Shear parallel to collisional orogenic trend: Global review and paleostress analyses from the NW Garhwal Lesser Himalayan Sequence, India

Soumyajit Mukherjee[1], Tuhin Biswas, Narayan Bose, Dripta Dutta
Email: soumyajitm@gmail.com, IIT Bombay

Abstract

Prospect in exploring collisional orogens for hydrocarbon is debated and a mixed opinion can be found amongst the geoscientists. Nevertheless, Himalayan terrain has been of interest to petroleum geoscientists. Arc-parallel shear is an important deformation mechanisms in orogens worldwide.A number of driving forces can result in orogen-parallel shears. Reviewing these mechanisms/theories from orogens worldwide including the Himalaya, we compile 44 locations with orogen-parallel shear. During collision in collisional orogens, rock mass escapes parallel to thethe orogenic trend. Fieldwork and microstructural studies in the northwest LHS (India) reveals orogen-parallel brittle and ductile shears: *(i)* top-to-NW up, *(ii)* top-to-SE up, *(iii)* top-to-NW down, and *(iv)* top-to-SE down. Paleostress analysis indicates top-to-SE down and top-to-NW down shears occurred due to stretching along ~ 131°-311° (D_{ext}), and top-to-SE up and top-to-NW up shear happened due to shortening along ~133.5°-313.5° (D_{compr}). Orogen-parallel extension took place ~ 15-5 Ma in the Himalaya. The Delhi-Haridwar Ridge below the LHS acted as a barrier and finally produed NW-SE/orogen-parallel compression.

Introduction

Structural geology and tectonics of collisional orogens primarily govern the spatial distribution of the hydrocarbon reserves (Cooper, 2007).Orogensis has been worked out mostly by studying regional/ mega-scale thrusts (e.g., Gansser, 1964) leaving behind meso-scale ductile and brittle deformation structures. However, these later structures have great potential to unravel the tectonics of the mountains.

Review undertaken in this work

The review is presented as follows (Table 1; Fig. 1).

Table 1. Globally reported orogen-parallel extension and compression, compiled in this study.

Sl no.	Model name	Example
1.	Gravitational Collapse	Yilgarn Craton, Australia
		Samnagawa metamorphic Complex
		Alpine orogen
		Himalayan orogen

2.	Radial Thrusting and Expansion	GIlbraltar Arc in Alboran Sea
		Himalayan orogen
3.	Oroclinal Bending	Himalayan orogen
		Central Anatolian Plateau
		New England orogen
		NW and Central Iberia
		Median Tectonic Zone of New Zealand
		South Carpathians
4.	Removal of Mantle	Himalayan orogen
		Trans-Hudson orogen
		Western Anatolia
		Southern Tibet
		Zargos mountains
		Delamerian-Ross fold belt in Australia
5.	Oblique Convergence	Himalayan orogen
		South-Central CanandianCordillera, Western Alps, Variscides of France
		NE Venezuela
6.	Dome Extrusion	Eastern Alps
		Betics in southeast Spain
		NW Iberia in Spain
		The Menderes massif in southwest Turkey
		Variscan French Massif
		Himalayan orogen
7.	Rigid Plate indentor	Alps mountain belt
		Aegean arc
		Himalaya orogen
8.	Basement influence on cover	Southern Urals
		Himalaya

		Zagros Mountain
		NW Taiwan
		N Apennines
9.	Mass accumulation and stored energy dissipation	Himalayan orogen
10.	Oblique Convergence	Central America
		Northern Chile Forearc/Andes
		Central Andes
11.	Plate Rotation	Northern Apennines
12.	Abrupt termination of lateral mass flow	Himalayan orogen

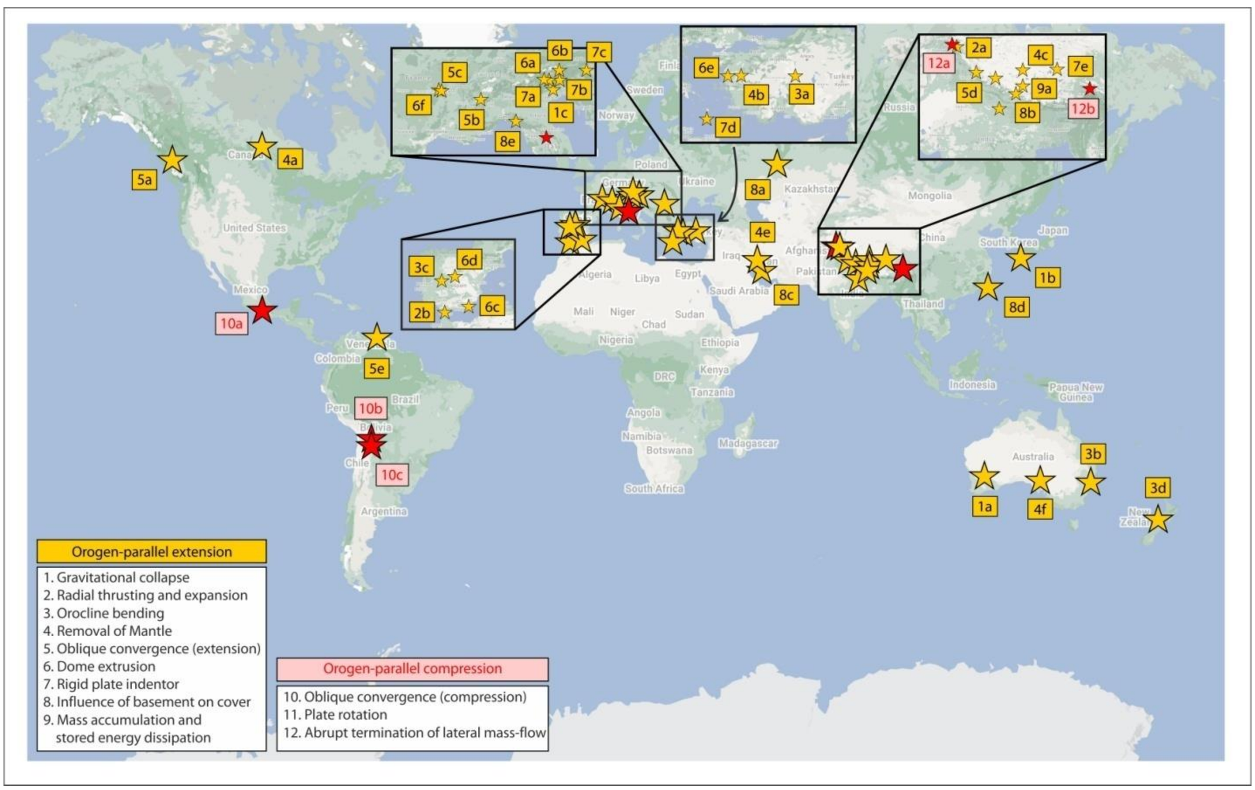

Fig. 1. Global distribution of orogen-parallel deformation.

Geology of the study area

The Lesser Himalayan Crystallines (LHS; Fig. 2) is delimited by Main Boundary Thrust at south and Main Central Thrust at the north. The entire LHS was deposited under marine conditions. See Bose and Mukherjee (2019) for detail.

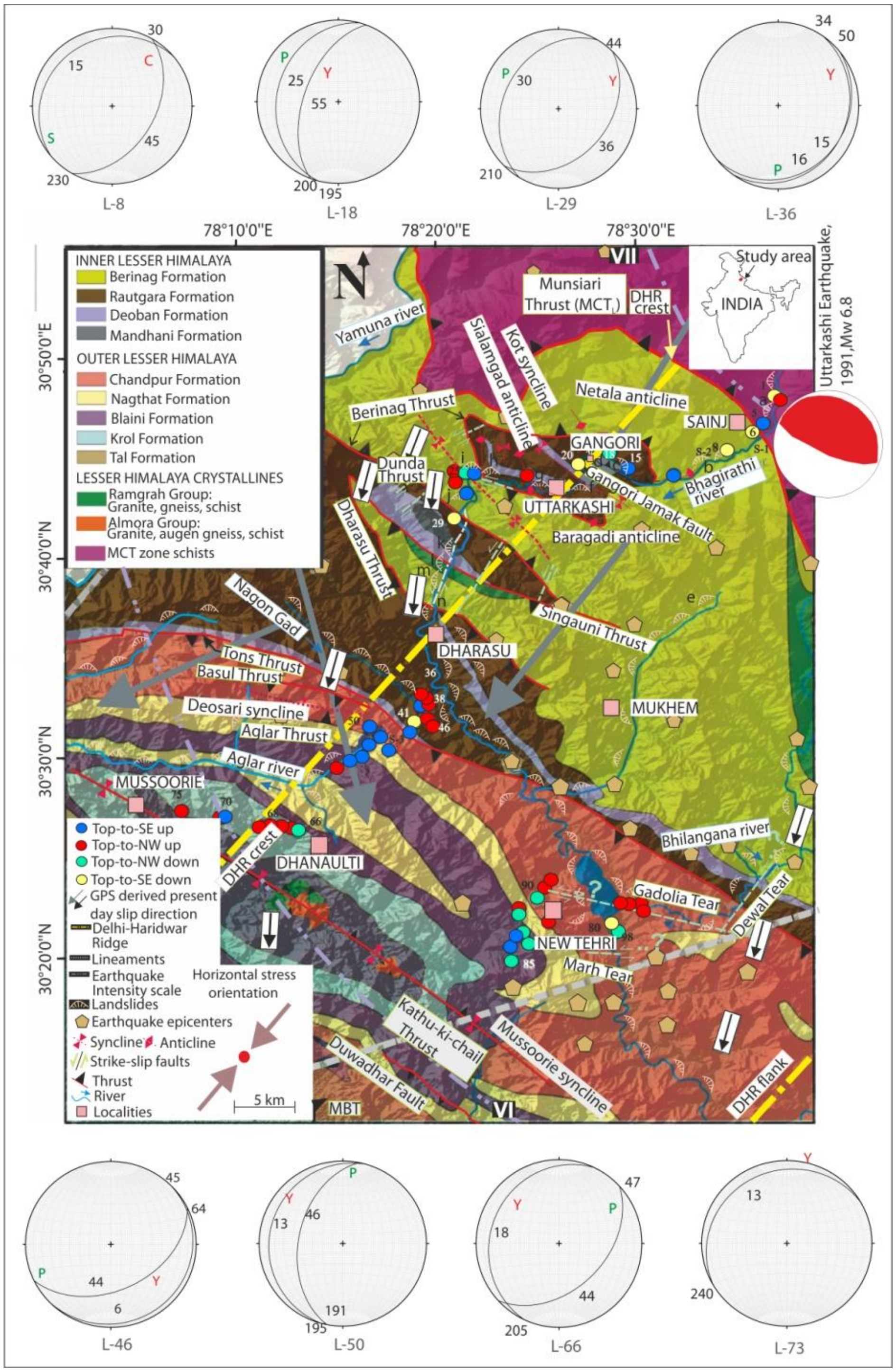

Fig. 2. Field locations on a map of the LHS. Geological data compiled from literature. Stereoplots are the data collected in this study.

Present work

Fieldwork was undertaken from ~10 km NE of Uttarkashi up to Mussoorie,In this traverse schists, phyllites, slates, quartzites, dolomites, conglomerates and limestones crop out. Y-planes and P-planes/Riedel shears, sigmoidal bulges and vein geometries are applied to decipher the shear senses (Fig. 3).

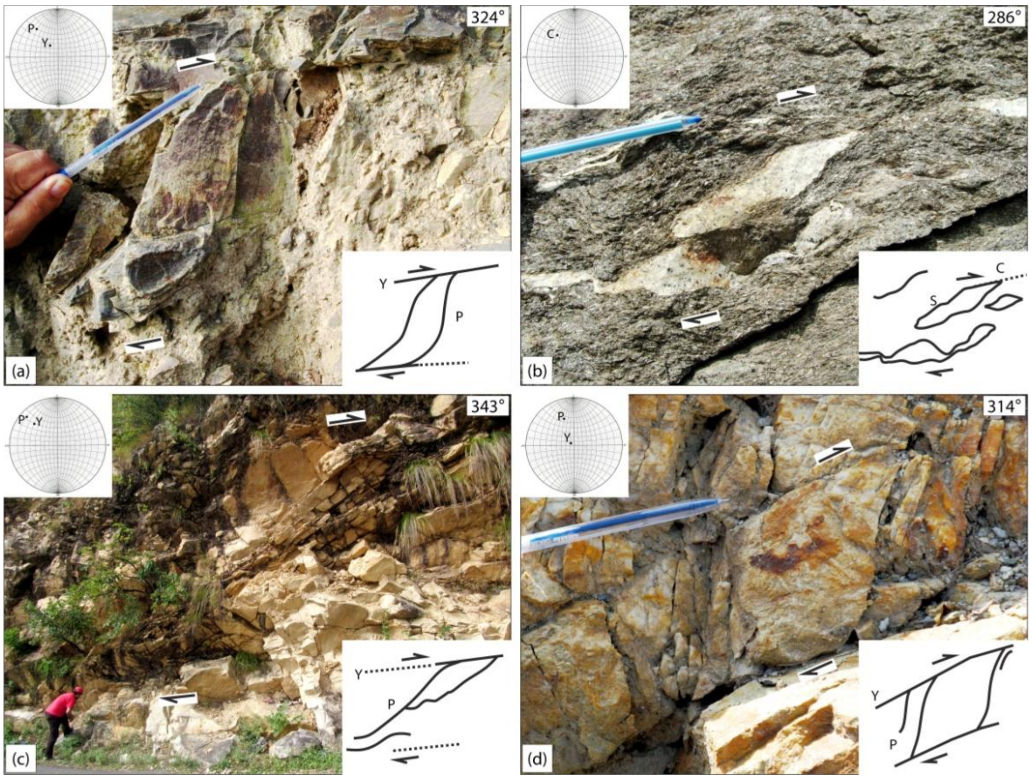

Fig. 3. Field evidences of top-to-NW/WNW (up) shear. Locations: (a) Rautgara Slates. (b) MCT Zone. (c) Berinag Quartzite. (d) Nagthat Quartzite.

84 fault kinematic data were used for paleostress analyses with three free software SG2PS (V.2), T-TECTO and (iii) Win-TENSOR.

Results

Arc-parallel shear worldwide is a common issue but has lacked focused study so far. Arc-parallel extension in the NW Indian LHS could be explained by: (i)"radial thrusting and expansion model", (ii) "removal of mantle", (iii) accumulation of mass and energy due to collision and release of stored energy, or (iv) basement influence on the cover.The "oblique convergence model". The Delhi Haridwar ridge could have acted as a barrier to the creeping rock mass due to collision between Indian and Eurasia and could have ultimately developed arc-parallel shear. *A full version of this article has been published in Biswas et al. (2022) where block diagrams are presented.*

Results of paleostress analyses

Table 2 presents the outcome.

Table 2. Paleotstress results.

Slip sense	**SG2PS** (trend/plunge, in degree)			**T-Tecto** (trend/plunge, in degree)			**WinTensor** (trend/plunge,in degree)		
	σ_1	**σ_2**	**σ_3**	**σ_1**	**σ_2**	**σ_3**	**σ_1**	**σ_2**	**σ_3**
Top-to-NW down & top-to-SE down	203/90	43/0	313/00	180/88	32/2	123/2	315/88	222/0	132/2
Top-to-NW up &top-to-SE up	315/0	45/0	217/90	309/6	40/3	149/81	317/8	225/11	83/77

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