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Editorial

Evolution of Modern and Ancient Orogenic Belts

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Orogens are broadly grouped into accretionary and collisional types [1], and their formation is explained by the Wilson Cycle [2]. The formation of both ancient and modern orogenic belts involves subduction of the oceanic and continental lithosphere, followed by crustal thickening and, often, movement of the lithosphere into the asthenospheric mantle, followed by subsequent exhumation and uplift through complex tectonic processes.

The evolution of orogens depends on many factors and processes, such as the thermal state and width of the orogens (cold vs. hot [3]); the rheology of the materials; the localization of deformation; metamorphism; magmatism; the balance between tectonic erosion and isostatic equilibration; syn- to post-collisional extensional tectonics; and indentation, the angle of convergence and deformation partitioning. Whereas the processes linked to subduction are quite clear, exhumation processes involving the metamorphic core of orogens are still debated (see, for example, the Himalayas [4]).

In the last few years, the use of a multidisciplinary approach integrating modern analytical techniques and data from different geological disciplines has highlighted a complex process in orogens and allowed us to better understand the evolution of different orogenic settings around the world. In particular, the combination of micro-scale analysis with meso- to macro-scale analysis has shed new light on the tectonic processes affecting modern and ancient orogens.

In this Special Issue, we present papers that integrate data and models from different disciplines, such as structural geology, numerical and physical modeling, isotope geochemistry, geophysics, tectonics, geochronology, petrology, and basin analysis, to better understand the processes and mechanisms of the tectonic evolution of orogenic belts formed in different geological contexts and in various parts of the world.

Modeling is becoming increasingly important in modern tectonic studies, and can be applied to explain structures and tectonic processes at several scales. The monoclinic and triclinic symmetry of the shear zone play an important role in the kinematic interpretation of structures [5–7]. The paper by Alonso-Henar et al. (2022) [8] conducts in-depth modeling of a shear zone (the El Salvador Fault Zone) formed in a complex context of triclinic transtension in the Central American Volcanic Arc. The analytical model used in this work can be very useful in the kinematic study of active volcanic arcs. Similarly, models obtained by integrating seismic, geophysical and GPS data collected in large-scale areas and integrated with field and regional geology can explain the geodynamic evolution of

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large crustal sectors. Mantovani et al. (2022) [9] provide an example of this approach enabling better definition of late Cenozoic evolution as well as the present tectonic setting of a complex sector of the Mediterranean area (the Aegean–Hellenic Arc), while Viti et al. (2022) [10] study late Cenozoic extrusion processes in the western and central Mediterranean area.

In recent decades, constraining the timing of deformation events and shear activity has been one of the main topics of research on the tectono-metamorphic evolution of orogenic belts. Carosi et al. (2022) [11] present a review of a combined structural and geochronological approach (mainly examining U-Th-Pb geochronology via an in situ analysis of monazite coupled with chemical zoning of the dated minerals; see [12]) used to constrain the time of activity to two regional-scale ductile shear zones in two large hot collisional orogens; the first one affecting medium- to high-grade rocks of the metamorphic core of the Himalayas in a still active orogen, and the second one affecting the Variscan basement in the Mediterranean area, in the exhumed roots of an ancient orogen. Detailed dating across the shear zone allowed the authors to better constrain the type of shear zone and its evolution through time (Type II according to Fossen and Cavalcante, 2017 [13]).

Burke et al. (2022) [14] present another example of the use of U-Pd zircon geochronology, here coupled with zircon-He thermochronology, to record the last stages of exhumation in low temperatures. These data aimed to constrain the timing and rates of exhumation in the Dajiamang Tso rift (South–Central Tibet) and provide a basis for evaluating dynamic models of synconvergent extension on the Tibetan plateau.

Older orogens are often reworked in more recent orogenic cycles, such as the Variscan orogen in Southern Europe, which was largely reworked during the Alpine orogeny. Variscan geology is also the main focus of the paper by Faure and Ferrière (2022) [15], which investigates the complex reconstruction of the Variscan Terranes in the Alpine Basement and discusses the available structural and metamorphic data acquired in the Variscan massifs in the Alpine orogen in the Western Alps, Southern Alps, and Austroalpine areas.

The reconstruction of the pressure–temperature (P-T) paths of rocks in the metamorphic core of orogens is a key point to consider when formulating and constraining tectonic models. Catlos et al. (2022) [16] deal with this topic by providing high-resolution pressure–temperature (P-T) paths taken from garnet-bearing metamorphic rocks across the northern and eastern portions of the Main Central Thrust (MCT) in the Sikkim region (NE India), one of the main shear zones affecting the Himalayas and running along the strike for more than 2000 km [17].

Structural (and microstructural) investigations, together with kinematic studies, represent a fundamental source of data in modern structural geology. Law et al. (2022) [18] provide a perfect example of a detailed structural and kinematic study of the Moine thrust (northern Scotland), summarizing and discussing geologic and isotopic age constraints in order to test the potential applicability of tectonic models proposed for the development of arcuate patterns of stretching lineations and transport directions in other orogens.

To conclude this Special Issue, a review by Andersen et al. (2022) [19] on the pre-Caledonian passive margin of Baltica provides an overview of the structure of the Scandinavia Caledonides. Here, the importance of pre-collision rift inheritance is emphasized, an important aspect that must always be considered when dealing with tectonic models of orogens.

The papers in this Special Issue are all valuable examples of how to integrate data and models from different disciplines, and the presented results demonstrate that a multidisciplinary approach is essential to establish a better understanding of the complex tectonic processes operating in orogens. Independent analytical methods for constraining the kinematics, temperatures and timing of deformation should always be systematically applied and combined in order to obtain data that enable us to address first-order questions on regional/continent-scale tectonics.

In conclusion, in recent decades, considerable advancements have been made in understanding the dynamics of orogen formation and evolution. While many questions still need to be addressed, researchers are able to understand and explain the main processes of subduction and subsequent continental collision. On the contrary, exhumation processes are still debated and, in some tectonic settings, are still unclear. Hence, future research conducted at several scales of observation is needed, with the close integration of observations of active processes at high structural levels in modern orogens with deep-level observations of exhumed ancient orogens.

Conflicts of Interest: The authors declare no conflict of interest.

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