Synthetic cross-section across the Northern Apennines

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The section broadly captures the chronological and structural relationships between compression and extension across the Apennine orogeny. Evidence is also presented for the northeastward migration of the Apennine fold-and thrust belt, closely followed by back-arc extension throughout the Miocene to present.

The basement rocks of the section, found at the Farma River Section, and as Complex I on Elba show metamorphic fabrics related to the previous Variscan and Alpine orogenies. However the macro-scale recumbent folding and thrust imbrications observed at the outcrops are consistent with a 1 direction to the NE-SW, (Apennine deformation) occurring from the Early Miocene. Palaeozoic basement rocks are uplifted and exposed as part of the Tuscan Nappe complex or the Elba accretionary prism. There, the pre and syn-Variscan basement is uncomformably overlain by the Triassic conglomerates, which mark the break-up of Pangaea. They are virtually absent in Umbria-Marche.

The thick and mostly carbonate Mesozoic successions are easily correlated throughout the Tuscan to Marche sectors as they represent passive margin successions deposited offshore of the Adrian micro plate in the varying stages of Tethyan rifting. On the section they are shown to be stratigraphic equivalents, albeit with slight facies changes from W to E, which is a reflection of the Tethyan paleogeography. On Elba, the lower Tuscan carbonate sequence was metamorphosed during the Alpine orogeny and later deformed in a thrust stack [**?**]. Out of sequence thrusting inserted slivers of Ligurian units (ophiolite, Alpine flysh of complex V). On mainland Italy, the unmetamorphosed Tuscan carbonates are thrust in nappes as recumbent folds. This contrasts with the large horses or thrust-bound, relatively open carbonate anticline, which are a staple of the Umbria-Marche domain. The indices of deformation measured in the field (C-S fabrics, parasitic fold axes) yield consistent N-E oriented compression.

The late Oligocene Macigno formation (28.5-20.5Ma) found in Tuscany is the first syn-deformation sedimentary record. This turbidite sequence is a flysh to the Apennine thrust stack, then limited to the Tuscan sector and tracks the NE propagation of a fallen basin in the foredeep of the deformation front. The presence of 10 olistostromes testifies of the increasing instability on the foreland, while concomitant deposition of the top sequences of the Scaglia Cinerea in the Marche domain suggests it was then located near the forebulge of the

basin. Clast provenance studies indicate that the density flows were sourcing the metamorphic core of the Apine orogeny to the North. Palaeo-flow reconstructions in the field broadly agree with their funnelling down the then N-S oriented palaeo-Adriatic.

The younger Marnoso-Arenacea turbidites (20.5 -7.5 Ma) are found within the Umbria-Marche sector: they are the diachronous equivalent of the Macigno formation and exhibit syn-orogenic growth-strata geometry, which indicated that the thrust front had propagated north-eastward to the Gubbio area by the middle Miocene. The late Miocene Colombacci formation, and modern sediments now deposited in the present day Adriatic are their own diachronous equivalent. Seismic imaging reveals the northeastward propagation of open folds underneath the Adriatic Sea and similar growth-strata geometries in progressively younger formations. Total migration rates of the thrust front are estimated at around 8-9mm.yr-1.

An array of normal faults and associated horsts and graben is depicted west of the Apennine mountain belt, dissecting the imbricate thrust stacks, which has been linked to back-arc extension following the slab roll back. The expression of this extension and crustal thinning is exemplified at the active Gubbio fault scarp, which offsets the eastern and western limbs of the Gubbio anticline by as much as 3km, with a total throw of 2km. The 3 direction is to the NE-SW Further west, the Rapolano fault scrap is degraded due to the cessation of seismic activity since the late Pliocene, while the sedimentary succession Sienna basin points towards marine sedimentation having stopped alongside fault activity and accommodation space creation. Extension has therefore followed compression from Tuscany to western Umbria at rates of 6-8mm.yr-1. Hotter than average, buoyant mantle support is a mechanism likely to explain the current elevation of the Tuscan sedimentary basins.

Further west still, the enigmatic Zuccale fault is a low-angle, large displacement normal fault offsetting the thrust stack of Elba complexes I-V. Its transport direction is to the NE, although in the vicinity of the granitic plutons of Elba, the fault plane has large topography [**?**].

The Monte Capanne monzogranite, which was emplaced at a poorly constrained depth of 10km and crystallised 7.32Ma, has an associated thermal metamorphic overprinting the previous deformation fabrics of thrust complex V near Spartaia. The geochemistry of the melts indicates they were generated from mixing of a mantle derived K-rich member and surrounding crust. The pluton is the likely source of late stage hydrothermal fluid circulation throughout Elba, which is reflected in the presence of B-rich aplite dykes and Fe-rich, loosely strata-bound skarn mineralisation. The younger (5-3Ma) K-centres of the Tuscan magmatic (5-3Ma) province are the reflection of the eastward migration of igneous activity, likely tracking slab rollback and associated underplating.

References