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Structural geology in active tectonic regions: An introduction

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The study of active tectonics is at the interface of geoscience and society (e.g., King et al., 1994; Mondal et al., 2024; Ansari et al., in press). Geoscientists have been studying links between structures (e.g., Dasgupta et al., 2023), tectonics (e.g., Biswas et al., 2022; Raha et al., 2023), morphometry (e.g. Biswas et al., 2024a,b) and tectonic inheritance (e.g., Dasgupta et al., 2022) within active tectonic regions. The subject has been a very active field of research worldwide with several quantitative techniques included within it (review in Ren et al., 2018). Drainage pattern can be controlled by sub-surface structures, and the later can be governed by active tectonics. Terrains with a high Index of Active Tectonics magnitude are regarded as presently tectonically unstable (e.g. Biswas et al., 2022). Natural hazards such as seismicity and landslides might be high in such places (e.g., Chatterjee et al., 2024). For the seismic and landslide hazard assessment of any terrain, data on active faults constitute one of the crucial inputs (Ahmad et al., 2017). For example, from paleoseismological studies, one can estimate recurrence interval of faulting leading to earthquakes (e.g., Galadini and Galli, 2000). Morphologic and structural data set of terrains (deduced from Shuttle Radar Topography Mission Digital Elevation Model and also through fieldwork) are the input parameters for active tectonic studies (e.g. through the Multi Criteria Decision Analysis; Argyriou et al., 2014). Space-based observations provide one of the major inputs in recent studies in active tectonics (review in Elliott et al., 2016). Morphotectonic analysis in conjunction with geophysical techniques can also enable one to detect blind active structures (Alexopoulos et al., 2013). Active tectonic studies are crucial in areas of geological resources (e.g., Mukherjee et al., 2025) and major cities (e.g., Surabhi et al., 2024). Major engineering project locations have to be established in areas of low tectonic activities (e.g., Carbonel et al., 2019). Also, in land use planning, "environmental units" are defined based on spatial distribution of active tectonic zones (Rodríguez et al., 2021). In such studies, estimation of Index of Active Tectonics for the different watersheds delineated becomes an important exercise. As a general framework, we note the slightly different terminologies and their sources related to active tectonics in Table 1.

This special volume incorporates a multidisciplinary approach to active tectonics and consists of 18 papers from different terrains worldwide. These articles mainly link seismicity, seismic images, morphometry, structural geology and tectonics to form an overview of active tectonics.

Akgün et al. (2025) study the Pütürge segment of the East Anatolian Fault System, Türkiye and decipher an aseismic gap between the Mw6.8 Pütürge (Elazıg) and 7.8 Pazarcık (Kahramanmaras) earthquakes. They calculate different morphometric indices, performed paleostress analysis based on field data and studied ground deformation patterns. The results match with a first-order transtension and aseismic-slip related energy build-up.

Ansari et al. (2024) study recent tectonics in northeast Japan using the global navigation satellite system (GNSS) and tide gauge measurements. Breaks in GNSS-time series are documented and sources of alternative deformation postulated. Lithospheric uprise was inferred and linked with the plate subduction mechanism.

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Table 1
Definition of “active tectonics” and related terms in the literature. Publications that repeat almost the same definition are not presented. Some variation in the ages of tectonics are noted in these definitions.

Term	Definition	Source	Additional information
Active tectonics	Geologic–geomorphologic processes since 100–150 ka. Focus on present and future deformation.	Wu and Hu (2019)	-
Active tectonics	“Tectonics which are still active in Late Quaternary (circa 0.5 Ma to 0.15 Ma BP) and will be active in the future, and will be of concern to society”	Wallace (1987), Yeats et al. (1997)	Taken from Wu and Hu (2019)
Active tectonics	"Tectonic movements that are expected to occur within a future time span of concern to society.”	Studies in Geophysics, Active Tectonics, National Academy Press, Washington, D. C. (1986)	This definition is followed in the Keller and Pinter (1988) text book on active tectonics
Active tectonics	“Structures which have been active since the late Pleistocene, 100–120 ka BP, are still active recently, and will be active in a certain time period …”	Deng et al. (2003)	–
Active fault	A fault that may have displacement within a future period of concern to humans.	Lee et al. (2002)	–
Neotectonics	Study of late Cenozoic deformation … crustal movements which are recent enough to permit detail analysis and assessment of rate of change	Keary (1994)	–
Active fault	A fault along which there is a recurrent movement, usually indicated by small, periodic displacements or seismic activity	Bates and Jackson (1980)	–
Neotectonics	Study of post Miocene structures and structural history of the Earth’s crust	Bates and Jackson (1980)	–
Active fault	A fault that acted within last 35,000 yr	Fraser and Chief (2001)	In the context of study of dams

Bahrami et al. (2024) investigate how vertical growth of folds affect morphometry in the petroliferous Asmari Anticline, Iran. Geomorphic studies reveal that the SW limb of this fold has characteristic geomorphology and morphometric parameters characterized by a higher density of faults and trellis drainage.

Chen et al. (2024) study the 18-Dec-2023 Jishishan earthquake that occurred in the northeastern Tibetan Plateau (China) and produced a visually significant geological impact. A seismogenic blind fault is identified that is related to this earthquake. The key inference of this work is that continuing shortening towards the NE forms part of the India-Eurasia collision.

Ferranti et al. (2024) study the Pescopagano Fault (PF) related to the 1980, Mw 6.9 Italian earthquake. They state that PF could be an inherited Pliocene/Early Pleistocene structure that does not extend to deeper levels. They predict that the PF might be reactivated during very large, yet infrequent, seismicity related to the Irpinia Fault system. Whether the PF fits with the present tectonic scenario of the Southern Apennines is discussed.

Filippova et al. (2024) study the Mw 5.4 September 6, 2021 Tofalaria earthquake in eastern Siberia and infer that it took place due to NE-SW compression. Stress was locally redistributed after the mainshock and is bordered by small-scale faults. Geometric models for part of the Main Sayan fault is also deciphered. How faults affect stress redistribution in adjacent terrains will be an interesting avenue in any further research worldwide.

Koçyiğit et al. (2024) investigate the intraplate Lake Salt Fault Zone (LSFZ), Türkiye and suggest through focal mechanism studies a dominantly dextral strike-slip mechanism combined with normal-slip. They deduce that the earthquake (Mw $\geq$ 6.7) recurrence interval related to the LSFZ exceeds one thousand years, and that the LSFZ lies within a seismic gap.

Kökūm (2024) analyzed the 06-Feb-2023 Elbistan earthquake that created a zone of surface rupture. They invert coseismic slickenlines of faults from several outcrops and decipher a strike-slip regime. Interestingly, inversion of paleoslip slickenlines indicates a tensional stress regime that suggests a change in stress from the past to the present.

Li et al. (2024) note a lack of large earthquakes in the southern segments of the Red River Fault Zone (RRFZ). Based on trenching and geochronology, the mid valley trace in the southern segment of the RRFZ is identified as an active fault. The fault’s behaviour is complicated as in places it acts as a dip-slip fault while elsewhere it forms a strike-slip one.

Pan et al. (2024) investigate the crust of the South China Sea. They decipher structural evidence of the paleo-Pacific subduction that is linked with accretionary style deformation. The authors anticipate that subduction may reactivate if any extension develops. An important conclusion is that the lower crust thinned preferentially when rifting took place beneath the Chaoshan Depression.

Peiro et al. (2024) identify the Cucalón-Pancrudo extensional fault in Spain with a net-slip of 305–325 m, and a very low long-term slip rate (0.09 mm a^{-1}) within an intraplate regime. This structure had previously acted as a transpressional fault. Based on optically stimulated luminescence (OSL) dates, they document three tectonic events at 14.9 $\pm$ 1.4, 11.0 $\pm$ 1.0 and 6.9 $\pm$ 0.4 ka.

Puniya et al. (2025) perform structural fieldwork and paleostress analyses from the Lesser Himalayan region in India. Through additional morphometric and landslide studies, they postulate that areas with numerous local faults and landslides can be the potential zones where more seismicity has been reported.

Spyrou et al. (2024) analyse morphometric parameters of the River Acheron in Greece, and decipher different degrees of tectonic activity in the river basin and eight watersheds. Such a method can possibly work in other areas where data on uplift rates are insufficient.

Yuan et al. (2024) perform a multidisciplinary study to decipher four types of alluvial channels governed by strike-slip faults related to the Changdi Fault zone. This zone sheared dextrally and created the basin. How sediment dispersal patterns can be controlled by structural geology is discussed in this work.

Yue et al. (2025) study how stress transfer in southern Tibet is related to the Gorkha earthquake. They infer that seismicity along the Shenzha–Dingjie rift was initiated mainly by the co- and postseismic Coulomb failure stress induced by the 2015 Gorkha earthquake.

Alves et al. (2025) utilize outcrop and seismic data from several countries to develop a technique to identify segments of active and inactive faults using machine learning. They explain how the fault parameters ratios are to be chosen in such exercises in order to avoid bias in T/D, and T/Z ratios. They use T-throw, D-full length of fault, Z-depth to analyse data.

Taloor and Kothyari (2025) apply PSInSAR study from the Jammu Himalaya (India) and decipher active surface deformation, uplift and subsidence, from the Tawi basin. A high rate of erosion and crustal deformation is deciphered, with sand mining suggested to be a potential reason for explaining high subsidence.

Guna et al. (2025) study the 18-Nov-1929 (M 7.2) Grand Banks earthquake and comment on the neotectonics of the terrain based on seismic reflection data. The present-day stress regime was deciphered, with NW-trending normal faults potentially becoming a region of active deformation.

The importance of ‘active tectonics’ to society ensures that it will continue to remain a major component or research in the broad field of Geosciences. Future studies will build on work such as is presented in this special issue, and will provide a framework for a greater understanding of overall Earth processes.

CRediT authorship contribution statement

Soumyajit Mukherjee: Writing – review & editing, Writing – original draft. **Swagato Dasgupta:** Writing – review & editing. **G. Ian Alsop:** Writing – review & editing.

Declaration of competing interest

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