Cargèse 2023 School on Subduction Zone Processes
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Field trip in the fossil subduction zone of Alpine Corsica

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Structure of the excursion:

Part I: Overview of the regional geological context of Corsica - Stop 1.
Part II: Fragments of subducted Tethys seafloor and their meaning for subduction zone processes – Stop 2.
Part III: The fate of a continental margin entering a subduction zone: the Tenda massif – Stop 3.

I: Overview of the regional geological context of Corsica

Key points:

- Corsica: A **key element** of the puzzle for reconstructing the **geodynamic evolution of the Mediterranean realm**: understanding extensional features above a subduction zone in a large-scale convergent context
- **Long-term retreat of the subduction zone** towards the East of the Tyrrhenian sea and associated **network of normal faults** and magmatic activity. Ongoing magmatic activity and mantle exhumation in the Tyrrhenian basin.
- Tyrrhenian realm opening correlates with the **rotation of the Corsica-Sardinia block** over the last 30 Million years
- These **extensional tectonics** are visible along **large-scale shear zones** in Corsica mainland and marked by **greenschist-facies** (low pressure) top-to-the East verging structures
- These late structures post-date the **high-pressure/low-temperature (blueschist) imprint** marked by top-to the West fabrics

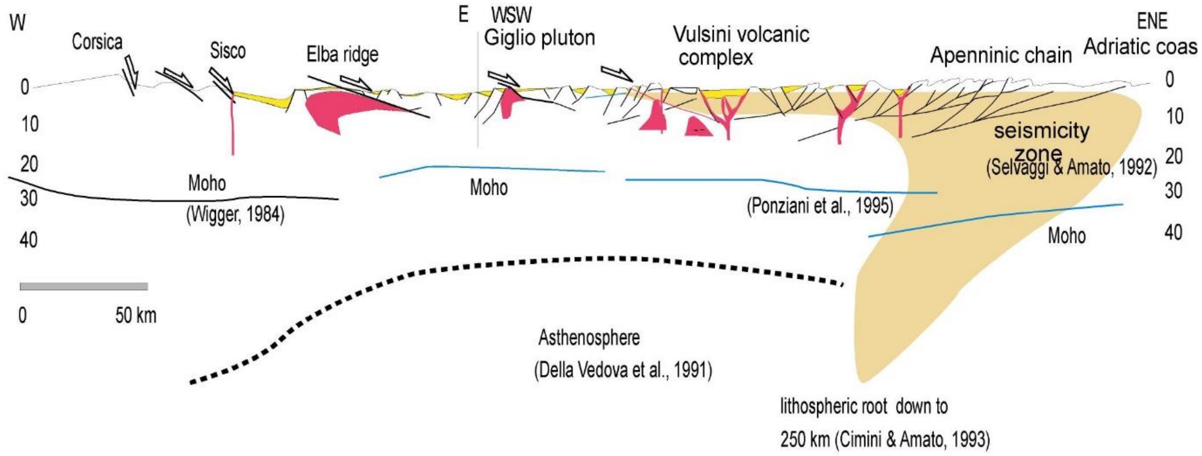


***Fig.1**: **Interpretative cross-section showing the tectonic style in the northern Tyrrhenian basin**, along with sheared magmatic bodies and asthenospheric mantle upwelling (modified after Jolivet et al. 1998)*

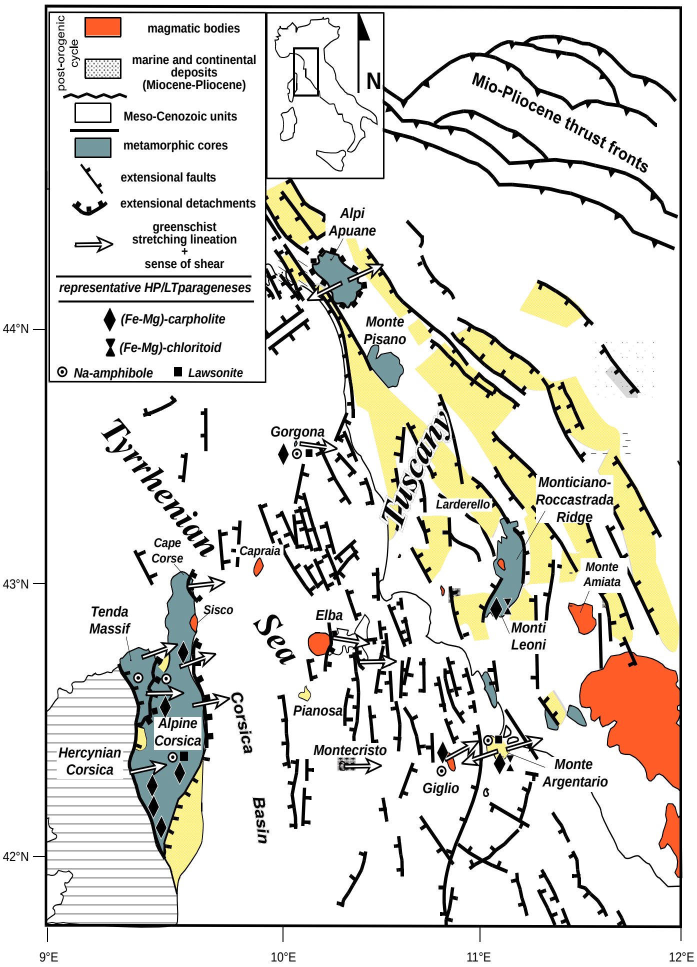


***Fig.2**: **Geological map of extensional faults in the Tyrrhenian realm and in Tuscany**, as well spatial distribution of key HP index minerals and structural features (after Jolivet et al., 1998)*

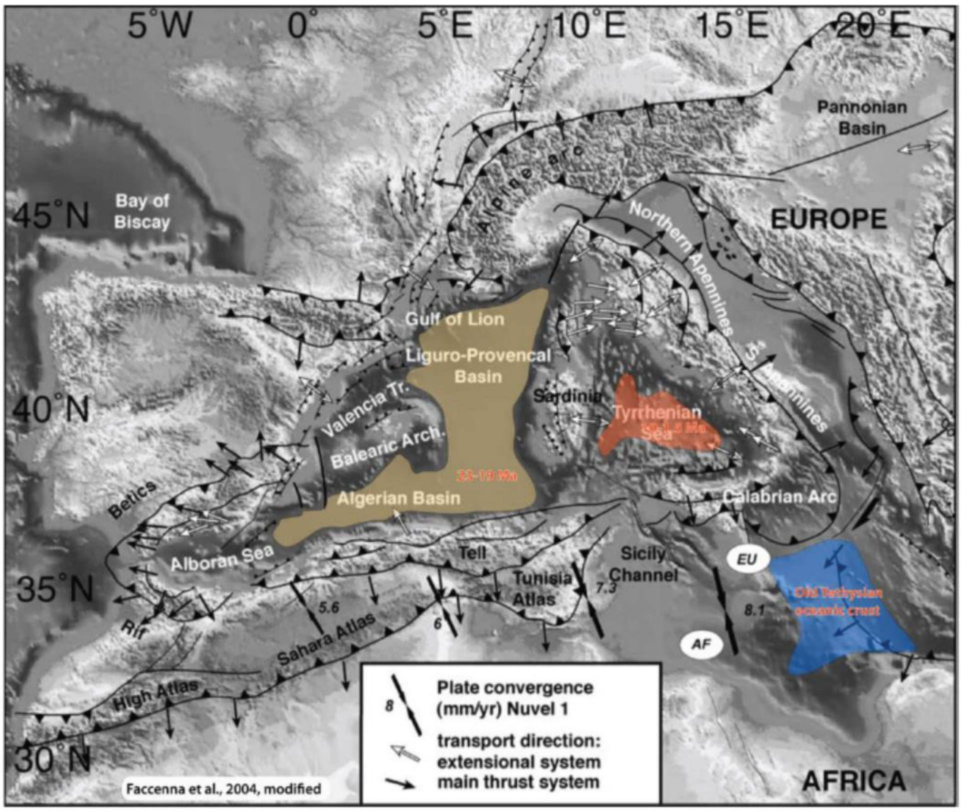


***Fig.3**: **Morphostructural simplified map of the Mediterranean realm** locating the main orogenic systems, the present-day kinematics and the age of opening of the different oceanic domains (modified after Faccenna et al., 2004 and Molli & Malavieille, 2011)*

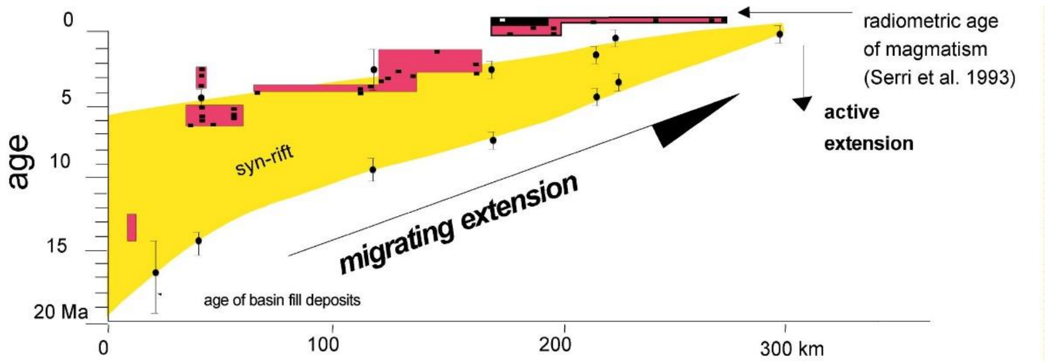


***Fig.4**: **Migration of the extension in the Tyrrhenian basin** combining various methodological approaches (Faccenna et al. 1997)*

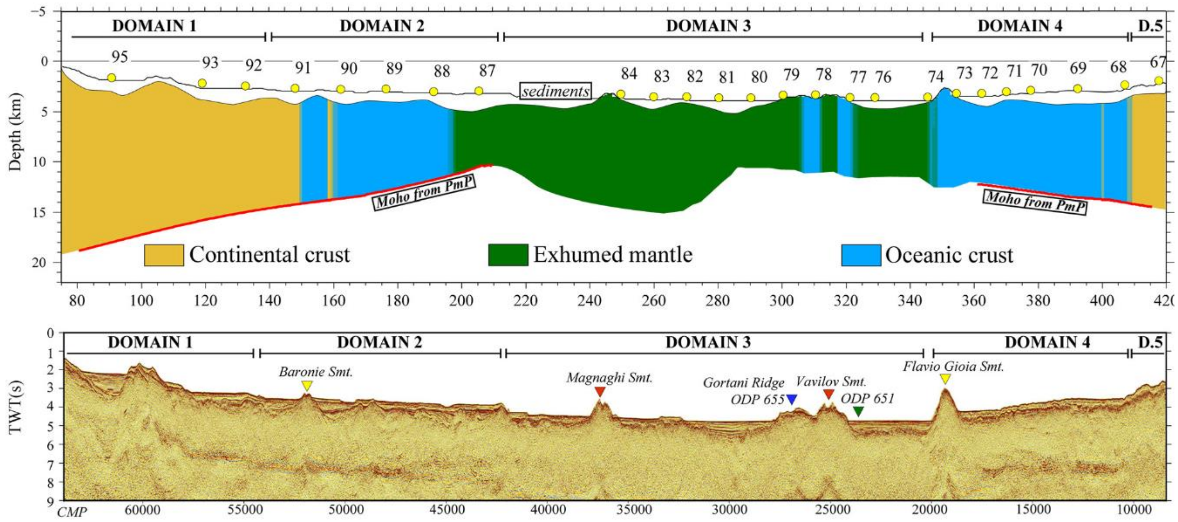


***Fig.5**: **Tomographic model of the Tyrrhenian basin (West-East) and associated seismic structures** (modified after Moeller et al., 2013)*

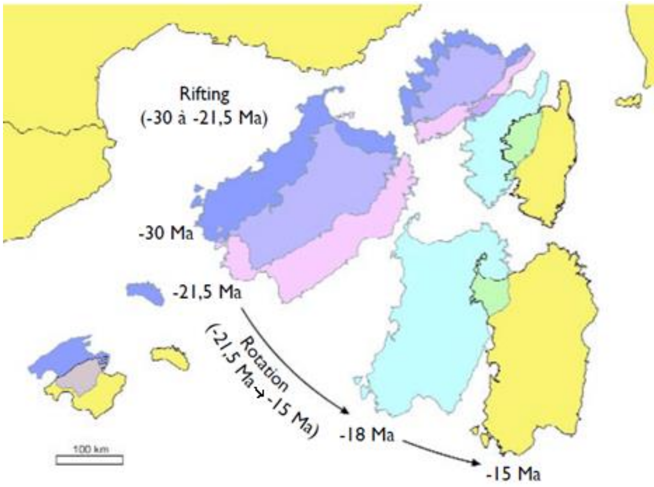


***Fig.6**: **Map showing the evolution of the Corsica-Sardinia block in the W. Mediterranean realm between 30 and 15 Ma** (after Ferrandini et al., 2010)*

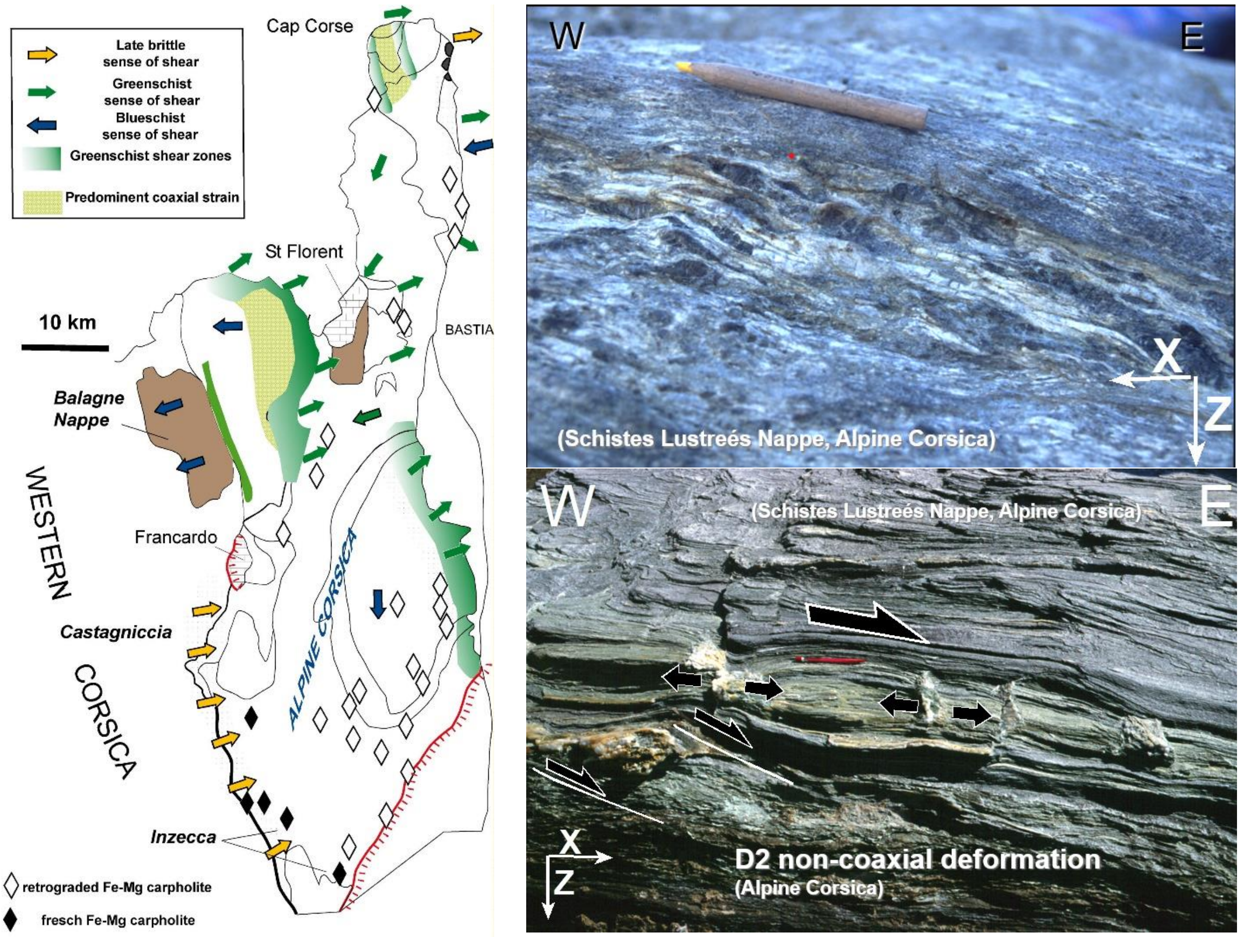


Fig.7 *(left)* ***Simplified geological map of Corsica*** *locating the place of the main structural features related with prograde and exhumation-related metamorphism (after Daniel et al. 1996). (upper right) Outcrop picture of sheared HP crystals showing top-to-the-W kinematic indicators. (lower right) Outcrop picture depicting the structural imprint left by the D2 non-coaxial deformation related with exhumation.*

II: Fragments of subducted Tethys seafloor and their meaning for subduction zone processes

Key points:

- Remnants from the **Cretaceous subduction** of the **slow-spreading Tethyan ocean** under the thinned continental margin of Apulia (with oceanic realms; e.g. Balagne nappe)
- Magmatic ages around **160 Ma** (gabbros, plagiogranites)
- **Initiation of subduction** during late Cretaceous? We do not know
- A **stack of km-thick slivers** with different lithological contents: some are rich in **metabasites** and serpentinized **ultramafics** (San Petrone and Lancône regions), some are rich in **metasediments** (Central and Eastern Castagniccia). Both for the complex of the '*Schistes Lustrés*'.
- **HP-LT metamorphism** (blueschist facies and lawsonite-eclogite facies) peak burial conditions reached **between 40 Ma and 34 Ma** (Brunet et al., 2000, Martin et al., 2011; Maggi et al., 2012, Vitale Brovarone and Herwartz, 2013)
- **Lawsonite-eclogite facies** rocks (c.500-520°C, 2.3 GPa) belong to a structure interpreted as an **ocean-continent transition zone** (Vitale Brovarone et al., 2011; Meresse et al., 2012). Presence of lenses of late variscan orthogneisses inserted within the meta-ophiolitic nappe-stack: **extensional allochtons**? (e.g. Serra di Pigno)
- **Top-to-the-W shearing during peak burial** (deep accretion in a subduction channel) followed by **Top-to-the-E shearing during exhumation up to greenschist-facies conditions** (300°C, 0.5 GPa)
- A **hairpin PT path** for the burial/exhumation cycle (i.e. 'cold' exhumation)
- The last stage of nappe emplacement is dated as Late Eocene (post-Bartonian; e.g. Egal, 1992)

- Pervasive dynamic metamorphism during exhumation above 350°C and localized semi-brittle to brittle deformation below 350°C
- The importance of continental margin subduction (Tenda massif) on exhumation of the meta-ophiolite is still debated. Influence of low-angle detachment faults and core-complex structures? (e.g. Jolivet et al., 1990)

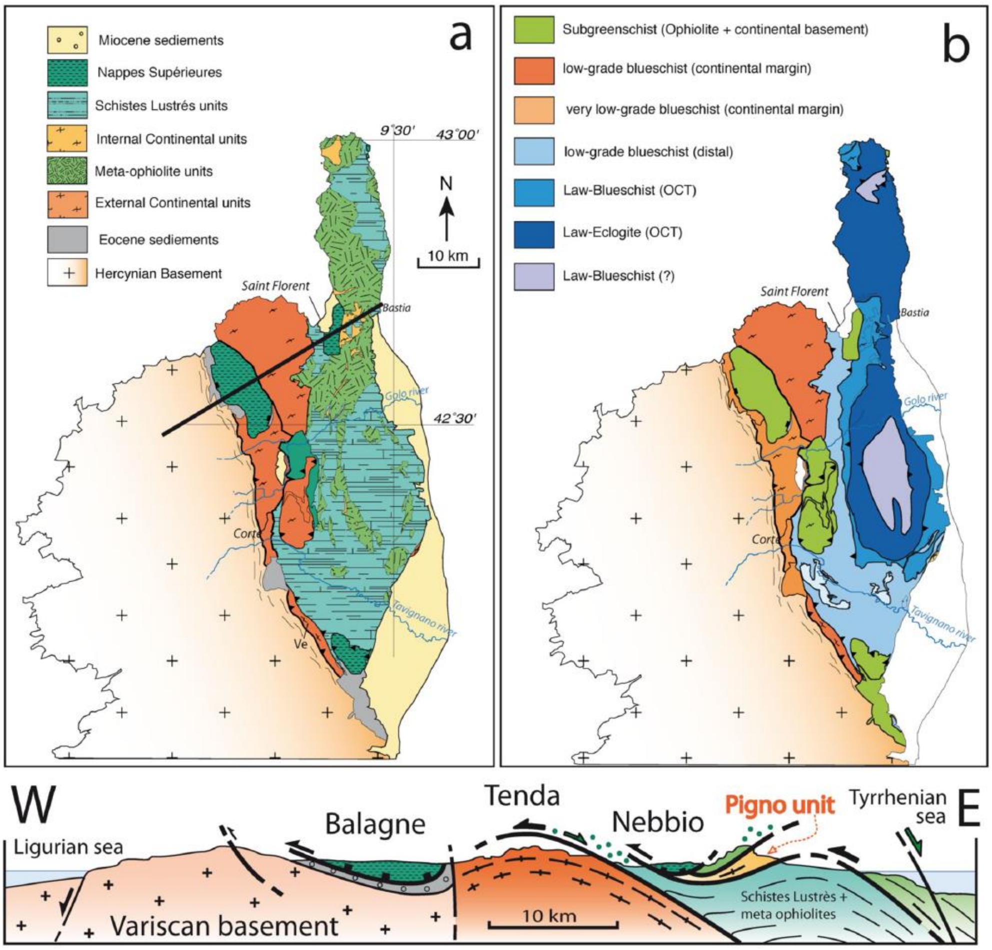


Fig.8: ***Geological structure of Alpine Corsica*** *showing (a) the lithostratigraphic sequence and (b) a map localizing the distribution of peak-burial metamorphic facies encountered by the units forming the Corsican slice-stack (after Vitale Brovarone et al., 2011). We focus in this part on the Schistes Lustrés meta-ophiolites (deep green on the cross-section).*

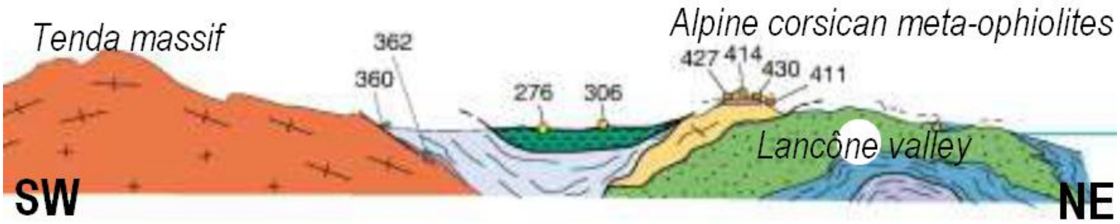


Fig.9: ***Cross section passing through the Lancône valley*** *showing the regional-scale structure of the nappe-stack as well as Raman Spectroscopy of Carbonaceous Matter (RSCM) maximum temperatures reached by metasediments. (after Vitale Brovarone et al., 2013)*

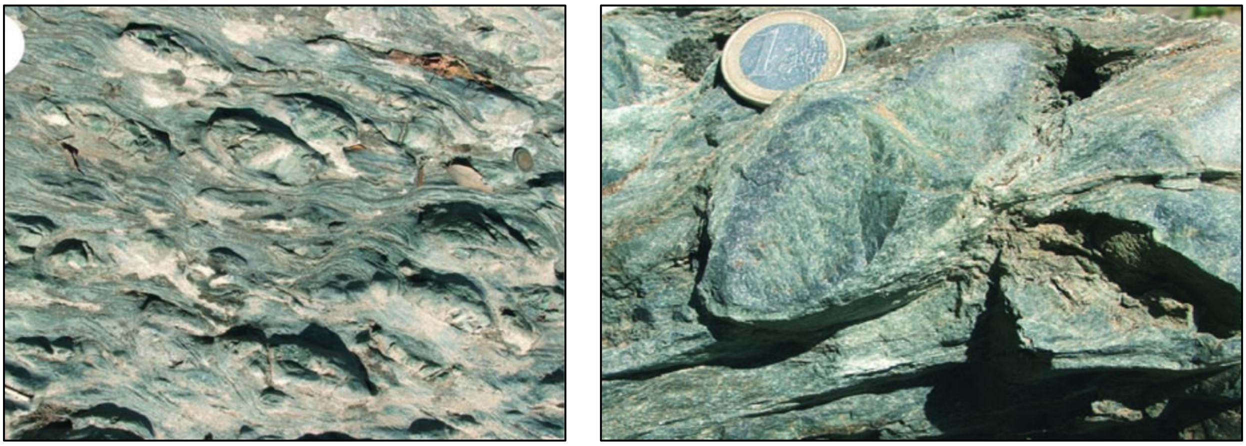
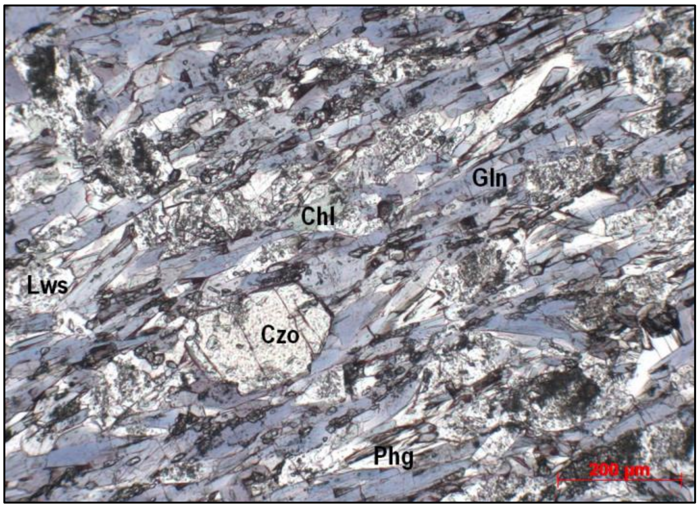


***Fig.10**: **Field pictures of Defilé de Lancône metabasalts.** (left) Pillow breccias visible in the creek at the bottom of the canyon (2 euros coin for scale). (right) Detail of a pillow clast showing a Lws-eclogite core (green) and a Lws-blueschist rim (deep blue). The matrix is also omphacite-rich. After Vitale-Brovarone et al. (2011).*

***Fig.11: Field view of a green pillow core** (rich in sodic-calcic clinopyroxene such as omphacite) wrapped within a **blueschist-facies foliation** (mostly made of glaucophane and lawsonite or clinozoisite). Field of view: 40cm.*

Lawsonite: $CaSi_2Al_2O_6(OH)_4$
Glaucophane:
$Na_2Al_2Mg_3Si_8O_{22}(OH)_2$
Omphacite:
$(CaMg\text{-}NaAl)_2Si_2O_6$
Clinozoisite:
$Ca_2Al_3(SiO_4)(Si_2O_7)O(OH)$
Phengite:
$K(AlMg)_2(SiAl)_4O_{10}(OH)_2$

***Fig.12: Thin section picture** (plane polarized light) **of a metabasite** from the San Petrone massif (Punta di Caldane, Castagniccia, Corsica) showing the typical assemblage visible in most Corsican blueschists, namely glaudophane, lawsonite (±clinozoisite), ±phengite, ±chlorite. Locally, omphacite and small garnet crystals can be observed in the matrix. Photo: D. Mollex (ENS Lyon). Sample: J.M. Caron.*



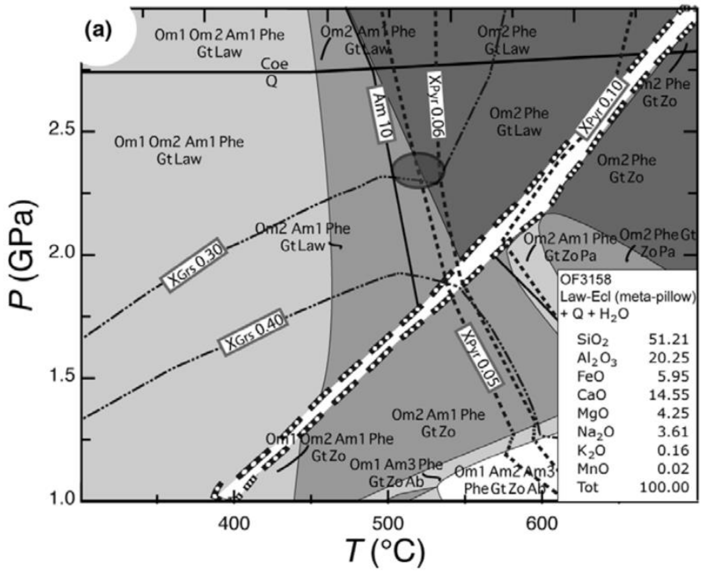


Fig.13: Pseudosection for a lawsonite eclogite from the Lancône metabasites*, calculated with the software Perplex. Peak burial conditions of 2.3 GPa and 520°C are estimated for the OF3158 sample (approximately 80km of burial), based on the peak assemblage Omphacite-Phengite-Garnet-Lawsonite-Glaucophane.*
(after Vitale Brovarone et al., 2011)

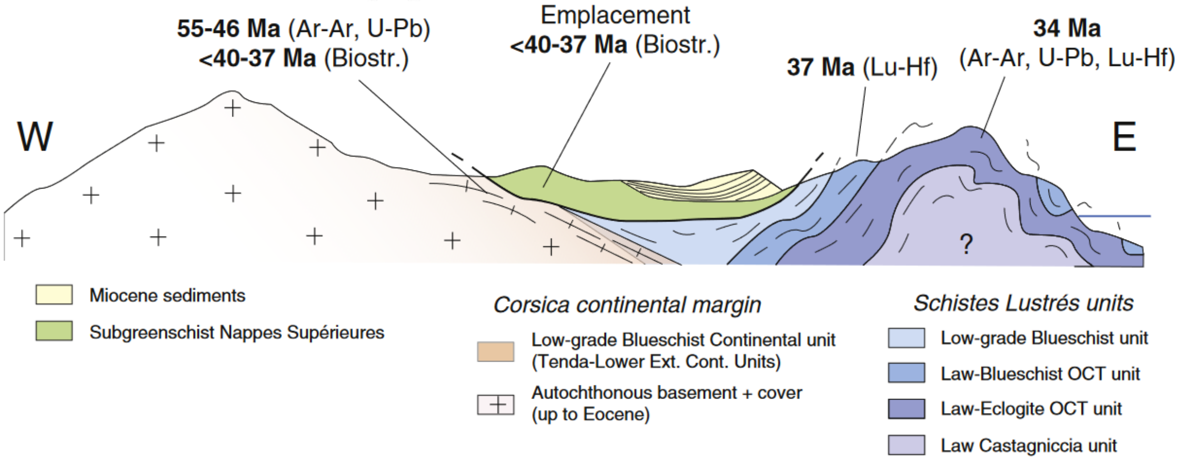


Fig.14: Cross-section showing the distribution of ages along an E-W transect across eastern Corsica *(after Vitale Brovarone & Herwartz, 2013)*

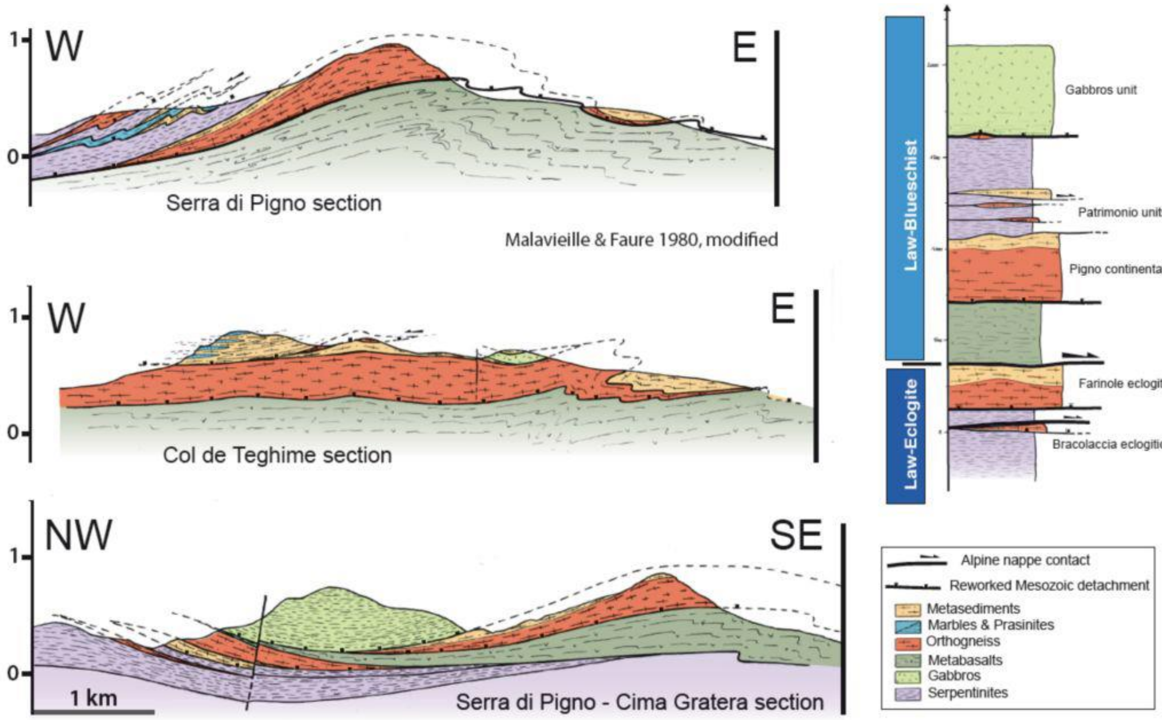


Fig.15*: **Cross sections in the Serra di Pigno-Col de Teghime area*** *(after Malavieille, 1983 & Malavieille et al., 2011).*

III: The fate of a continental margin entering a subduction zone: the Tenda massif

Key points:

- The Tenda massif is bounded to the East by a major ductile-to-brittle shear zone, the **East Tenda Shear Zone** (TSZ), the boundary between the continental margin of the European plate and the Liguro-Piemontese ocean (Schistes Lustrés)
- The east TSZ rocks experienced a **polyphase tectono-metamorphic evolution with a syn-blueschist top-to-the-W thrusting, overprinted by ductile** (syn-greenschist)-**to-brittle top-to-the-E extension** (Jolivet et al., 1990; Gueydan, 2003; Molli et al., 2006; Maggi et al., 2012; Rossetti et al., 2015; Beaudoin et al., 2017, 2020)
- **Peak metamorphic conditions estimated at 1.2 GPa and 350-400°C** (lower blueschist-facies) based on the presence of Na-amphibole, aegyrine (Na-clinopyroxene), high-silica phengite (3.5 atoms p.f.u. Si) and rutile or titanite (Maggi et al., 2012)
- Three groups of ages:
    - **54-45 Ma** (U-Pb rutile - Maggi et al., 2012 and Ar-Ar phengite - Brunet et al., 2000): **nucleation of the East TSZ**?
    - **35-32 Ma** (Ar-Ar phengite - Brunet et al., 2000; Beaudoin et al., 2020 and Rb-Sr multi-mineral – Rossetti et al., 2015) for the **lower blueschist-facies event: entrance of the thinned continental margin into the Alpine subduction zone and juxtaposition with the adjacent Schistes Lustrés** (meta-ophiolites)
    - **c. 30-25 Ma ages** (Ar-Ar phengite – Brunet et al., 2000; Beaudoin et al., 2020) mark the timing of the **extensional greenschist overprint**
- **Upper age limit for the end of the ductile Alpine imprint** is provided by the **early Miocene** sedimentation in the Saint Florent basin that seals the thrust contact (e.g. Ferrandini et al., 1998; Cavazza et al., 2007) and by the youngermost Ar-Ar ages from Beaudoin et al., 2020 at **20-25 Ma**).
- **Debate on the vergence of the subduction responsible for the HP recrystallization** (West-dipping or East-dipping?; Jolivet et al., 1990; Vitale Brovarone et al., 2013; Rossetti et al., 2023)
- **Key role of eastwards slab roll-back** on the opening of the Tyrrhenian Sea and the formation of low-angle detachment faults that were responsible for the thinning of the Corsica accretionary system (variscan basement and adjacent Schistes Lustrés; Jolivet et al., 1991, 1998; Fournier et al., 1991).

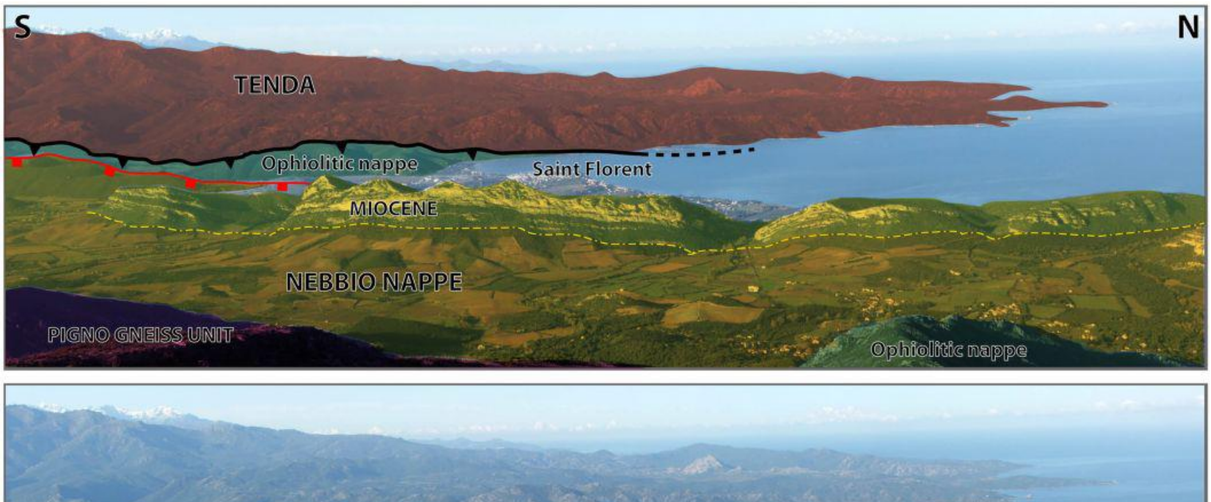


Fig.16: Panoramic view on the contact zone with the Tenda massif *(after Malavieille et al., 2011)*

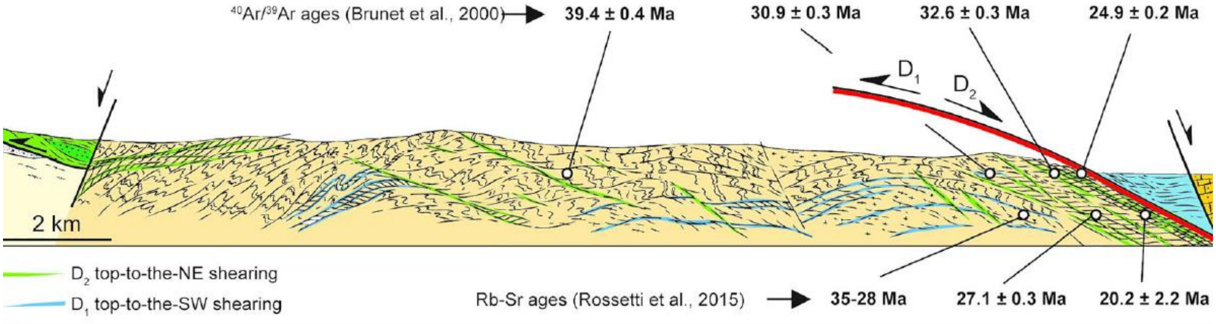


Fig.17: Interpretative geological cross section across the east TSZ (ETSZ) *showing the heterogeneous distribution of shear zone fabrics within the reworked Variscan basement rock (after Beaudoin et al., 2017)*

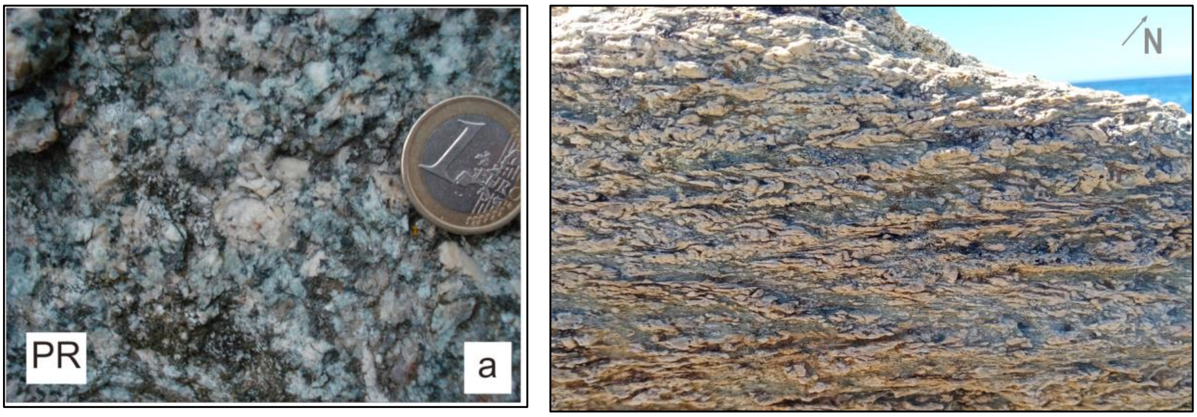


Fig.18: Field pictures of orthogneiss from the Tenda massif. *(a: left): undeformed granodiorite in the Casta region (center of the massif). After Maggi et al. (2014). (right) Picture showing the representative deformation patterns visible in the Tenda Shear Zone where variscan basement granitoids are affected by numerous shear bands.* *<u>Field of view</u>: approximately 1 meter.*

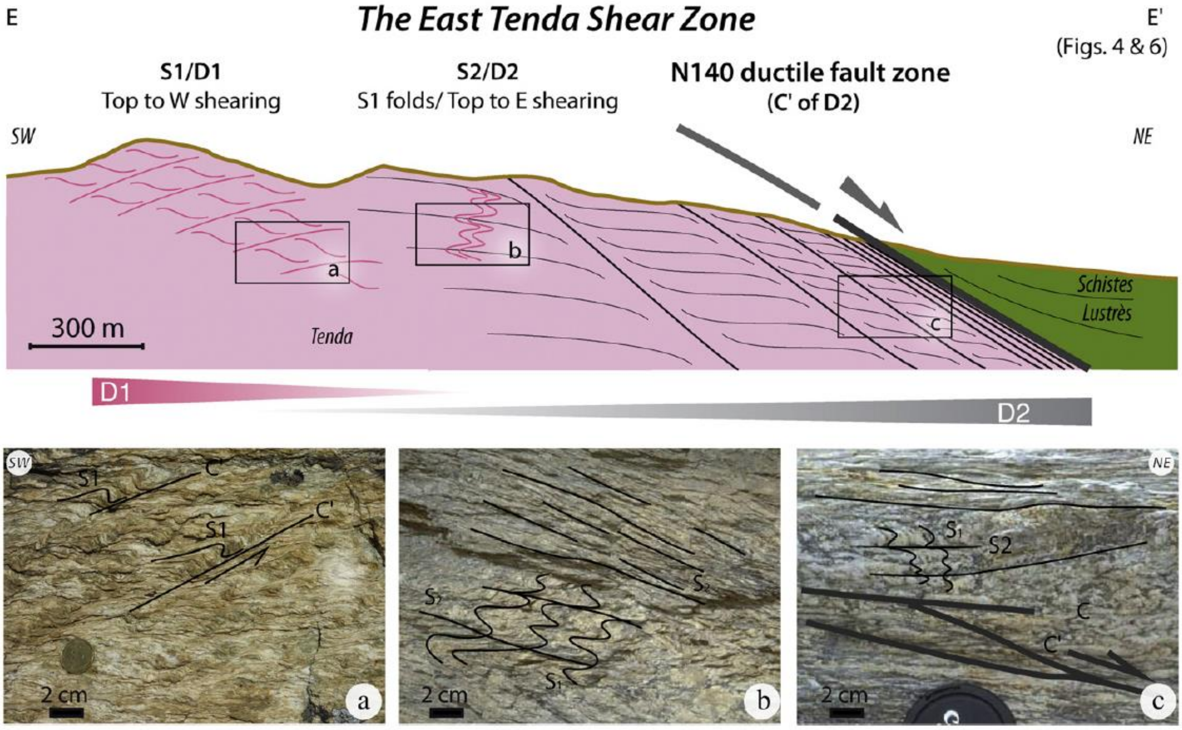


Fig.19: Cross section of the east TSZ showing the N140° shear zones with the increasing strain gradient eastwards. *a to c figures highlight representative structures visible at the massif scale. (Gueydan et al., 2017)*

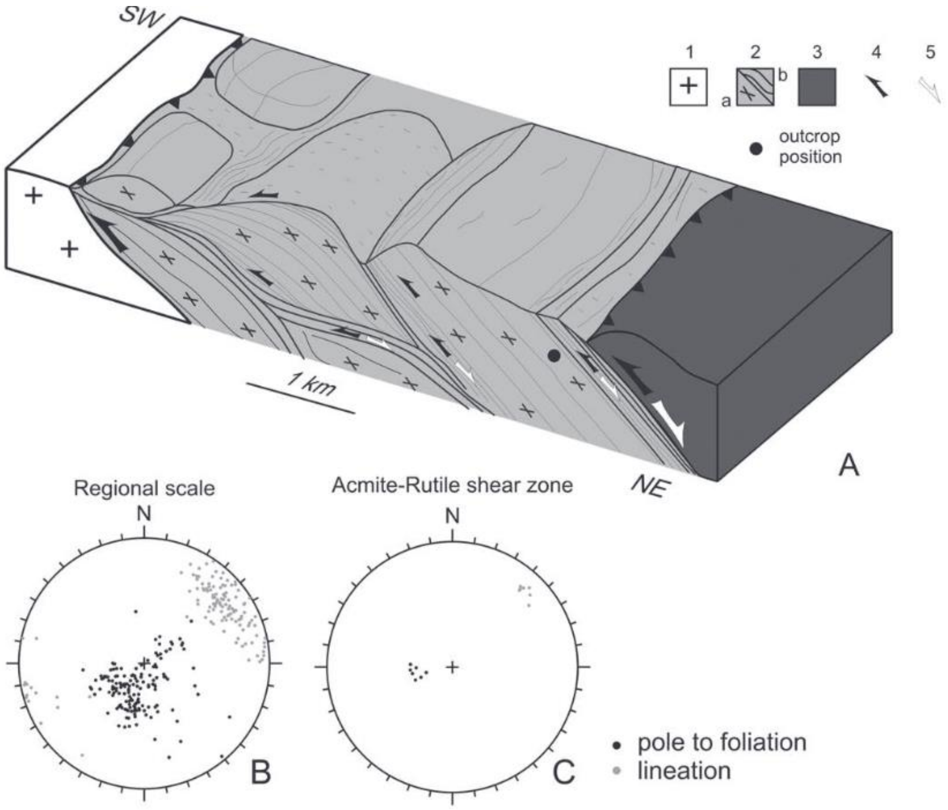


Fig.20: A. Schematic 3D interpretative diagram showing the structural architecture and shear fabric within the east TSZ. *Gneissic (massive) lenses are wrapped by high-strain domains (mylonites and phyllonites). 1. Protolith rocks, 2. East TSZ, 2a. massive lenses, 2b. shear zones. 3. Schistes Lustrés. 4. Compressional shear zones and 5. Extensional shear reactivation. B, C: representative stereoplots (Schmidt, lower hemisphere) showing the plano-linear shear fabrics at regional (B) and outcrop scale (C). Derived from Maggi et al. (2012). The studied sample corresponds to a blueschist-facies phyllonite which yielded a 54 +/- 8 Ma age.*

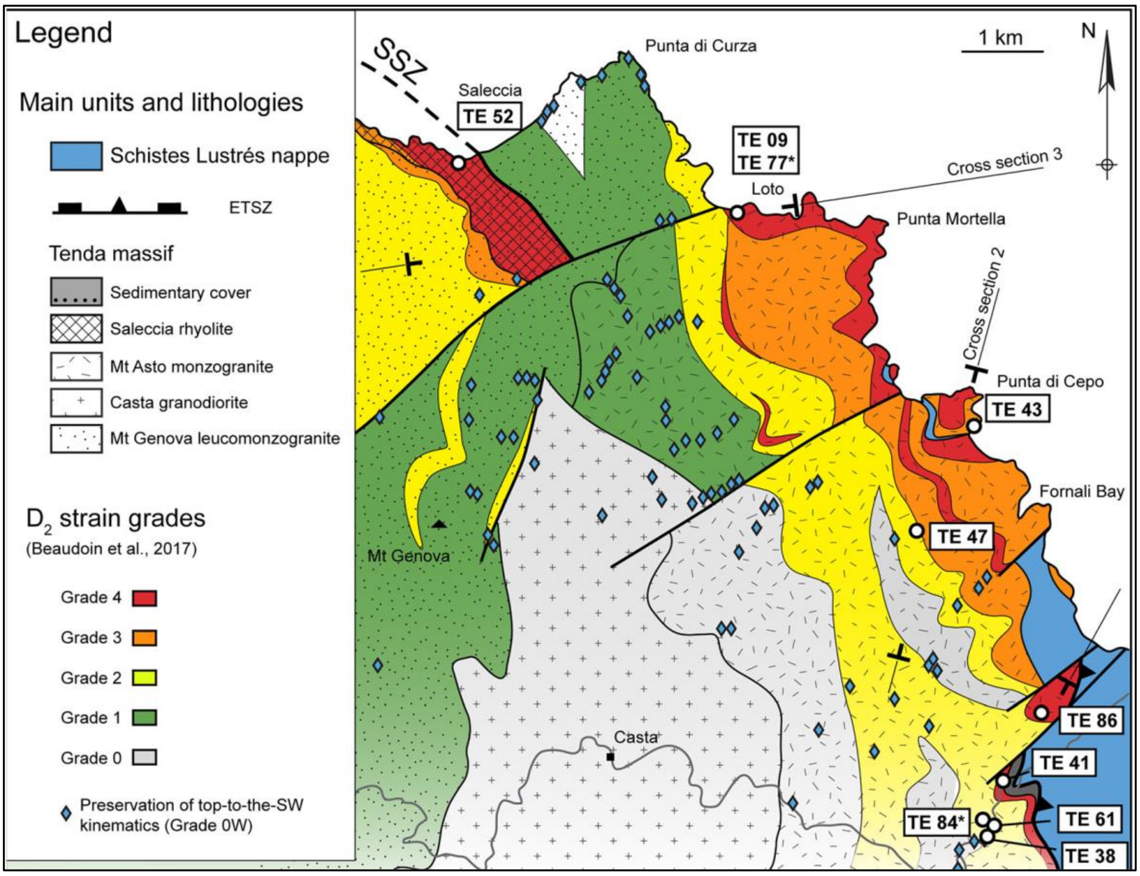


Fig.21: Deformation intensity map on the east Tenda Shear Zone *(after Beaudoin et al., 2017, 2020)*

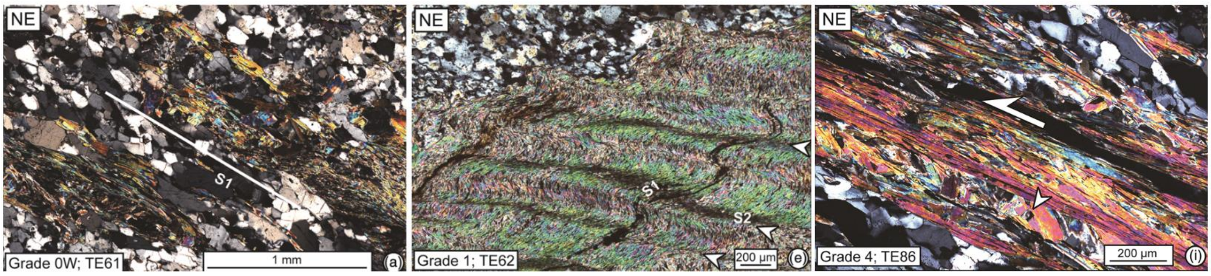


***Fig.22: Optical microscopy pictures** (PPL) showing the gradation in strain intensity from low-strained region (left) to intensely strained domains (right: mylonites). After Beaudoin et al. (2020).*

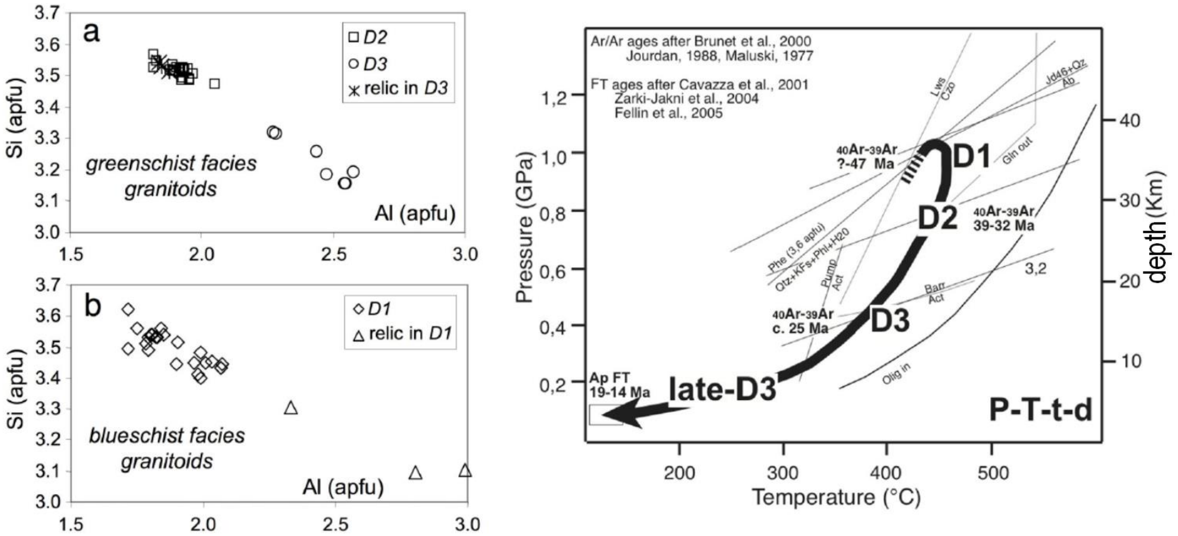


***Fig.23: Petrological data on white micas from the TSZ** (left) and **proposed P-T-t-d path for the Tenda massif** (modified after Molli & Tribuzio, 2004 and Malavieille et al., 2011)*

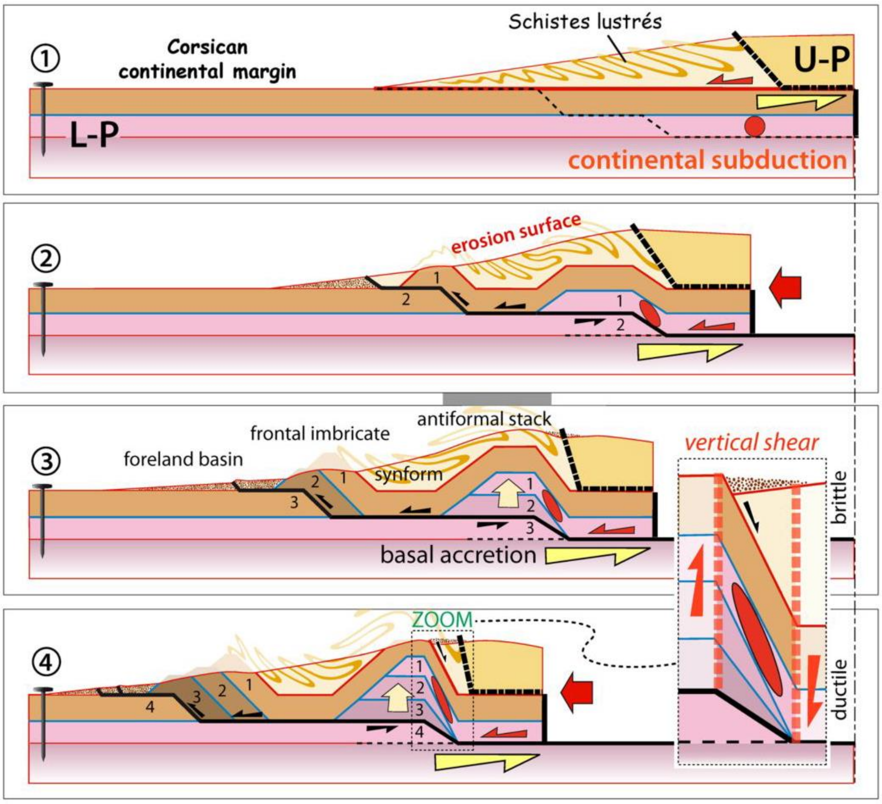


***Fig.24: Cartoon** after Malavieille (2010) depicting **strain partitioning and kinematics of units in a décollement wedge**. Some of the stretching and thinning as observed in the East TSZ could be explained by such close-field mechanism. Far-field deformation may also have played a role during D2 and D3 events. U-P: pre-structured upper plate, L-P: basement lower-plate.*

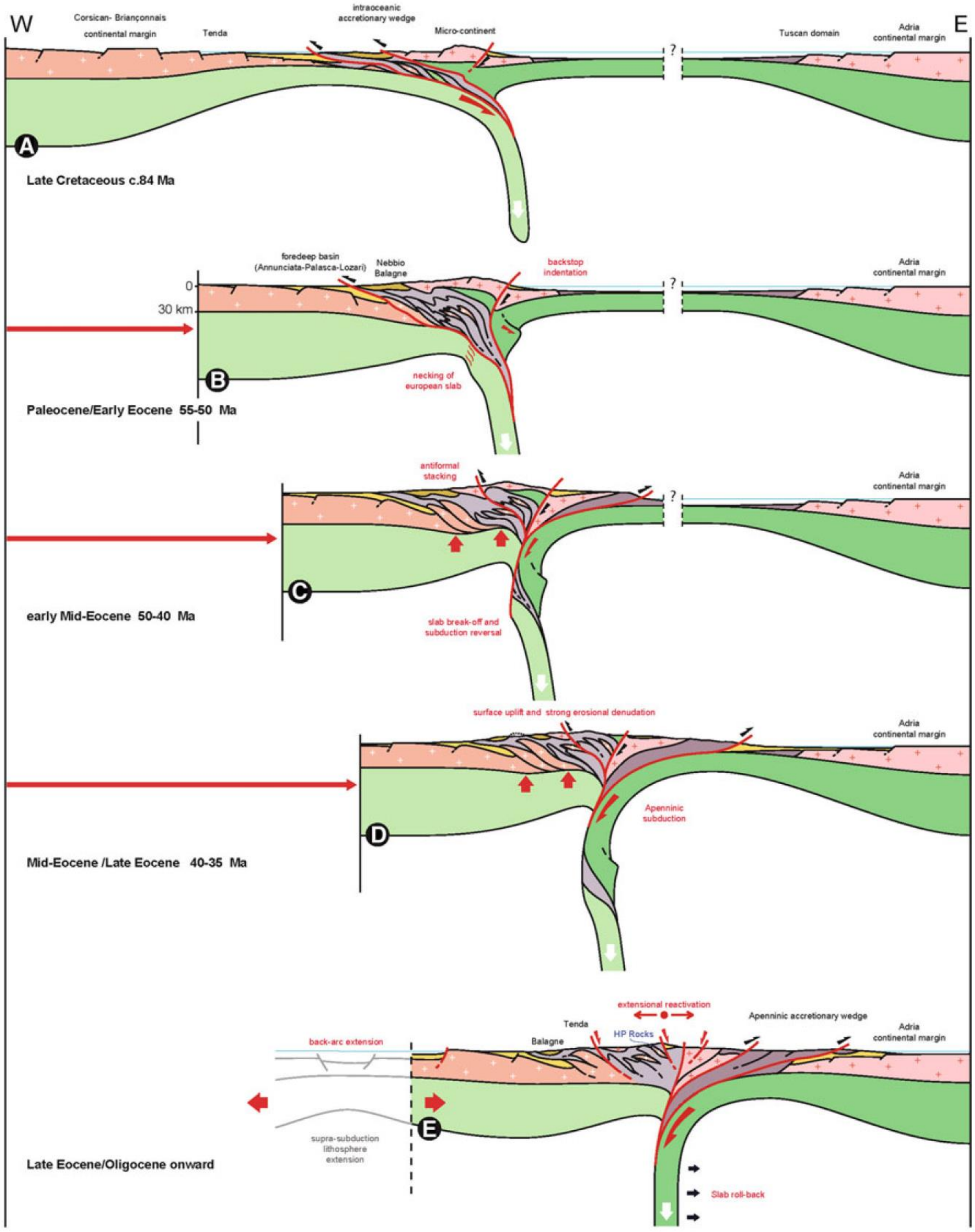


Fig.25: One evolutionary model proposed for the structuration of the rocks for Alpine Corsican rocks *from the Cretaceous to the Oligocene (Molli & Malavieille, 2011).*

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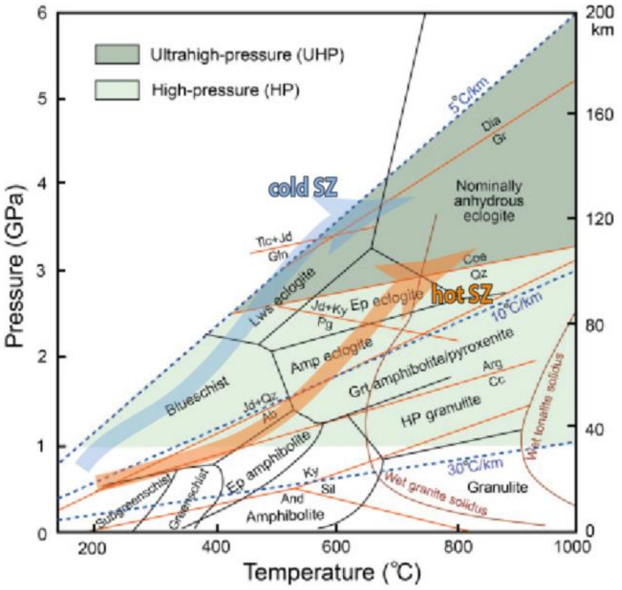
Metamorphic facies grid *with key reactions indicated as well as* ***representative PT paths for slab-top material*** *in* ***cold*** *and* ***hot*** *SZ settings (modified after Zheng & Cheng, 2017; Peacock, 1996)*




Tenda Shear Zone - stop 3
Col de Teghime - stop 1
HOTEL
St-Florent
GOLFE DE ST-FLORENT
BASTIA
Col de Teghime
Lancone valley - stop 2
Oletta
Cime du Zuccarello
BIGUGLIA
Champ de Tir de Casta Sud
Echelle 1 : 73 715
0
2 km