at shallow depth grades into plastic or ductile deformation at 250–300°C and 10–15 km depth where mylonite form predominantly by the mechanism of crystal plastic deformation. The microstructural behaviour of phyllonites across the gneissic rocks in the area indicates that the mylonite probably formed at deep continental crust and is now exposed at the surface due to uplift and erosion. This upliftment of the adjacent blocks is manifested by the development of steeply plunging stretching lineations on steeply dipping mylonitic foliations. Also, a distinct pressure difference is found[18] between the charnockite massifs of Shevroy (7.4 kb) and Kollimalai (8.6 kb) across the ASZ which indicates an uplifted Kollimalai w.r.t. Shevaroy. During the tectonic upliftment process, deep-seated fluids (H_2O and CO_2) conduits through the fractures of ASZ and causes widespread retrogression and metasomatism. The interaction of H_2O influx with the granulites causes retrograde hydration during the initial stage of exhumation. It has been interpreted that the retrogression effect of phyllonites is syn- to late stage phenomena of progressive mylonitization.

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