Zeitschrift: Eclogae Geologicae Helvetiae

Herausgeber: Schweizerische Geologische Gesellschaft

Band: 87 (1994)

Heft: 2: Pollution and pollutant transport in the geosphere, a major environmental issue : symposium held during the 173rd annual meeting of the Swiss Academy of Natural Sciences

Artikel: Repeated change from crustal shortening to orogen-parallel extension in the Austroalpine units of Graubünden

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Kapitel: 7: Conclusions

DOI: https://doi.org/10.5169/seals-167471

window is accentuated by a major northeast-striking antiform which we correlate with the Domleschg phase. The hinge of this antiform is near the southeastern border of the window (Fig. 15d; Gürler 1982).

According to a fault plane analysis along the Engadine line (Schmid & Froitzheim 1993), the least compressive principal stress (σ_3) was constantly oriented E-W all along the Engadine line, suggesting that an east-west stretch was accommodated by a combination of normal faulting and sinistral strike-slip movement. The sinistral movement along the Engadine line and the dextral movement along the Insubric line accommodated eastward extrusion (in the sense of Ratschbacher et al. 1991) of the triangular block bounded by these two lines (Fig. 15d), leading to local east-west directed extension also during this stage. Late Miocene deformation in the Southern Alps and along the Giudicarie line postdates this east-west stretch (Schmid & Froitzheim 1993). Therefore a Latest Oligocene to Early Miocene age is inferred for the movements along the Engadine line.

7 Conclusions

Two orogenic cycles, of Cretaceous and Tertiary age, have been demonstrated by the structural analysis of the Austroalpine nappes in Graubünden. The first cycle included west- to northwestward imbrication of upper crustal thrust sheets and sinistral transpression along the east-striking Albula steep zone (Trupchun phase), followed by east-southeast directed extensional overprint of the nappe edifice, involving low-angle normal faults and recumbent "collapse folds" (Ducan-Ela phase). In the second cycle, of Tertiary age, the Austroalpine and previously accreted Upper Penninic units were thrust northward and emplaced as an orogenic lid on the deeper Penninic units. Internal folding of the orogenic lid was associated with this northward thrusting (Blaisun phase, Eocene). Thrusting and folding were followed by a second phase of east-west extension, roughly contemporaneous with ongoing north-south compression (Turba phase, Early Oligocene). This second extensional event was followed by NW-SE shortening (Domleschg phase, Late Oligocene), and by sinistral slip and block rotation along the Engadine line near the Oligocene-Miocene boundary.

Regarding the Cretaceous orogeny in the Austroalpine realm, the following inferences can be drawn: (1) Cretaceous crustal shortening was accommodated by top-west to top-northwest thrusting. On the scale of the entire Austroalpine realm, this shortening propagated from east to west and was followed by an extensional collapse, also propagating from east to west. The westward migration of the orogenic wedge implies that Cretaceous orogeny did not result from the subduction of South Penninic oceanic lithosphere under the Austroalpine realm, but rather from a collision event east or southeast of the Austroalpine realm. (2) In the study area, we found no indications for Cretaceous dextral wrench movements as expected from broadly accepted models which assume a dextrally transpressive framework for the Cretaceous orogeny (Ratschbacher 1986, Ring et al. 1989, Ratschbacher et al. 1989). On the contrary, a sinistrally transpressive shear zone is observed (Albula steep zone), in accordance with models of Trümpy (1976) and Bechstädt (1978).

The recognition of two orogenic cycles contradicts the classical view of the Alpine orogeny as a continuous tectonometamorphic evolution. This view regarded all high-pressure metamorphism, even in the Penninic units, to be of Cretaceous age. Since our data indicate two cycles of crustal shortening followed by exhumation, they lend additional support for models postulating a second period of subduction in the Tertiary, leading to the closure of the North Penninic ocean (Schmid et al. 1990, Gebauer et al. 1992, Becker 1993). Our reconstruction of the tectonic evolution suggests that the high-pressure metamorphism within northern parts of the Penninic zone, e. g. in the Dora Maira massif, the Adula nappe, and the Tauern window, may be of Tertiary age.

Acknowledgments

This work was supported by Swiss National Science Foundation grants 21-25252.88 and 20-29869.90, and by the Deutsche Forschungsgemeinschaft grant Fr 700/1-1. We thank G. Eberli, U. Eichenberger, H. Furrer, M. Handy, G. Manatschal, P. Nievergelt and M. Weh for stimulating discussions. Reviews by G. Eberli, W. Frisch and M. Handy helped to improve a first version of this paper. We dedicate the present article to Rudolf Trümpy for two reasons. Firstly, this work would not have been possible without the solid stratigraphic-sedimentological framework layed out by his research group at ETH. Secondly, he has been a constant source of inspiration also concerning tectonic interpretations. We benefited from many discussions with him, both in the field and in the laboratory.

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