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The Oligocene Alps: Domal unroofing and drainage development during early orogenic growth

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Abstract

The source of huge volumes of quartzofeldspathic detritus feeding Oligo-Miocene foredeep turbidites of the Apennines has long remained an unsolved geological enigma. In this article we reinterpret the available sandstone petrography, fission-track, stratigraphic, and geomorphological evidence to demonstrate that the Adriatic foredeep was dominantly sourced by a "Himalayan-type tectonic aneurysm" growing in the Central Alps since the late Oligocene: the Lepontine Dome. The Lepontine Dome is the envelope of distinct subdomes that formed stepwise from east to west during northwestward indentation of Adria beneath the axial Alps. Focused erosion of domal culminations cut by antecedent drainage started suddenly in the late Oligocene, with unroofing of recently-emplaced plutons and young amphibolite-facies gneisses. Exhumation was tectonically driven, and possibly accelerated by positive feedback between erosion and uplift of hot weak rocks from depth. The huge volumes of resulting detritus (Gonfolite–Macigno clastic wedge) were transported southward for hundreds of kilometers along the rapidly subsiding foredeep, formed since middle Eocene times in front of the Alpine retrobelt and nascent Apennine forebelt. Such massive sediment influx, following 15 ± 2 Myr of starved-foredeep sedimentation, testifies to rapid formation of mountain relief in the Central Alps, synchronous to dextral activity along the Insubric Fault.

The Lepontine Dome remains today as the only deeply-dissected region in the Alps, where medium-grade metamorphic rocks of the axial belt are extensively exposed. The relationships between geological structures and drainage patterns still mirror those formed originally at Oligocene times. River headwaters have not been significantly displaced since then, and their thalwegs constrain finite lateral displacement relative to the Southalpine retrowedge to a maximum of 10–20 km. Our reconstruction has wide implications, not only for a better understanding of the Tertiary evolution of the Alps–Apennines orogenic couple, but also for general relationships among tectonic activity, relief formation, drainage development, erosion distribution, and long-distance sediment transfer during continental collision and orogenic growth.

Keywords: sandstone petrography; fission tracks; Gonfolite; Macigno; antecedent drainage; tectonically-driven exhumation

1. Introduction

The geological evolution of orogenic systems produced by continental collision is a four-dimensional puzzle, complicated by interactions among diverse endogenic and exhogenic processes varying through time. Unraveling paleotectonic scenarios is thus a hard task, which requires us to consider and recombine all available information from both the orogenic belt and sedimentary basins. Petrological, structural and geochronological data on bedrock allow us to identify magmatic, tectono-metamorphic, and exhumation events. Stratigraphic, petrological and geochronological data on sediments allow us to pin-point key paleotectonic stages, to identify signatures of source areas, and to detect foci of accelerated unroofing. Because detritus is transferred over distances of ~10^3 km, and accumulates not only adjacent to the orogen but also in distant depocenters, synorogenic clastic wedges permit us to make comparisons, test hypotheses, and find independent constraints in diverse basins. The sedimentary archive thus offers an orogen-wide overview at a larger scale than classical bedrock studies, and

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ideally preserves a complete high-resolution record of orogenesis. Many new concepts and models of mountain building and unroofing, including positive feedbacks among climatic and tectonic processes ("channel flow" of Beaumont et al., 2001), spatial relationships between drainage development and syntaxial exhumation ("tectonic aneurysms" of Zeitler et al., 2001), diagnostic mineralogical–petrographical signatures (Garzanti et al., 2004a), and long-distance mass transfer of detritus (Ingersoll et al., 2003), have been developed in the Himalayas. In such a mighty and tectonically active mountain range, structural and geomorphological processes are particularly intense and evident, although the current state of knowledge is generally insufficient to put firm and laterally controlled age constraints on the full sequence of paleotectonic events.

The Alps and the Apennines are considerably smaller orogenic systems (Fig. 1), but detailed geological studies carried out for over a century have provided far more detailed and compelling geological and geochronological information. They represent an excellent laboratory in which to apply and test the experience gained and the concepts developed in other larger mountain ranges. Formed in contrasting subduction settings as reflected by contrasting structural and geomorphological features (Doglioni, 1994), these two belts display a still poorly understood transition, overlapping in both time and space ("Ligurian knot" of Laubscher et al., 1992). Onset of continental collision, marked by arrival of thinned European continental crust at the trench, was followed by its attempted subduction, consequent jamming of the subduction zone, and stacking of high-pressure metamorphic units showing different exhumation paths (Roure et al., 1990; Rubatto et al., 1998). Arrival of continental crust of closer-to-normal thickness initiated the subsequent indentation stage of mountain building, triggering a major pulse of relief formation, sediment production and long-distance transfer of detritus to subsident sedimentary basins ("morphogenic phase" of Gansser, 1982). Our attention is focused on this latter turning point in erosional and sedimentary evolution of the Alps–Apennines system, one of the most intriguing issues of Mediterranean tectonics.

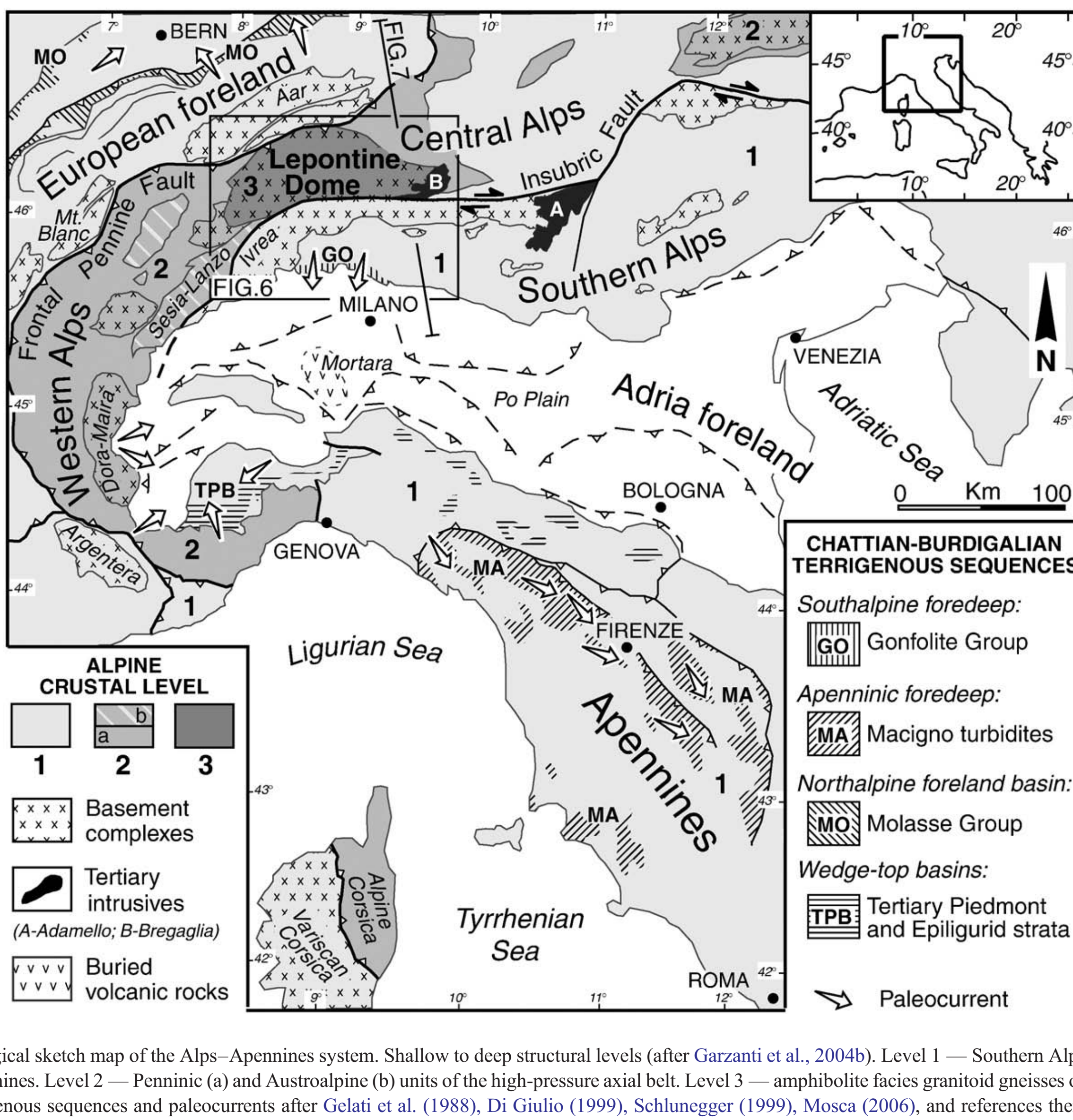

Fig. 1. Geological sketch map of the Alps–Apennines system. Shallow to deep structural levels (after Garzanti et al., 2004b). Level 1 — Southern Alps, Austroalpine lid, and Apennines. Level 2 — Penninic (a) and Austroalpine (b) units of the high-pressure axial belt. Level 3 — amphibolite facies granitoid gneisses of the Lepontine Dome. Terrigenous sequences and paleocurrents after Gelati et al. (1988), Di Giulio (1999), Schlunegger (1999), Mosca (2006), and references therein.