The formation of the arc of the Western Alps is associated with WNW-directed indentation of the rigid Ivrea mantle geophysical body formed by mantle rocks that are part of the Adria lithosphere, partially exhumed already during mid-Jurassic rifting. The geometry of the Ivrea body is well constrained by a high-resolution 3-D P-wave model of the Alpine crust (Diehl et al. 2009) that our contribution integrates into a series of Alpine transects across the Western Alps. Oligocene (35-25 Ma) top-WNW indentation of Ivrea mantle was preceded by dextral transpression in the future Western Alpine arc during Eocene collision, confined between dextral shearing along the Tonale-Simplon-Valais strike slip zone in the N and a sinistral strike slip zone near Cuneo in the S. A third stage of arc formation is related to the opening of the Ligurian-Provencal and Tyrrhenian basins starting at around 30 Ma, affecting the Alps-Apennine transition zone from Mid-Miocene times onward. It led to oroclinal bending severely affecting the Ligurian Alps and associated with N-directed thrusting of the Ligurian Alps including the Tertiary Piedmont basin along the Apennines front in the Monferrato and Torino Hills; the southern part of the Western Alps arc was affected by ongoing Apennines orogeny.

Alps and Apennines are two orogens characterized by opposite subduction polarity. However, we argue that the Alps, characterized by a lower plate position of the European margin, formerly continued all the way to Corsica and the Northern Apennines Internal Ligurides further to Calabria, Peloritani Mts., Kabilies into the Betics until some 30 Ma ago, following ideas proposed by Elter & Pertusati (1973) and Michard et al. (2002). The West Ligurian Ocean, i.e. the SE-ward continuation of the Piemont-Liguria Ocean of the Alps proper, was closed between Europe-Iberia and the ALKAPECA micro-continent, while the East Ligurian Ocean remained open (Handy et al. 2010). Mantle lithosphere delamination and negative buoyancy of the still open East Ligurian Relic Ocean induced a change in subduction polarity, associated with severe roll back of the Adria continental lithosphere and adjacent East Ligurian Ocean. It is this roll-back that led to the Apennines orogeny, i.e. thrusting of the East Ligurian Ocean (preserved in the external Ligurides) together with parts of the former Alps (Internal Ligurides, Calabria and Peloritani continental slices) onto the Adria continental margin. Rollback and Apennines thrusting was associated with massive extension in the upper plate leading to the opening of the Ligurian-Provencal and Tyrrhenian basins and the rotation of Corsica-Sardinia. The above described oroclinal bending affecting the Ligurian Alps occurred during the final stages of Apennines orogeny in Mid-Miocene to recent times when the Ligurian Alps eventually became part of the Apennine orogen.

This demands that, in the Eocene, there must have been a major along-strike change within the Alps and their southwestward continuation. Continent-continent collision in the Alps of Eastern Switzerland and Austria led to the suturing of the European plate (including the Briançonnais micro-continent) with the Adria plate (Austroalpine nappes) along the Piemont-Liguria oceanic suture. In the Western Alps, however, there is no Austroalpine upper plate; the Sesia Zone with its high-p history is clearly in a lower plate position below the Adria margin including the Ivrea Zone. Instead, the upper plate in the Western Alps was formed by the East Ligurian Ocean lacking high-pressure overprint and only preserved in a few places such as, for example the Montgenèvre ophiolites. Further SE it is the East Ligurian relic ocean that formed the upper plate.

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Analysis of Cretaceous to Miocene ductile and brittle fault systems in Austroalpine units to the southeast of the Tauern Window (Eastern Alps)

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The eastern part of the Tauern Window and the Austroalpine units immediately to the south of it (in the Kreuzeck and Sadnig Mountains) were in the focus of structural and geochronological studies in the past years (e.g. Schmid et al. 2013; Wölfler et al. 2014). While for the Subpenninic and Penninic units within the frame of the window detailed maps are available, the Austroalpine part and the fault pattern therein were shown only schematically and inconsistent in published overview maps. In this contribution we present additional structural and geochronological data from the area and a detailed tectonic map prepared by mapping in scale 1:10.000 and by the use of a high resolution digital elevation model. The map shows the interference and overprint relationship of the Oligocene and Miocene fault systems an gives the opportunity to attribute the pre-existing Ar-Ar, Rb-Sr and fission track ages to individual tectonic units and to reconstruct the structural evolution of the area in much more detail then before. From bottom to the top the tectonic column of the study area includes the following elements: The Sonnblick nappe of the Subpenninic unit consisting of huge masses of deformed Varicsan granites and some paragneisses is overlain by several Penninic and Subpenninic nappes and slices composed mainly out of Permian to Cretaceous metasediments. These units are characterised by a dominant Alpine (Oligocene-Miocene) structural and metamorphic imprint. Above Lower Austroalpine units including Permian to Triassic metasediments (“Alpiner Verrucano”) and phyllonites (Sadnig Complex) with a penetrative Alpine (Eoalpine?) imprint followed by a Variscan metamorphic basement (Melenkopf Complex) are present. Upper Austroalpine units are represented by the Prijakt nappe characterised by an Eoalpine (Cretaceous) overprint and the tectonically uppermost Kreuzeck-Gailtaler Alpen nappe showing well preserved pre-Alpine (Variscan and Permian) assemblages and textures. This tectonic column is dissected by an Eocene-Oligocene and a Miocene fault pattern. Eocene-Oligocene NW-SE trending dextral faults include a precursor of the Mölltal fault system and the Ragga-Teuchl fault system. The latter is steeply dipping and E-W trending and represented by a several decameter wide cataclastic fault zone which shows a dextral offset. In the western part of the Kreuzeck Mountains the fault forms the boundary between the Kreuzeck-Gailtaler Alpen nappe and the Prijakt nappe, whereas in the east it cuts through the Prijakt nappe which contains eclogites only to the north of the Ragga-Teuchl fault. The Ragga-Teuchl fault is cut off by the Miocene Mölltal fault system in the East and by the Zwischenbergen fault system in the West. The Miocene Mölltal fault system forms the boundary of the Prijakt nappe in the Kreuzeck Mountains towards the Penninic and Subpenninic units in the Reiseck Mountains towards the Northeast. In the North it does not cut into the Tauern Window but it seems to continue into the E-W orientated frame of the Tauern Window. There the schistosity in the Penninic and Lower Austroalpine units is dipping to the South and shows a stretching lineation dipping towards SSE with a sinistral motion. The Zwischenbergen fault system separates parts of the Kreuzeck from the Sadnig Mountains. It is WSW-ENE orientated, sinistral and splits near to its ENE end into a number of SW-NE orientated parallel faults. Furthermore a branch of the Zwischenbergen fault system reactivates the western part of the Ragga-Teuchl fault with a sinistral offset. The SW-NE orientated faults are cut off at the boundary of the Tauern Window, but in its vicinity they show an increasing south directed dip slip component. In combination with the thermochronological data the downward migration of brittle deformation during cooling of the different tectonic levels can be demonstrated. Even if space problems lead to complex overprinting relations especially at the triple junctions of the faults the movement of the brittle blocks can be reconstructed properly.

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Curie temperature depths in the Alps and the Po Plain (northern Italy): evidence for a hot crust along maximum crustal thickness zones of the Alps

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Although hot Alpine chains are theoretically put forward by several geodynamic models, real heat flow data from the orogens are contradictory, and do not seem to systematically document hot belts. Data from the Italian Alps yielded in the past heat flow values ranging between 45 and 80 mW/m2 (Cataldi et al., 1995), suggestive of a cold to intermediate crust, but a recent data compilation and re-evaluation by Pasquale et al. (2012) raised heat flow values from the internal part of the Alps to 80-90 mW/m2. However, heat flow data of the Italian Alps were gathered either in shallow wells (depth < 1 km) or by road/railways tunnels, thus likely biased by shallow hydrological circulation of cold meteoric waters.

Here we report on the spectral analysis of the aeromagnetic residuals of the Alps and the Po Plain (northern Italy) to derive the Curie point depth (CPD), assumed to represent the 550°C isotherm depth. We analysed both the aeromagnetic residuals of northern Italy gathered by Agip (now Eni) and the recent EMAG2 compilation. We used the centroid method on 44 and 96 (respectively) 100x100 km2 windows considering both a random and a fractal magnetization distribution, but found that, at least for the Alps, the fractal model yields unrealistically shallow CPDs. Analyses considering a random magnetization model give CPDs varying between 12 and 39 km (22 to 24 km on average considering the two data sets, Figure 1) in the Po Plain, representing the Adriatic-African foreland area of the Alps, in substantial agreement with recently reported heat flow values of 60-70 mW/m2. In the Alps, the Eni data set yields shallow CPDs ranging between 6 and 23 km (13 km on average). EMAG2 analysis basically confirms the “hot” Alpine crust, but reduces it to three 50 to 100 km wide patches elongated along the chain, where CPDs vary between 10 and 15 km. Such “hot” Alpine domains occur in correspondence of maximum (>40-45 km) crustal thickness zones of the Alps, whereas no relation is apparent with local geology. Assuming an average crustal thermal conductivity of 2.5 W/m°C and a steady-state conductive model, CPDs from the hot zones of the Alps translate into heat flow values of 100-110 mW/m2, that are slightly higher than the 80-90 mW/m2 values recently reported for the internal part of the chain. Thus we quantify to ~20% the cooling effect of cold-water