Ductile shearing of the Proterozoic Chor Granitoid in the Lesser Himalaya and its Tectonic Significance

A newly identified Chor Thrust demarcates the southern margin of the Proterozoic Chor granitoid massif within the Jutogh Group metamorphics of the Lesser Himalaya in Himachal Pradesh. Numerous shear criteria reveal a top-to-SW overthrust-type intense ductile strain along this margin and are consistent with the southward propagating nappes.

Introduction: The Jutogh Group metamorphics of the Chor Hills expose almost-circular body of the Chor granitoid within an important widespread nappe of the Lesser Himalaya (Pilgrim and West, 1928; Bhargava, 1980; Valdiya, 1980). According to Pilgrim and West (1928), this granitoid intrudes the metamorphics as a laccolith in the core of the large-scale recumbent fold (also Das and Rastogi, 1988), which was postulated to explain the repetition of strata and inverted metamorphism (*see* also Naha and Ray, 1970, 1971). On the contrary, Kishore and Kanwar (1986) opined that the Chor granitoid may have been derived by partial melting of the metasedimentary rocks within lower to middle crust. In this work, an alternative tectonic model has been postulated for the emplacement of the Chor granitoid.

Field Relations: On the southern slopes of the Chor peak (3647 m), gently-dipping sequence of quartzite, carbonaceous schist, black marble, staurolite/kyanite/garnetiferous mica schist and a few bands of amphibolite have been classified into the Jutogh Group (Fig.1; Pilgrim and West, 1928). These are thrust over the low-grade metamorphics of the Chail Group along a well-demarcated Jutogh Thrust and constitute an extensive Jutogh Nappe (Fig.1a; Pilgrim and West, 1928; Naha and Ray, 1971; Sharma, 1977; Valdiya, 1980; Bhargava *et al.* 1991; Thakur, 1993).

The Proterozoic Chor granitoid (Rb/Sr whole rock age of 1000 Ma - Kwatra *et al.* 1989 and U-Pb zircon age of » 900 Ma - Singh *et al.* 1994) consists of non-foliated homogeneous granite, porphyritic granite, porphyroclastic granite gneiss and biotite granite gneiss, and physically overlies the Jutogh Group metamorphics (Figs.2a,b). These are intruded by dolerite dykes, which cut across the granite-metamorphic contact (Fig.1b). Biotite granite gneiss is mainly developed along the outer margin of the Chor massif and characterised by strongly lineated mylonitic foliation/gneissosity having preferred orientation of mica, feldspar and quartz. Porphyritic facies of the Chor granitoid, observed near the margin, reveals gradual grain-size reduction from undeformed coarse-grained variety to well-foliated mylonitic augen gneiss and ultimately to fine-grained gneiss on the outcrop scale (Figs.2a, b). Marginally, the granite gneiss contains many xenoliths of the low grade metamorphic rocks. The foliation within the granite gneiss and Jutogh metamorphics is almost parallel to each other. A few bands of ultramylonite are also developed within the granite gneiss at the contact.

Towards the margin of the granitoid, large megacrysts in the mylonitised augen gneiss are extremely elongated (Fig.2b). The northerly-dipping foliation is dominated by typical characters of ductile shear zone, wherein the S-foliation is sigmoidally bent by millimeter-

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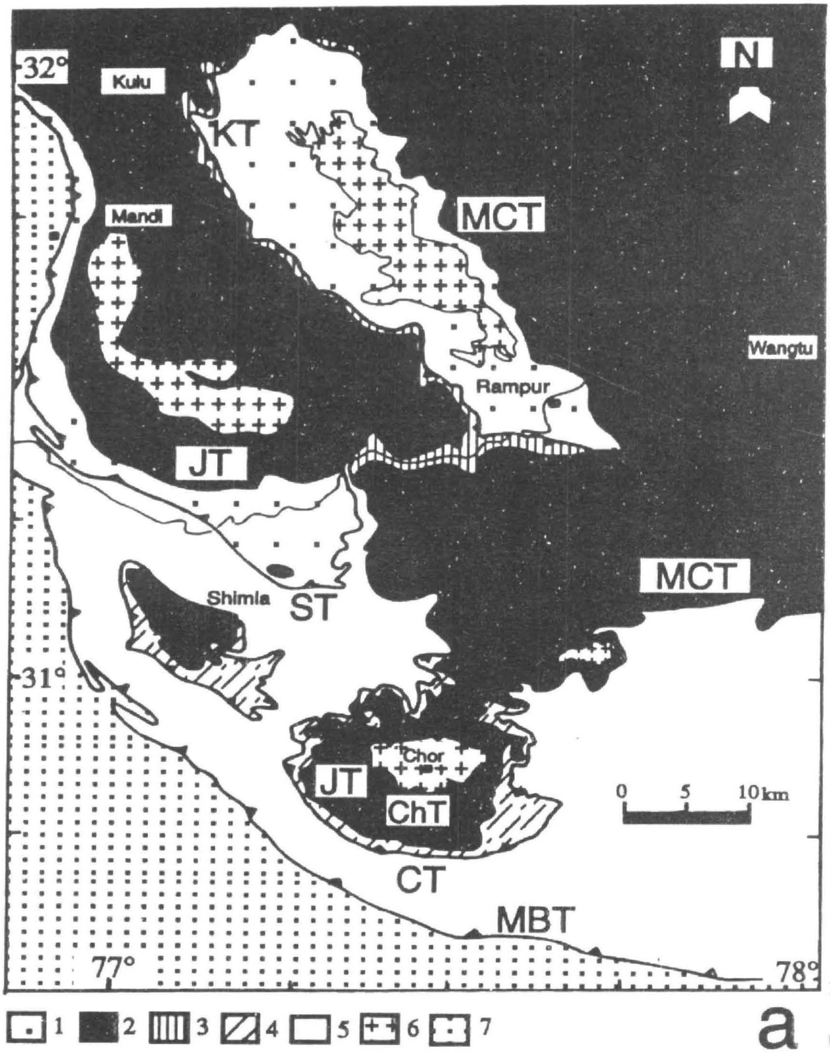


Fig.1a. Regional geological map of Himachal Pradesh. (1) Rampur-Kulu-Shali Window, (2) Jutogh Nappe, (3) Bajura-Kulu-Nappe, (4) Chail Nappe, (5) Simla-Deoban-Garhwal Group para-autochthon, (6) Granite/Granite Gneiss, (7) Sub-Himalayan Tertiary Belt. MCT-Main Central Thrust, ChT-Chor Thrust, JT-Jutogh Thrust, KT-Kulu Thrust, CT-Chail Trust, MBT-Main Boundary Thrust, (Compiled from published literature and our own observations).

spaced C-shear surfaces on a small-scale (cf. Berthe *et al.* 1979). S-C fabric consistently indicates top-to-SW overthrust sense of ductile shearing (Fig.2b) and is marked by a prominent stretching mineral lineation. This lineation is oriented in the direction to tectonic transport towards S/SW, not only near the margin of the Chor granitoid, but also throughout the Jutogh Group metamorphics. Other shear criteria indicating consistent SW tectonic transport include asymmetric augen, pressure fringes, boudins, folds, shear bands, rotational garnet fabric etc. Many such ductile shear criteria are localised within a few hundred meters of the Chor granitoid along its margin.

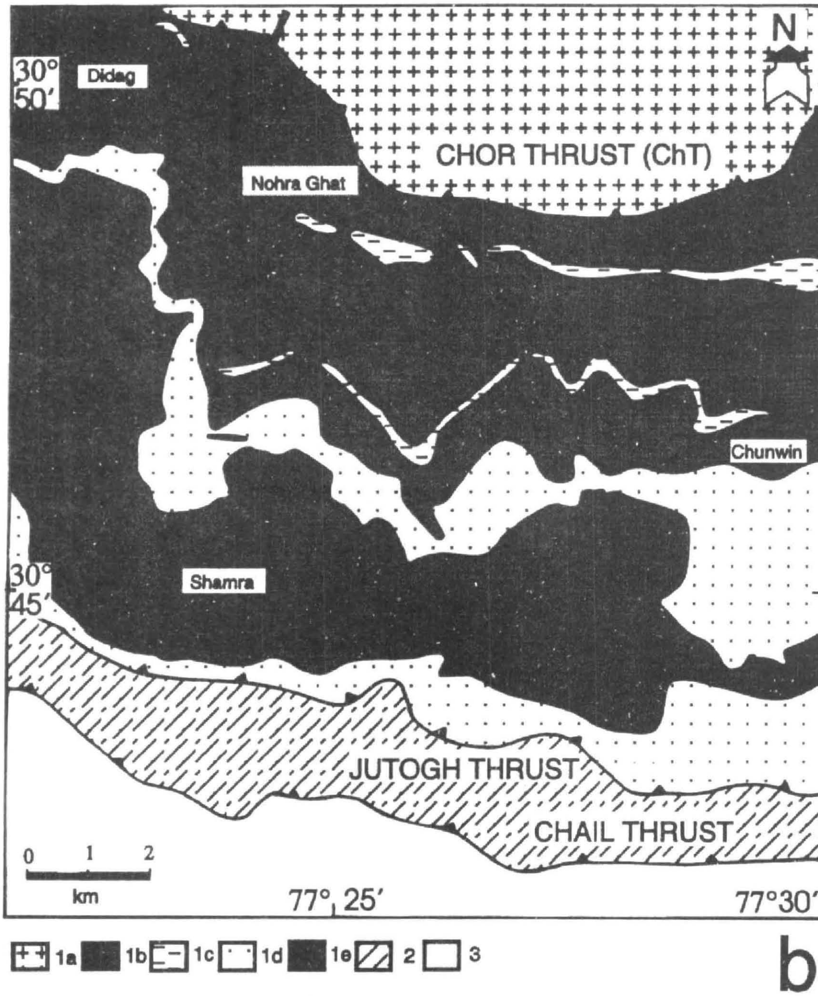


Fig.1b. Geological map of the Chor Mountain region, Himachal Pradesh. (1) Jutogh Group- (a) Chor granitoid, (b) staurolite/kyanite/garnetiferous mica schist/gneiss, (c) marble with carbonaceous phyllite, (d) quartzite and (e) dolerite dyke. (2) Chail Group and (3) Lesser-Himalayan sedimentary sequence (modified after Pilgrim and West, 1928).

It has been universally observed in several orogenic belts that the thrust-related mesofabrics are mostly confined to or near the fault zones at the base of nappe and transpose earlier structures during its emplacement. Since the structures characterising the ductile shearing are confined to the margin of the Chor granitoid, it is likely that the contact between Jutogh metamorphics and Chor massif is of tectonic origin due to variations in ductile flow/ strain rates. Depending upon these evidences, the tectonic contact between Jutogh metamorphics and Chor massif has been locally termed as the **Chor Thrust** (Fig.1; also Singh, 1993).

Summary and Conclusions: The Proterozoic Chor granitoid ($\approx$ 900 Ma) has initially intruded

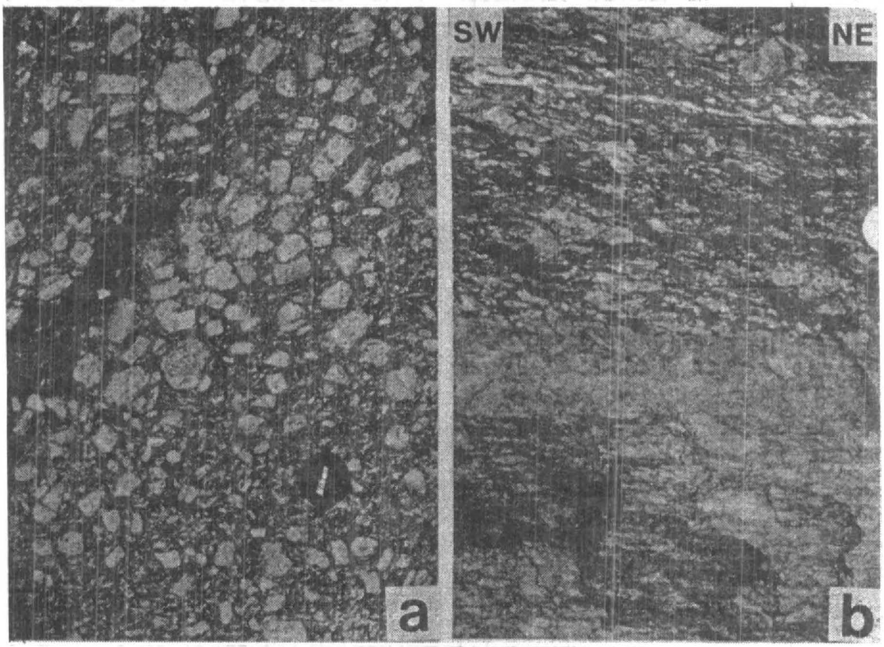
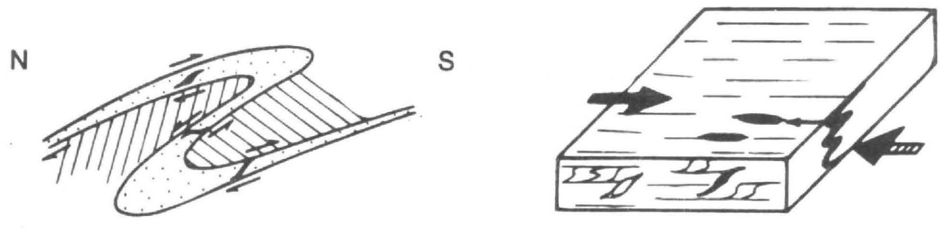


Fig.2a. Porphyritic granite of the Chor granitoid about 5 km ENE of Nohra. Many subhedral feldspar megacrysts show strong preferred orientation without any shape modification in foliated fine grained groundmass. Scale: lens cap of 55 mm diameter.

b. Porphroclastic augen gneiss of the Chor granitoid near the margin with the Jutogh Group metamorphics along Raundar Ka Khata nala about 4 km NNW of Nohra. Also note well foliated mylonitic augen gneiss having elongated and asymmetric augen. Distinct S-C shear fabric development reveals SW-shear vergence. Scale: 50 paisa coin on right hand margin.

the Jutogh metamorphics and subsequently undergone ductile shearing during the Cenozoic Himalayan Orogeny. Consistent top-to-SW sense of displacement, as deciphered from various shear criteria within Chor granitoid and Jutogh metamorphics (Singh, 1993), do not support the recumbent fold-model emplacement of the Chor granitoid (Pilgrim and West, 1928). Structures, likely to be associated with recumbent fold-model and indicative of shear sense, would reveal reversal of vergence of shear criteria on the limbs of antiforms and synforms (Fig.3a). In that case, shear criteria will have southerly vergence on normal limbs and northerly vergence on inverted limbs of such large folds (Fig.3a). On the contrary, consisitent and ubiquitous top-to-SW shear vergence within the Jutogh metamorphics and Chor granitoid (Fig.3b) indicates ductile shearing within a large-scale ductile shear zone. Present investigations reveal that the main foliation is contemporaneously developed during the main ductile deformation in a shear zone.

Many such Proterozoic and Early Paleozoic granitoids have now been mapped within the metamorphic nappes in the Lesser Himalaya, either as large-scale concordant sheets (Dalhousie-Mandi granite) or as isolated elliptical-shaped bodies like the Chor and Kaichanwa granitoids in Himachal Pradesh and Lansdowne granitoid in Uttar Pradesh and elsewhere. Our observations of many such granitoids reveal localised high ductile shear strains along their margins, where numerous shear indicators consistently reveal initial top-to-SW verging displacement, having overthrust geometry. It is likely that many such bodies might represent



a b

Fig.3a. Model showing shear indicators in large-scale overturned fold with reversal of vergence on limbs of antiform and synform.
b. Model showing shear indicators in intracontinental ductile shear zone of overthrust-type showing development of main foliation, lineation and folds.

remnants of distinct granitoid sheets, which were intensely deformed during ductile shearing within the Lesser and Higher Himalayas.

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