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# The Western Alps - Eastern Alps transition: tectonics and deep structure

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## 1 MAJOR TECTONIC UNITS OF THE ALPS

For a large-scale overview the major tectonic units of the Alps may conveniently be grouped according to their paleogeographic provenance (Fig. 1). As is apparent from figure 1 at a first glance, the eastern Alps are largely made up of tectonic units derived from the Apulian plate, the Austroalpine nappes (= " Apulian plate N of Periadriatic Line"), while the western Alps are exclusively made up by more external, and tectonically lower units (European margin, *Briançonnais terrane*, Margna-Sesia fragment and intervening oceanic units, Froitzheim *et al.,* 1996). Note that the western boundary of the Austroalpine nappes, coinciding with the boundary between western and eastern Alps, runs N-S and perpendicular to strike across eastern Switzerland. This erosional boundary is not far from the western frontal ramp of the Austroalpine nappes, which were internally stacked and sutured to the Piemont-Liguria ocean by top WNW shearing during a first (Cretaceous) orogenic cycle which only affected the eastern Alps.

Another major change across the boundary between eastern and western Alps concerns the presence or absence of a *Briançonnais terrane*. The easternmost remnants of this *terrane* are found in the Engadine window (Fig. 1). We interpret the core of the Tauern window to be made up by tectonic units attributed to the European margin. As a consequence, the two oceanic domains (Piemont-Liguria and Valaisan) spatially coincide in the Eastern Alps. However, we still treat Piemont-Liguria and Valais units separately from each other for the following reason: the remnants of the Piemont-Liguria ocean in the eastern Alps (*e.g.* Matrei zone) were sutured to the Austroalpine nappes during Cretaceous orogeny, while the Valais ocean (*e.g.* the Rheno-Danubian flysch and the outer rim of the Tauern window) did not close before the Late Eocene and at the end of a second orogenic cycle (Schmid *et al.,* 1996). This Paleogene cycle shaped both western and eastern Alps. Stacking of paleogeographic and tectonic units was top N to NNW, the European plate was subducted to the south and below the Apulian plate.

As far as the youngest (post-collisional) stages of Alpine orogeny are concerned, yet another across-strike boundary is found near the transition between western and eastern Alps. The sinistrally transpressive Giudicarie belt forms the western margin of an indenter situated in the eastern part of the Southern Alps during the Miocene. This led to massive N-S shortening in the Tauern window. This shortening is contemporaneous with (1) substantial orogen-parallel extension across the Brenner normal fault (Fügenschuh *et al.*, 1997), and, (2) lateral extrusion of the Eastern Alps east of this normal fault, associated with strike slip movements along the Periadriatic (dextral) and Inntal (sinistral) lines (Ratschbacher *et al.*, 1991). Hence, it is obvious that very substantial out-of plane movements are expected across the TRANSALP transect, situated immediately east of Giudicarie belt and Brenner line (Fig. 1).

## 2 TRANSECTS IN THE WESTERN ALPS

Figures 2a to 2c depict geological-geophysical transects across the Western Alps s. str. (ECORS-CROP and NFP-20 WEST), and a transect near the transition into the eastern Alps (NFP-20 EAST) (see discussion in Schmid and Kissling, 2000). These profiles illustrate the following major changes which occur along strike, *i.e.* when going from the Western Alps *s.str.* (Figs 2a and 2b) towards what may be referred to as "Central Alps" (Fig. 2c): (1) = Duplication of European lower crust in the Western Alps *vs.* wedging of Apulian lower crust into the European crust; (2) = Apulian Moho rising towards the Alps (Ivrea body) vs. descending Apulian Moho at the base of the lower crustal wedge; (3) = increasing amounts of back-thrusting in the vicinity of the Insubric line; (4) = increasing amounts of Miocene shortening within the Southern Alps.

## 3 CHANGE IN SUBDUCTION POLARITY BETWEEN WESTERN AND EASTERN ALPS

Recent results from high-resolution tele-seismic tomography, focussing on the lithosphere and upper mantle P-wave velocity structure beneath the entire Alps, reveal a change in subduction polarity between Western and Eastern Alps. The European lithospheric slab descends towards southeast underneath the Apulian lithosphere

(Fig. 3a) , steepening eastwards and towards the Tauern window. East of a point situated underneath the western part of the Tauern window, the Apulian lithospheric slab is seen to descend underneath the European lithosphere by some 170km (Fig. 3a). This is surprising at first sight, since there is no indication for an along-strike change in the stacking order of the major paleogeographic units in the Alps (Fig. 1). However, two major orogen-perpendicular post-collisional features coincide with this change in subduction polarity: Giudicarie belt and the Brenner normal fault. This suggests that the change in subduction geometry was not induced before some 20 Ma ago, *i.e.* when these across-strike features started to form. Assuming that subduction polarity was initially identical to that observed in the western Alps, and that polarity indeed changed some 20 Ma ago in the Eastern Alps, this would result in a plate convergence rate of 0.85 cm per year for the last 20 Ma. In order to test this working hypothesis, we attempted to re-interpret the TRANSALP geophysical-geological transect (TRANSALP WORKING GROUP, 2002) in the light of these findings on the deep structure of the Alps.

## 4 TRANSALP TRANSECT AND ALPS-DINARIDES-CARPATHIANS TRANSITION

The interpretation of the TRANSALP transect depicted in ficure 2d closely follows that proposed by TRANSALP W. G. (2002) regarding the near-surface structures, but differs in terms of the interpretation of the deep structure (compare their "models A" and "B" in their figure 3). While we agree with their "model A" regarding the continuation of S-dipping "Tauern window reflectors" underneath the Southern Alps, we do not interpret the Apulian lower crust to wedge into European crust (as observed in the NFP-20 East profile, see figure 2c). Instead we let the Apulian Moho descend northwards under the European lithosphere, as is suggested by the lithospheric configuration revealed from tomography and depicted in figure 3b.

This re-interpretation, although provisional and of qualitative nature, leads to an easily retro-deformable transect, if one assumes a change in subduction polarity and a "wedge into split apart structure" between Apulian lower crust and the frontal thrust of the Miocene to recent thrust belt of the eastern part of the Southern Alps.

This re-interpretation also explains the lack of a clear separation between easternmost Southern Alps and external Dina rides at the earth's surface. Such a separation would be expected if Alps and Dinarides would still exhibit opposite subduction polarity, as they did during the Eocene. Since no separation is visible between Southern Alps and Dinarides (see Fig. 1), both are expected to presently occupy the same, *i.e.* upper plate, position. Instead, a major change occurs across Giudicarie belt and Brenner line. We interpret both these first-order tectonic features as the surface expression of a change in subduction polarity which initiated at around 20 Ma and which had a profound influence on the style of post-collisional deformation. Note that the postulated change in subduction polarity was also accompanied by very major dextral strike slip movement of the Southern Alps and northern Dinarides in respect to Alps and Western Carpathians along the Periadriatic lineament and "Mid-Hungarian line" (Fig. 1).

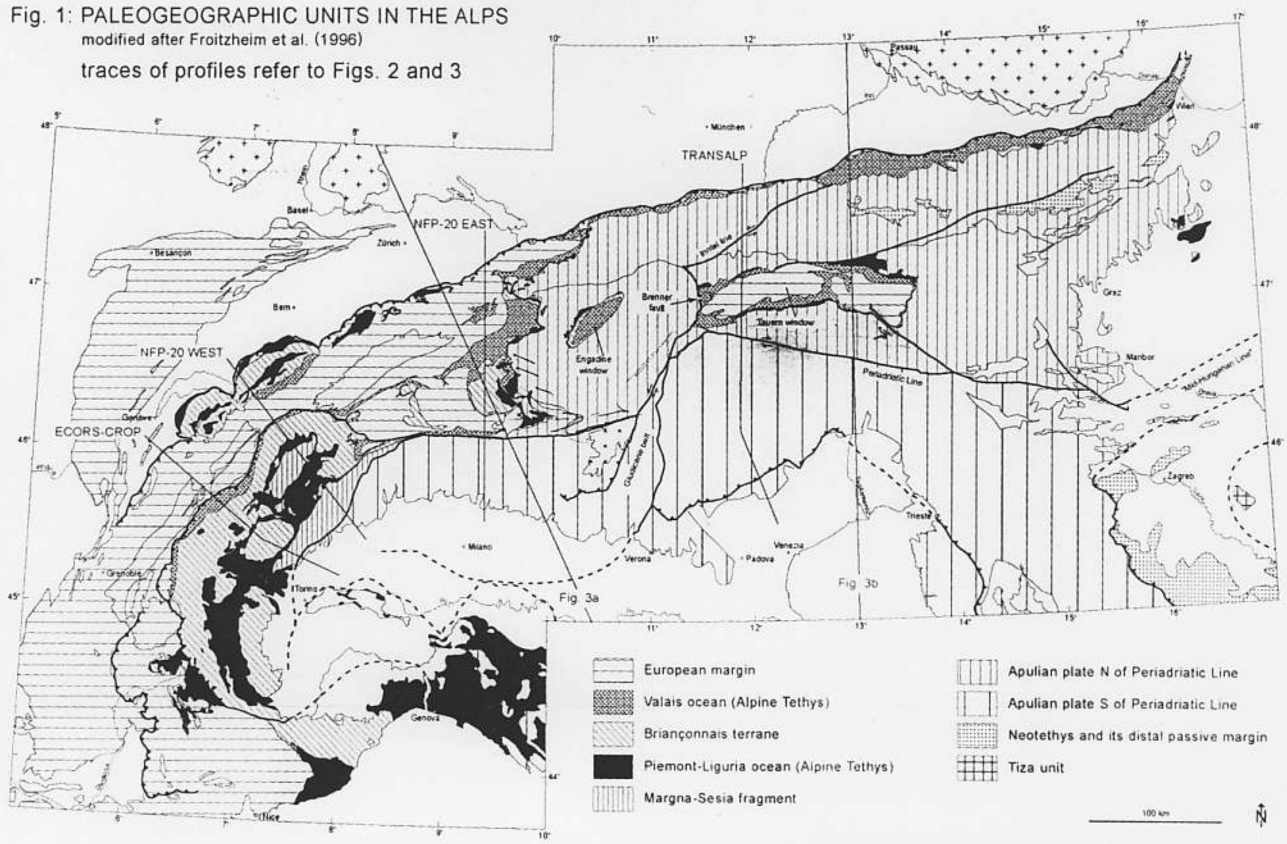


Fig. 1 - Map of the Alps and traces of profiles depicted in Figs 2 and 3.

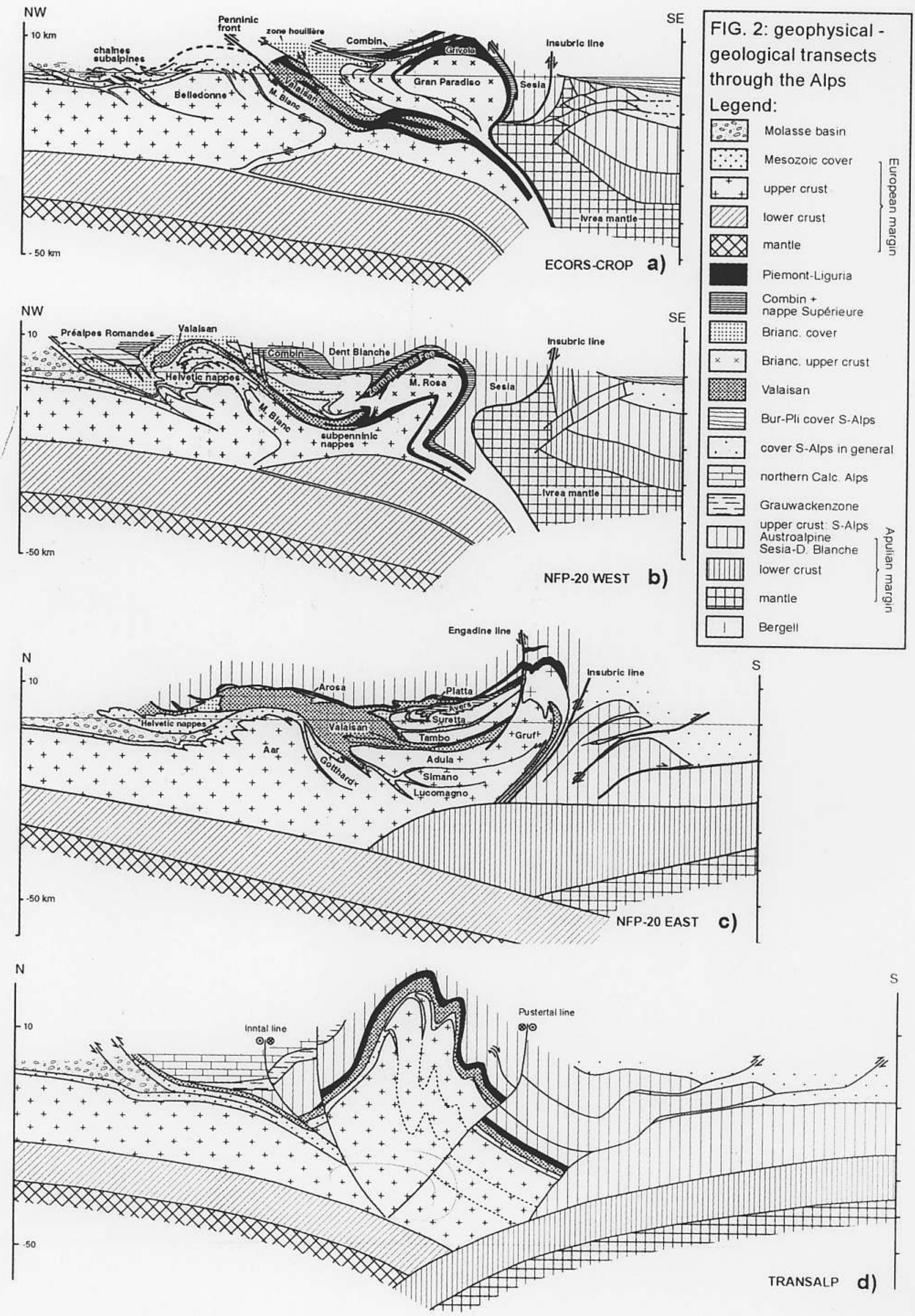


Fig. 2 - Geophysical-geological transects through the Alps.

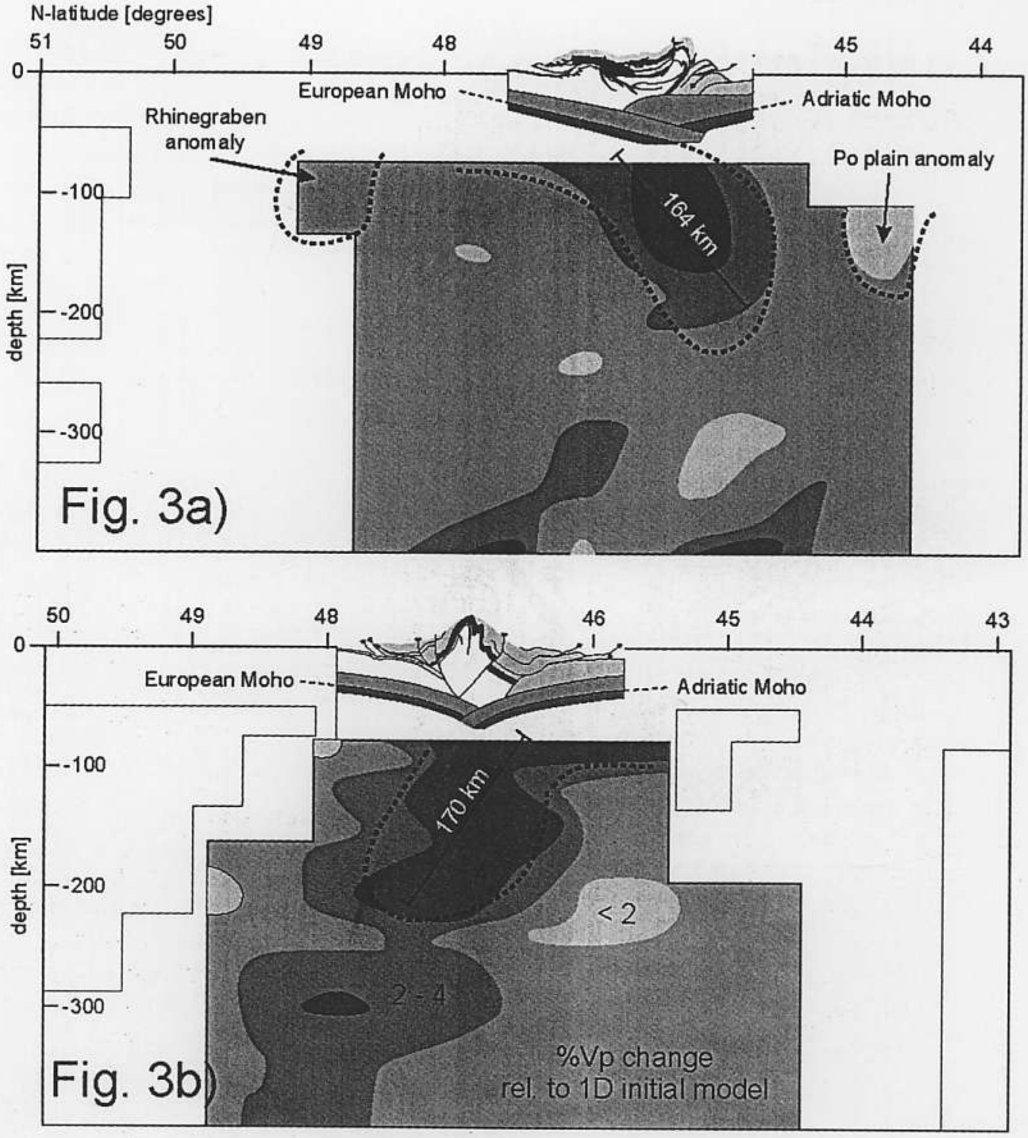


Fig. 3 - Sections through the tomographic model with transects Figs 2c and d superimposed.

The polarity of the suture between the Rhenodanubian flysch ("Valaisan") and the northern rim of the Austroalpine nappes ("Apulian plate" in figure 1) does not change along strike from west to east. This indicates that the northern rim of the Apulia upper plate remains unaffected by the Miocene change in subduction polarity, which only concerns the southern part of the TRANSALP transect (Fig. 2d). Instead, the northern rim of the Alps can be followed eastwards into the Carpathian loop. There, subduction roll-back and slab break-off initiated at about 20 Ma ago. Possibly, this roll-back allowed for the change in subduction polarity, postulated to have occurred along the TRANSALP profile.

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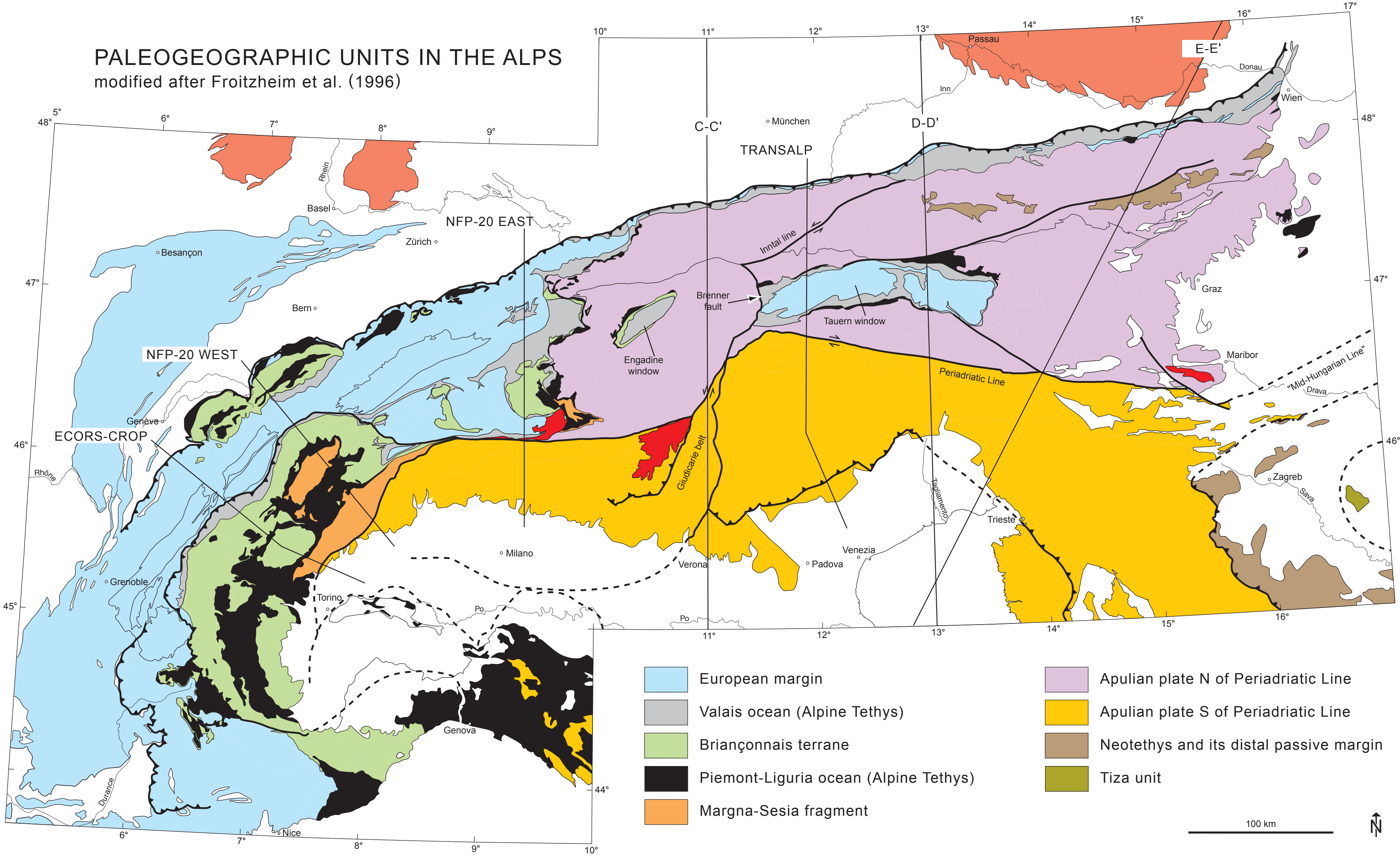
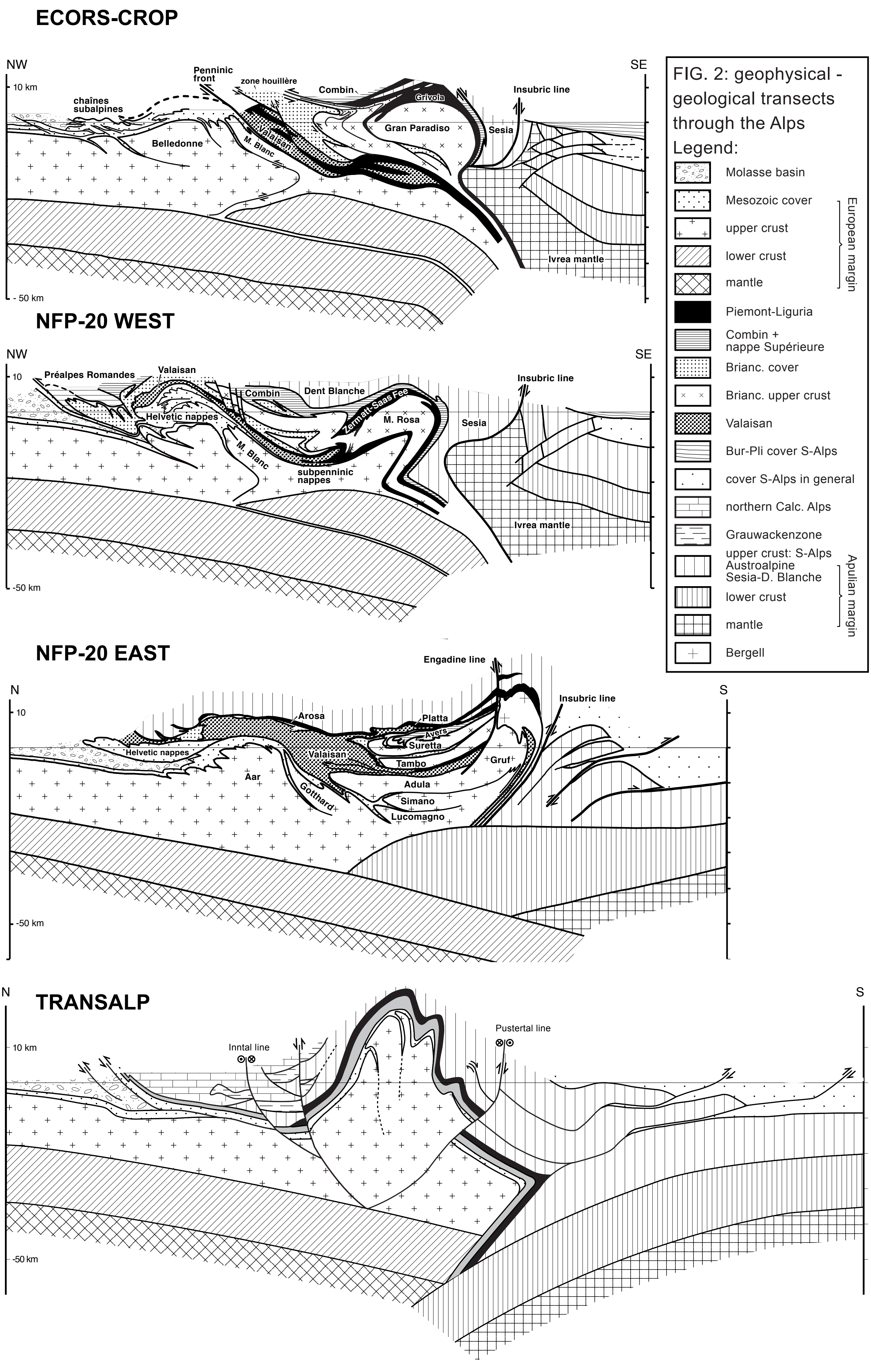
# PALEOGEOGRAPHIC UNITS IN THE ALPS

modified after Froitzheim et al. (1996)





ECORS-CROP
NW
SE
10 km
- 50 km
chaînes subalpines
Penninic front
zone houillère
Combin
Grivola
Insubric line
Belledonne
Valaisan
M. Blanc
Gran Paradiso
Sesia
Ivrea mantle
NFP-20 WEST
NW
SE
10
-50 km
Préalpes Romandes
Valaisan
Combin
Dent Blanche
Insubric line
Zermatt-Saas Fee
Helvetic nappes
M. Rosa
Sesia
M. Blanc
subpenninic nappes
Ivrea mantle
NFP-20 EAST
N
S
10
-50 km
Engadine line
Insubric line
Arosa
Platta
Avers
Suretta
Helvetic nappes
Valaisan
Tambo
Gruf
Aar
Adula
Gotthard
Simano
Lucomagno
TRANSALP
N
S
10 km
-50km
Inntal line
Pustertal line
FIG. 2: geophysical - geological transects through the Alps
Legend:
Molasse basin
Mesozoic cover
upper crust
lower crust
mantle
European margin
Piemont-Liguria
Combin + nappe Supérieure
Brianc. cover
Brianc. upper crust
Valaisan
Bur-Pli cover S-Alps
cover S-Alps in general
northern Calc. Alps
Grauwackenzone
upper crust: S-Alps Austroalpine Sesia-D. Blanche
lower crust
mantle
Apulian margin
Bergell

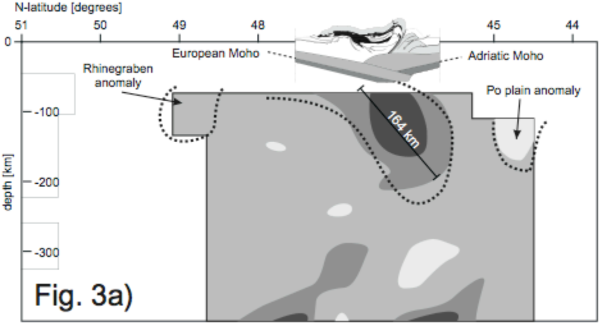

N-latitude [degrees]
51
50
49
48
45
44
0
-100
-200
-300
depth [km]
European Moho
Adriatic Moho
Rhinegraben
anomaly
Po plain anomaly
164 km

Fig. 3a)

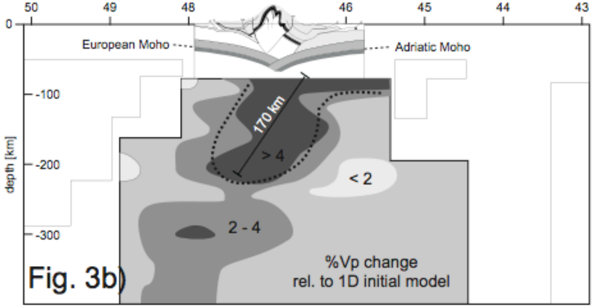

50
49
48
46
45
44
43
0
-100
-200
-300
depth [km]
European Moho
Adriatic Moho
170 km
> 4
< 2
2 - 4
%Vp change
rel. to 1D initial model

Fig. 3b)