Orogen-parallel extension in the central Alps, Graubünden region, Switzerland

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Introduction

Work in the Swiss Alps over the past two decades (Mancktelow, 1992; Nievergelt et al., 1996; Meyre et al., 1998; Wey and Froitzheim, 2001; Wawrzyniec et al., 2001) has shown that there have been several periods of orogen-parallel extension in the central Alps both during and after main-phase ("Neoalpine") deformation. Principal periods of extension include 38-30 Ma along the Turba mylonite zone-Gürgaletsch shear zone (TMZ-GSZ) in eastern Switzerland and ~17-3 Ma along the Simplon Line in western Switzerland. Both of these zones occur in Penninic rocks. No one has identified extensional zones that mirror the TMZ-GSZ in western Switzerland or the Simplon line in eastern Switzerland. Likewise, it is unknown how much extension has been accommodated in other levels of the structural stack, including along the base of the main Austroalpine overthrust (hauptüberschiebung).

This project seeks to answer several questions with regard to extension in the central Alps: 1. Has extension occurred at the base of the Austroalpine overthrust, a structural contact that historically has been viewed as a 'passive' orogenic lid? 2. If so, what is the relationship between extension at the Austroalpine-Pennine contact and that observed deeper in the structural stack (within the Pennine Zone proper, i.e, the TMZ-GSZ and the Simplon line)? 3. Can we further elucidate the structural and paleogeographic postion of equivocal, intermediate nappes such as the Corvatsch teildecke, the Margna-Sella nappe, and the Platta ophiolite, whose positions, whether Austroalpine or Penninic, has long been argued (c.f., Trümpy, 1980)? 4. Lastly, can we correlate structurally and paleogeographically the western-most exposure of the Austroalpine sheet, the Dent Blanche klippe, to the much more prominent Lower East Alpine nappes, such as Err-Bernina or, possibly, the subjacent Corvatsch teildecke?

Methdology

We seek to answer the above questions using a combination of a) field work that involves structural measurements and kinematic analysis of important deformation fabrics (foliation, mineral lineations, fold axes, etc.) and b) noble gas thermochronometry on He- and Ar-producing minerals (i.e., apatite, zircon, white mica, biotite), and c) paleomagnetism.

Five weeks of field work have been completed in 2011 and 2013 during which structural measurements were made and samples for thermochronometry were collected. Additional fieldwork is anticipated in 2014. The thermochronometry is currently underway: U/Th-He measurements on apatite and zircon are being done in the Farley lab at Caltech. Ar/Ar measurements will be made in conjunction with Gordon Lister and Marnie Forster at the Australian National University.

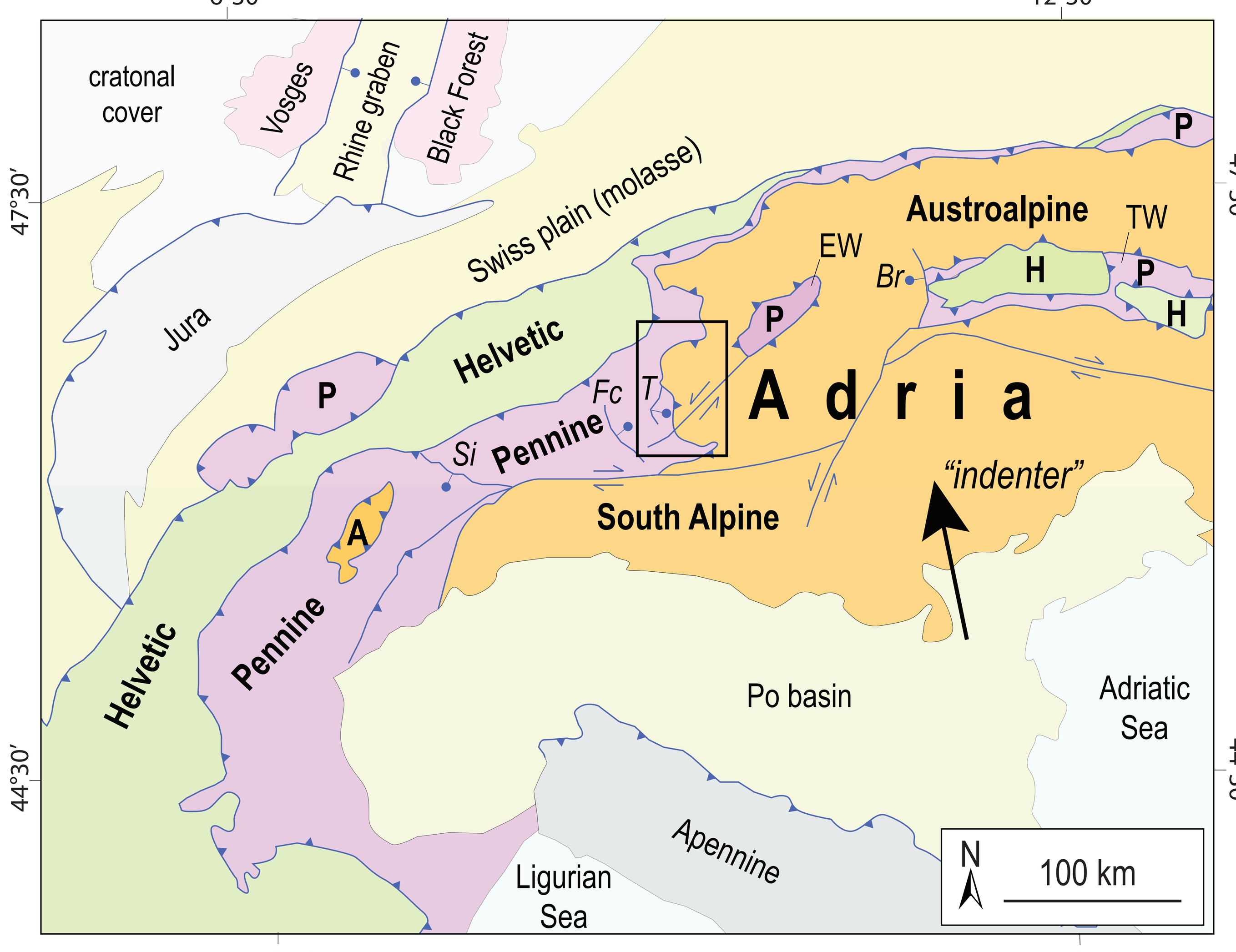


Figure 1. Tectonic map of western and central Alps, showing location of the study area in black box. Location of Adria 'indenter' shown by bold arrow. Important normal faults and shear zones in other parts of the range include Simplon (Si), Forcola (Fc), Turba (T), and Brenner (B). Engadine window (EW) and Tauern window (TW) are also shown.

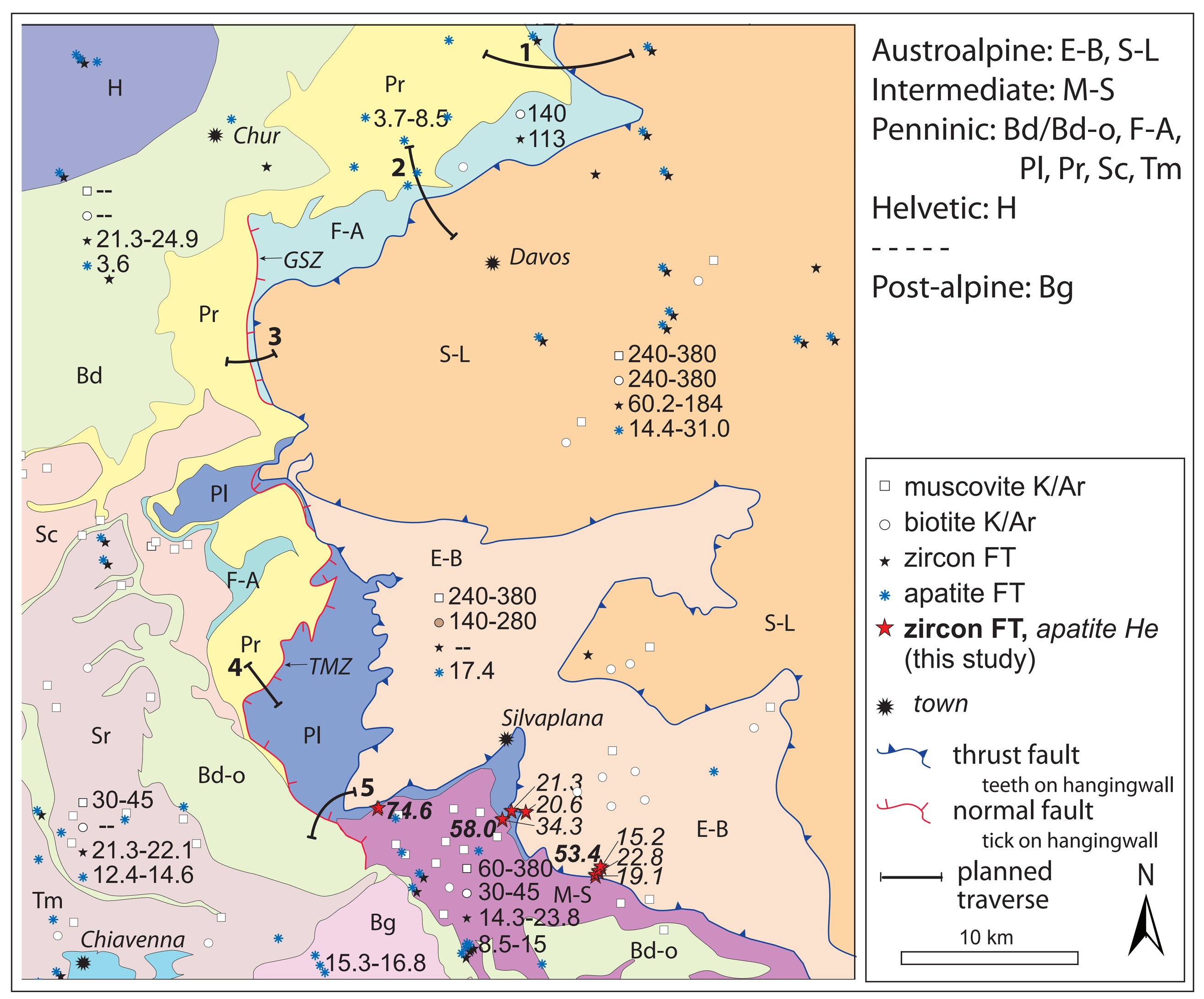


Figure 2. Distribution of thermochronometric data in eastern Switzerland, primarily from Hunziker et al. (1997), Vernon et al. (2008) and our preliminary data overlain on a generalized tectonic map. Groups of ages are summaries of the individual data points shown in each major domain. Note the dearth of data along the boundary between the Pennine and Austroalpine zones. Red stars show transects from our preliminary 2011 study; lines numbered 1 to 5 show location sample transects for the 2013 and 2014 field seasons. Late Engadine fault omitted for clarity. Bd/Bd-o: Bündnerschiefer (-o with ophiolite), Bg: Bergell, E-B: Err-Bernina, F-A: Falknis-Sulzfluh-Arosa, GSZ: Gürgaletsch shear zone, H: Helvetic, undifferentiated, M-S: Margna-Sella, Pl: Platta, Pr: Prättigau, S-L: Silvretta-Languard, Sc: Schams, Sr: Suretta, Tm: Tambo, TMZ: Turba mylonite zone.

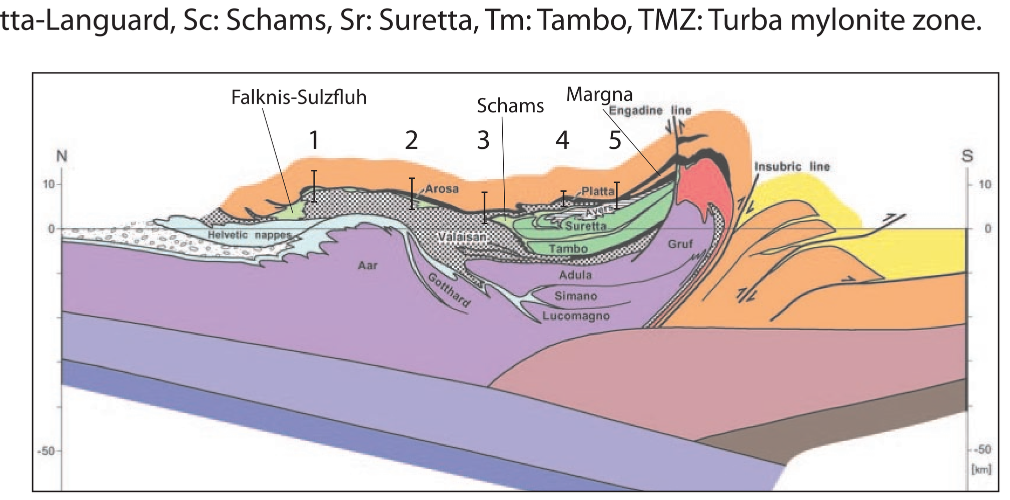
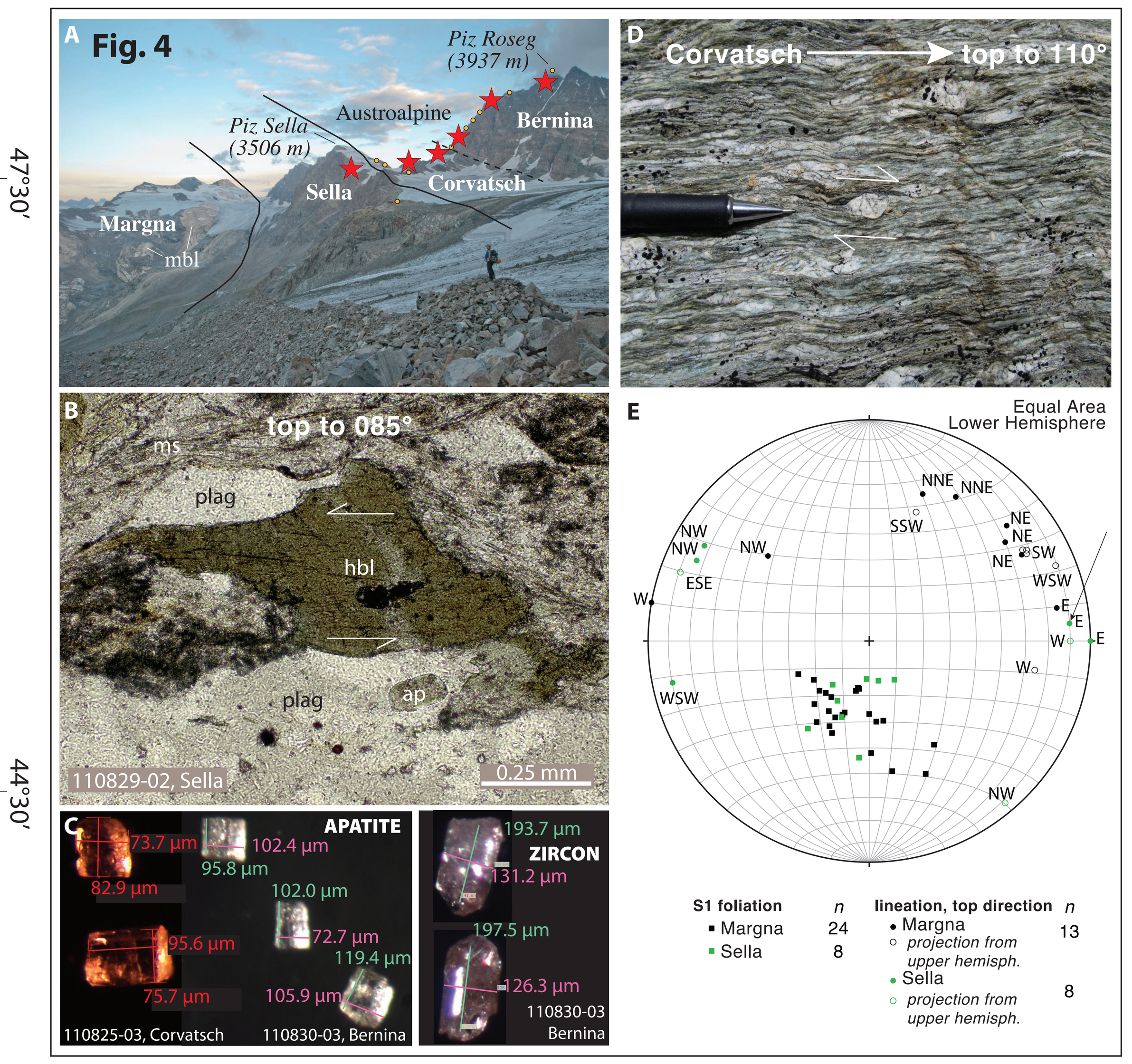
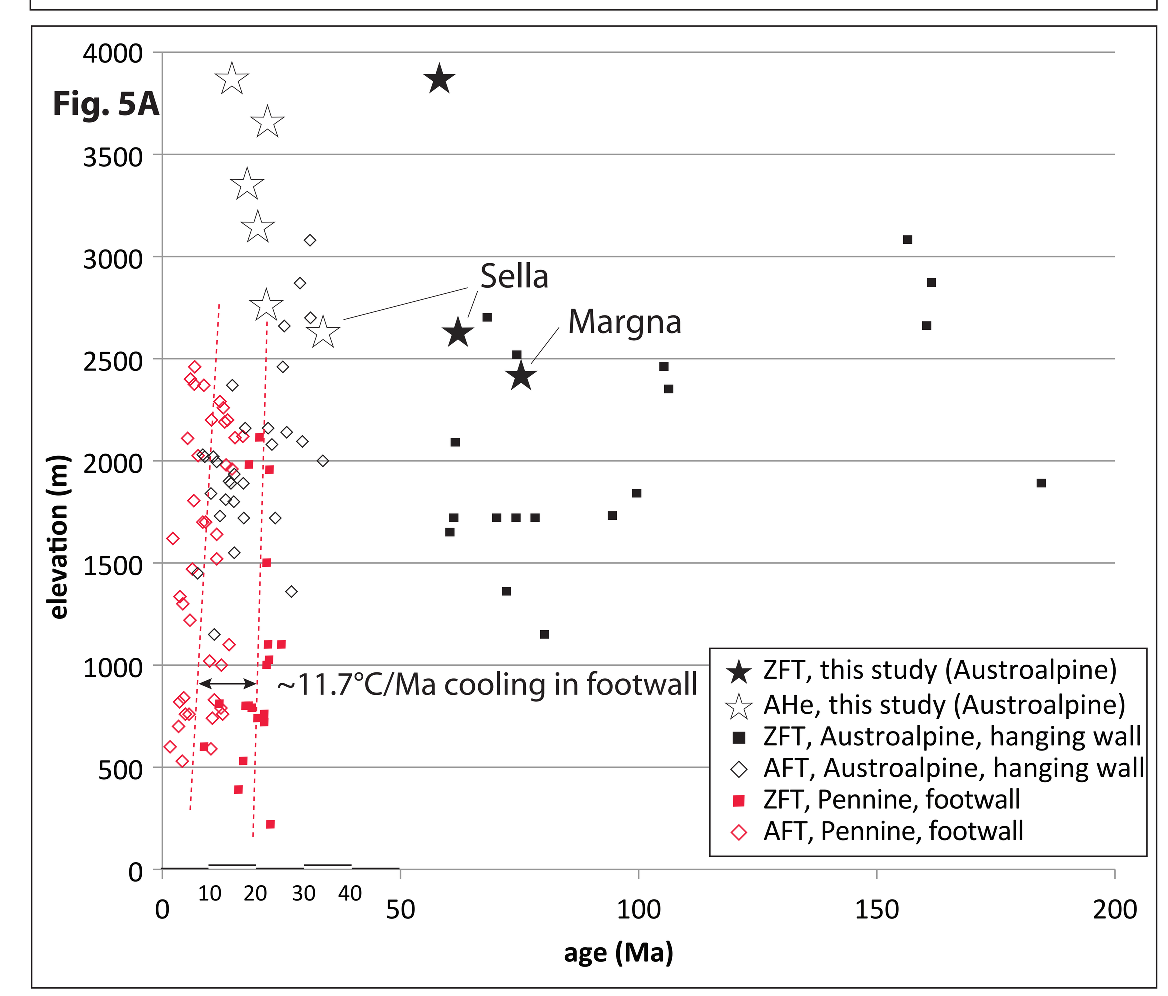
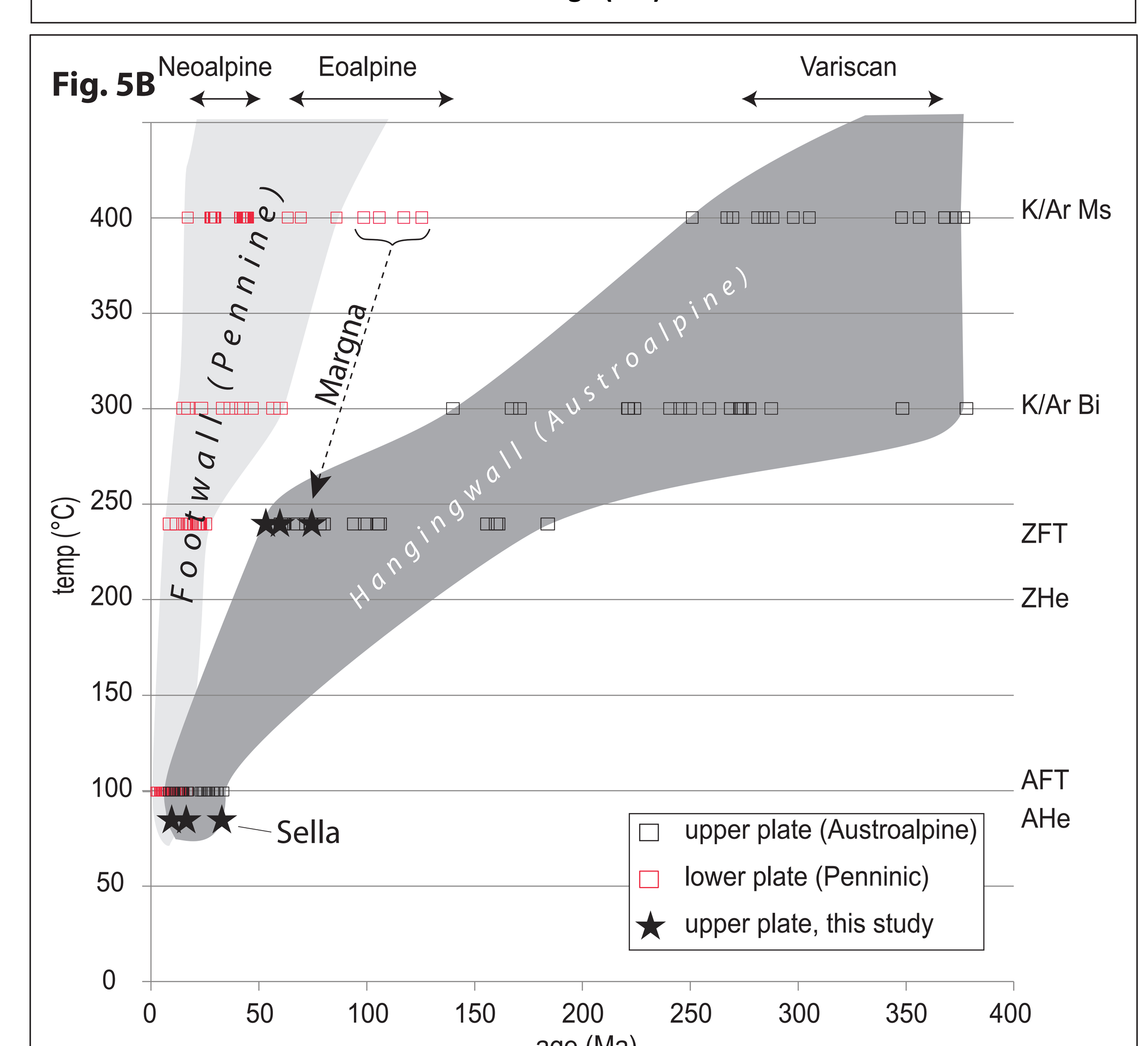


Figure 3. North to south cross section through the central Alps (modified after Schmid et al., 2004). Vertical bars show proposed sample transects (Figure 2) projected onto the section.







Progress Report

We are using a combination of a) field work that involves structural measurements and kinematic analysis of important deformation fabrics (foliation, mineral lineations, fold axes, etc.) b) noble gas thermochronometry on He- and Ar-producing minerals (i.e., apatite, zircon, white mica, biotite) and, potentially, c) paleomagnetism. The He work is currently underway in the Farley lab at Caltech. The Ar work will be done in conjunction with Gordon Lister and Marnie Forster at the Australian National University.

A compilation of existing thermochronometric data (Fig. 2) shows that the Austroalpine domain has been "cold" (<~200°C) since the JuraCretaceous, whereas Pennine rocks have cooled below 200°C more recently, during the Late Oligocene. While the thermal discontinuity between the two zones is dramatic, the defining thermal boundary has not been identified, and it may lie at the Austroalpine overthrust or lower in the structural section, i.e., at the Turba mylonite zone-Gürgaletsch shear zone. These data also show that some of the intermediate nappes (i.e., Margna-Sella) have cooled since the late Cretaceous and were probably already attached to the underside of the Austroalpine sheet prior to main "Neoalpine" deformation.

Structural measurements and kinematic analysis in the field and in thin section (Fig. 4) show dominant movement in the Margna-Sella and Corvatsch nappes to the NE, E, and ESE, approximately orthogonal to the expected northerly transport direction of the Apulian 'indenter'. In general, the timing of the easterly extension is not well constrained, but the Turba mylonite zone, which puts Platta ophiolite down onto Bündnerschiefer oceanic sediments, is cut by the 30-32 Ma Bergell pluton thereby providing an upper limit for the age.

Thermochronologic ages (Hunziker et al., 1997; Vernon et al., 2008; this study) are plotted against elevation (Fig. 5A) and nominal closure tempurature (Fig. 5B). Both plots show that the Austroalpine hangingwall cooled independently of the Penninic footwall until roughly 40-30 Ma, at which time they were juxtaposed and cooled together. Penninic footwall rocks cooled at a rapid rate, ~10-12°C/Ma, during exhumation from ~10-25 km depth, likely along one or more normal faults.

Figure 4. A) Photograph of a portion of the sample traverse on Piz Sella and Piz Roseg (central red stars, Figure 2). Red stars, samples selected for (U-Th)/He analyses; orange circles, other samples. B) Photomicrograph (plane polarized) showing penetrative ductile deformation in Sella quartz diorite. Hornblende porphyroclast (hbl) shows top-left displacement (~10°/085°). Note the nearly euhedral apatite grain (ap) ~125µm in length; ms, muscovite/phengite, plag, plagioclase feldspar. C) Examples of apatite (left and center) and zircon (right) grains from sample sites shown in A (bright areas are surface reflections, not inclusions). D) Outcrop photo of sheared augen gneiss (top-110°) in the Corvatsch digitation (central transect in Figure 2). E) Lower hemisphere equal area stereoplot of S1 foliation of Margna and Sella measured in outcrop (n=32) and the top-direction of oriented L-S tectonite samples determined petrographically (n=21). Arrow highlights datapoint corresponding to B.

Figure 5. A) Scatter plot of age versus elevation of all low-temperature samples in the area of Figure 2; Dashed red lines show approximate best-fit trend lines of AFT and ZFT for footwall samples and record an almost elevation-invariant cooling rate of ~11.7°C/Ma. B) Scatter plot of age versus nominal closure temperatures for various thermochronometers for samples in the area of Figure 4.