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Deformation Microstructures in Rocks

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*Dedicated to my grandfather late
Mr. Sukhamoy Mukherjee who continues
to remain my role model*

Preface

Study of microstructures is an indispensable component of understanding structural geology of any terrain. A number of 'new' microscopic structures, such as 'flanking microstructures', trapezoid-shaped mineral grains, micro-duplexes, reversal of ductile shear sense, migration of grain boundaries, pull-aparts of V- and parallel types, and new minerals nucleated inside host minerals have recently been described in individual papers. However, for the sake of brevity, these microstructural papers could not present numerous variations in their morphologies. *This book aims to highlight these structures selectively.* Nearly all these photomicrographs come from different western Himalayan shear zones. Ductile and brittle shear senses, where possible to interpret, have been referred in the captions. This book starts with photos of mineral fish that are perhaps the most common ductile shear sense indicators. Captions for photographs have intentionally been kept brief. For full-length discussion of these structures, kindly consult the 'References' section. Students and researchers of structural geology will find this book useful. Please send me comments and counter-arguments on interpretations of the presented microstructures at: soumyajitm@gmail.com

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Editorial handling by Helen Rachner, Christian Witschel, Christian Bedall, Annett Büttner ('Earth Sciences & Geography' division, Springer), S.A. Shine David (Scientific Publishing Services (P) Ltd), and Nithiya Sivaraman (Production Editor, Springer). Mentored by Chris Talbot (retired from Uppsala University). Geology students of Indian Institute of Technology Roorkee whom I acted as a Teaching Assistant during 2002-2007 raised many unconventional questions on microstructures. Discussions with Achyuta Ayan Misra and Rajkumar Ghosh (IIT Bombay) were fruitful. Roberto Weinberg (Monash University) provided thin sections from which two photos- Figs. 4.11 and 4.12- were taken. I am grateful to Bhim Bhatt and Ramesh Chand (IIT Roorkee), and Anil N Waghmare, Niranjan Panda, Narendra Vengurlekar, and Vasant Kashiram Dalvi (IIT Bombay) for preparing many thin-sections. Thanks to my wife Payel Mukherjee for bearing loneliness while I wrote this book.

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Chapter 1

Mineral Fish and Ductile Shear Senses

Mineral fish are either single or aggregates of minerals that are ductile sheared (Figs. 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 1.14, 1.15, 1.16, 1.17, 1.18, 1.19, 1.20, 1.21, 1.23, 1.24, 1.26, 1.29, 1.30, 1.31, 1.32, 1.33, 1.34, 1.35, 1.36, 1.37, 1.38, 1.40, 1.41, 1.42, 1.43, 1.44, 1.45, 1.46, 1.48, 1.49, 1.50, 1.51, 1.52, 1.53, 1.54, 1.55, 1.56, 1.57, 1.58, 1.59, 1.60, 1.62, 1.63, 1.64, 1.65, 1.66, 1.67, 1.68, 1.72, 1.73, 1.83, 1.85). Three common shapes of mineral fish are sigmoid, lenticular and parallelogram (ten Grotenhuis et al. 2003; Mukherjee 2011). These fish are bound by parallel (Figs. 1.3, 1.5, 1.9, 1.13, 1.15, 1.21, 1.23, 1.24, 1.37, 1.38, 1.49, 1.56, 1.59, 1.62), and rarely by non-parallel primary shear C-planes (Figs. 1.25, 1.26). Migration of quartzofeldspathic minerals and sometimes high-grade metamorphic index minerals towards them destruct their ideal morphologies. A top-to-S/SW ductile shear sense is revealed from these mineral fish from most of the Himalayan ductile shear zones. This indicates foreland vergent fore-thrusts of the northern portion of the Indian plate (Mukherjee et al. 2012; Mukherjee *in press-1, 2*). (Figs. 1.22, 1.27, 1.28, 1.39, 1.47, 1.69, 1.70, 1.71, 1.74, 1.75, 1.76, 1.77, 1.78, 1.79, 1.80, 1.81, 1.82, and 1.84). How shear heat (Mukherjee and Mulchrone 2013), and reinterpreted ductile shear kinematics (Mukherjee 2012; Mukherjee and Biswas, *submitted*) affect shear fabric need to be studied further.

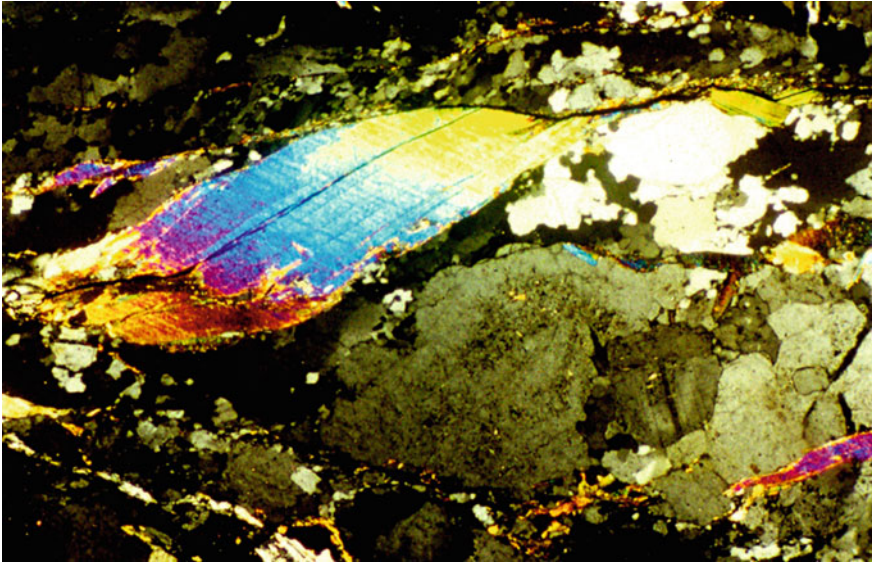


Fig. 1.1 A sigmoid mica fish. *Top-to-right* shear. Recrystallized and sheared quartzofeldspathic minerals in the matrix, above the fish, shows the same shear sense within a *narrower zone*. The primary shear C-plane is characterized by fine grained micas. Reproduced from Fig. 1.3b of Mukherjee (2011). Cross-polarized light. *Location* Karakoram Shear Zone (India). Mukherjee (2012) presented a reinterpretation of ductile (simple) shear. *Width of view* 2 mm

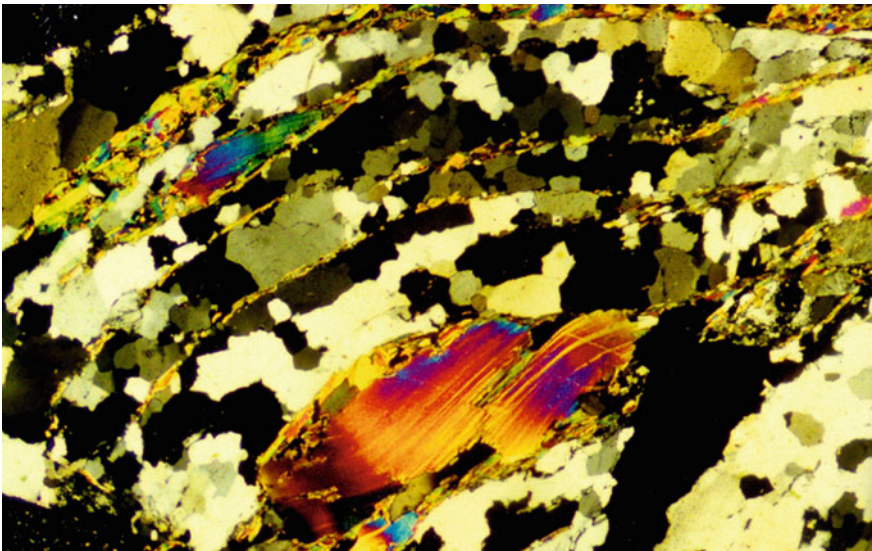


Fig. 1.2 Two adjacent sigmoid mica fish. *Top-to-right* shear. Trails of micas bound sigmoid quartzofeldspathic domains of same shear sense. Reproduced from Fig. 1.3a of Mukherjee (2011). Cross-polarized light. *Location* Karakoram Shear Zone (India). *Width of view* 2 mm