# Geological Map of the Eastern Elba Nappe Stack (EENS) between Rio Marina and Terra Nera

Mapped and compiled by Eric James Ryan as part of the MSc Thesis "*The Structural and Metamorphic Evolution of the Eastern Elba Nappe Stack, innermost Northern Apennines, Central Italy*" at the Norwegian University of Science and Technology.
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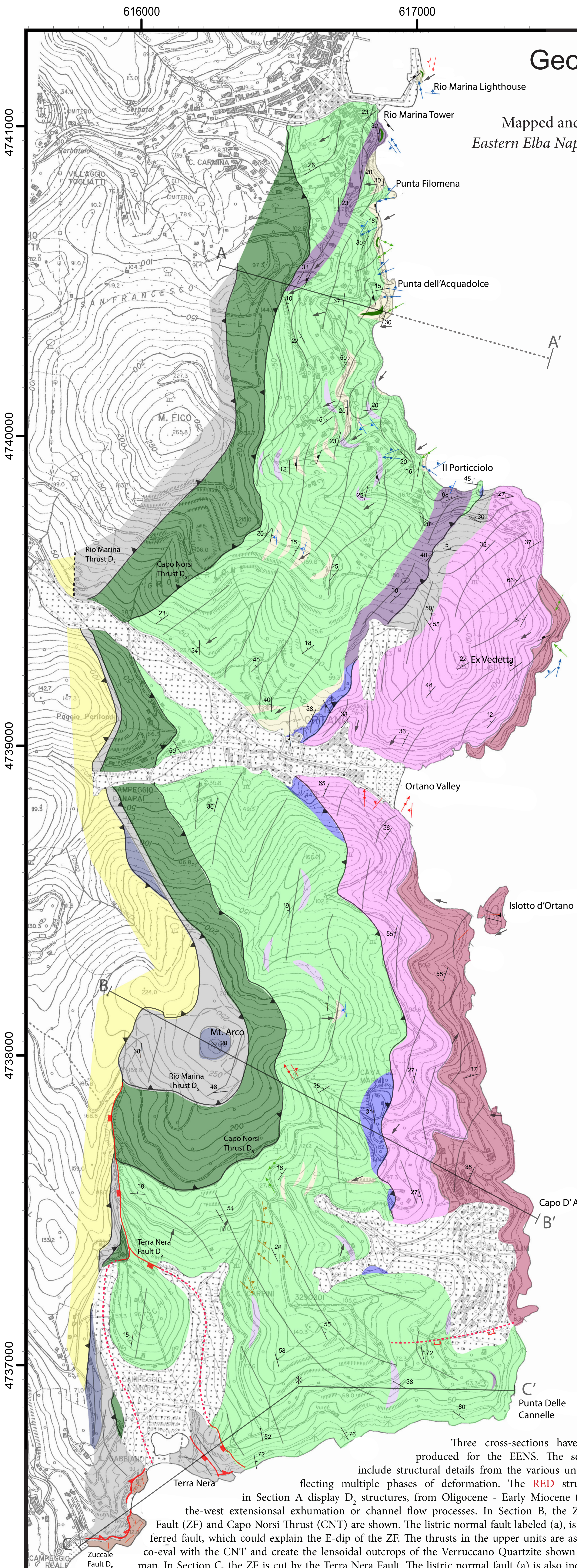



## The EENS Tectonostratigraphy

N

500 m

- **Quarternary Fill -** Anthropogenic and erosional cover.
- **Leucograntic Dike -** Granitic dike from the Porto Azzurro Pluton (≈ 6.2 Ma)
- **Calcare Cavernoso -** Late Triassic, grey, vacuolar massive, brecciated, cavernous dolomitic limestone.
- **Verrucano Quartzite -** Middle to Upper Triassic, light colored quartzite and metasiltstone, fluvial or deltaic deposits. Tectonized by the Capo Norsi Thrust.
- **Rio Marina Shale -** Late Carboniferous to Early Permian, black to grey metasiltstone, graphitic phyllite and quarzitic metasandstone.
- **Ligurian Serpentinite -** Jurassic, fine to medium-grained, tectonized, dark green serpentinite with lizardite, chrysotile and antigorite.
- **Acquadolce Unit -** Early Cretaceous. Lowermost white-grey massive, calcitic Ortano Marble, with minor quartz, white mica, amphibole, and local pyroxene. Overlain by calcschist, with upwards-increasing phyllite content, and uppermost phyllite with large, meter-scale lenses of calcschist and decameter lenses of meta-psammitic rocks. Local lenses of metabasite include HP-LT mineral assemblages.
  - Metabasite
  - Psammitic
  - Calcschist
  - Ortano Marble
- **Skarn -** Green, at times weathered, mineralized skarn depost. Locally characterized by large, radiating hedenbergite crystals. Post-pluton emplacement (≈ 6.2 Ma).
- **Ortano Unit -** Middle to Late Ordovician, brown to light-colored, felsic metavolcanics rocks. Feldspar phenocrysts common, with non-homogenous distribution overlain by silver-grey phyllites and graphitic, arkosic metasandstone.
  - **Metasomatized silver-grey phyllites -** Metasomatized felsic volcanic rocks with talc and white mica along foliation planes and the presence of Fe-minerals (hematite and magnetite).
  - **Capo D` Arco Schist -** Silurian quartzitic mica schists. Characerized by dark color at basal levels, grading upward into brown and lighter-colored rocks very similar to the Ortano Metavolcanics.
- **Calamita Unit -** Early Carboniferous, medium to high-grade pelitic-psammitic schist.

## Structural Symbology

- Main Foliaton
- Foliation Trace
- Thrust Fault
- Normal Fault
- Inferred Fault
- Zuccale Fault
- Reverse shear band
- Normal shear band
- Stretching Lineation
- $D_1$ Fold Axis (FA) (AP parallel foliaton)
- $D_2$ Axial Plane (AP)
- $D_2$ Fold Axis
- $D_3$ Axial Plane
- $D_3$ Fold Axis
- Parasitic $D_3$ Fold AP
- Parasitic $D_3$ Fold FA

## Deformation Phases

**$D_1$** — Eocene-Oligocene. The first nappes were accreted into the Northern Apennines Wedge. Few, highly transposed structures are preserved from this phase, including isoclinal folds, with axial plane cleavages parallel to the main composite foliaton.

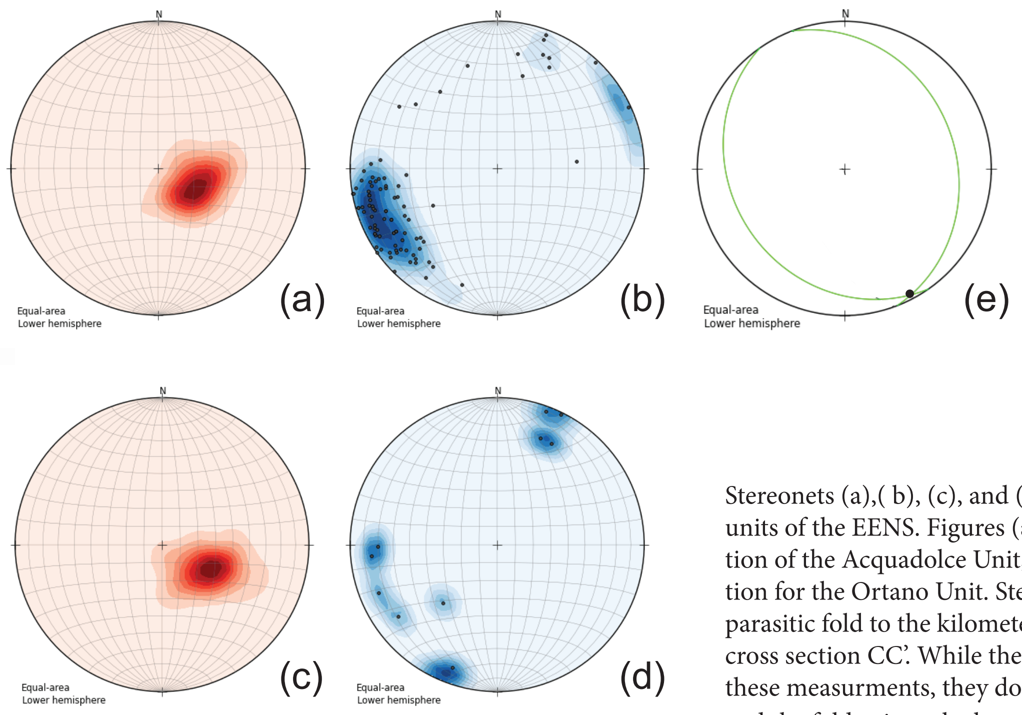
**$D_2$** — Oligocene - Early Miocene. Westward extension exhumed the HP-LT mineral assemblages of the Acquadolce Unit. Mylonitic fabrics indicate westward-directed flow. Westward extensional shear bands, and W-vergent folds are common.

**$D_3$** — During the Miocene, a new phase of compression occured. Out-of-sequence thrusts and E-vergent folds deformed the EENS at all scales.

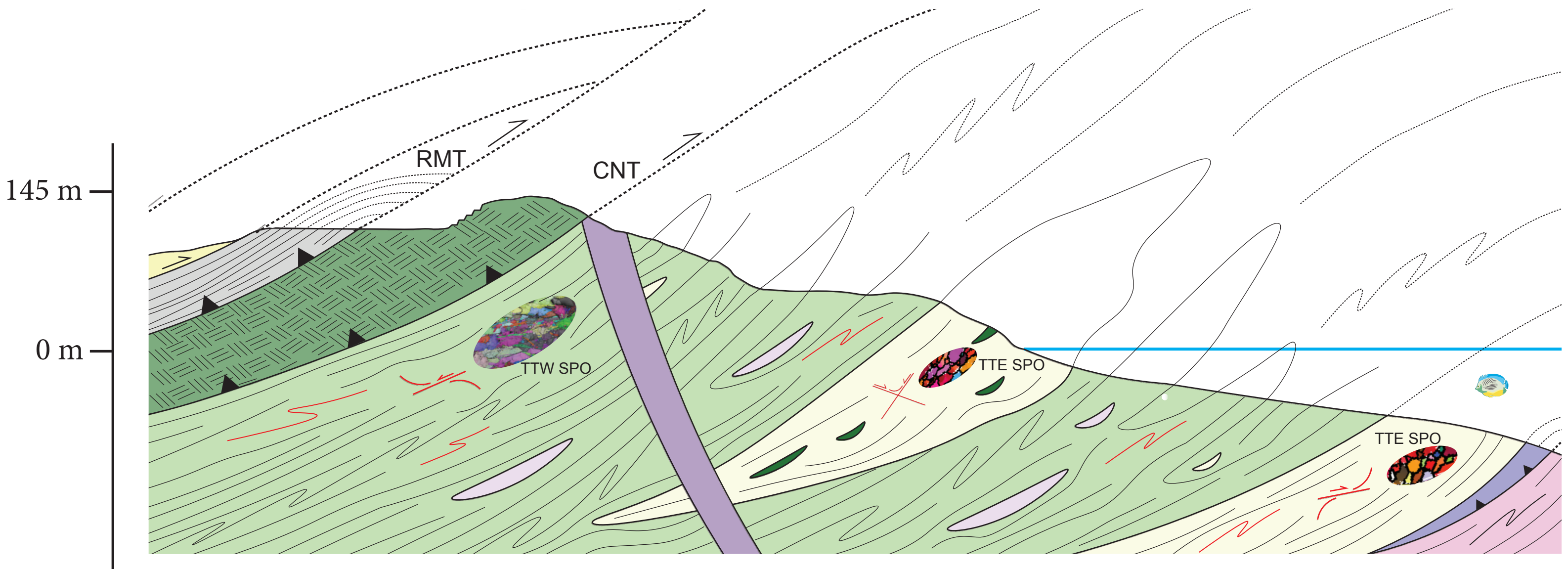
**$D_4$** — Mid - Late Miocene. Regional eastward extension. Poorly recorded in the EENS. Early eastward thrusts may have been reactivated. Some local extensional crenulation cleavages may be realated to this phase.

**$D_5$** — Late Miocene - Pliocene. Syn-contact metamorphic eastward thrusts were active. Later compression locally inverted the metamorphic grade through thrusting and led to the formation of the Zuccale Fault.

**$D_6$** — Late Pliocene - Pleistocene uplift and exhumation of the EENS. NS-trending brittle normal faults with W- and E-dips extended and exhumedthe nappe stack.




Stereonets (a),( b), (c), and (d) are from the two most comprehesively mapped units of the EENS. Figures (a) and (b) show the foliation and stretching lineation of the Acquadolce Unit, whereas (c) and (d) show the foliation and lineation for the Ortano Unit. Stereonet (e) shows west and east dipping limbs of a parasitic fold to the kilometeric scale $D_3$ Acquadolce Antiform fold, shown in cross section CC'. While the dip of the axial plane cannot be determined from these measurments, they do indicate the strike of the axial plane (NW- SE) and the fold axis to the large fold (153/03).




Three cross-sections have been produced for the EENS. The sections include structural details from the various units, reflecting multiple phases of deformation. The RED structures in Section A display $D_2$ structures, from Oligocene - Early Miocene top-to-the-west extensionsal exhumation or channel flow processes. In Section B, the Zuccale Fault (ZF) and Capo Norsi Thrust (CNT) are shown. The listric normal fault labeled (a), is an inferred fault, which could explain the E-dip of the ZF. The thrusts in the upper units are assumed co-eval with the CNT and create the lensoidal outcrops of the Verruccano Quartzite shown in the map. In Section C, the ZF is cut by the Terra Nera Fault. The listric normal fault (a) is also included. The large, E-vergent Acquadolce Antiform found in the Southern Portion of the field area is seen best here. In all sections, strongly E-vergent folds are shown repeating the Acquadolce lithological sequence. The respective scales are shown along the y-axis. All sections are created without vertical exageration.