Tertiary Sedimentary and Tectonic Evolution of Apulian Platform in the Val d'Agri Subsurface Area (Southern Italy)*

Alfredo Pugliese[1], Manlio Ghielmi[1], Giulia Barbacini[1], Paolo Carubelli[1], Corrado Magistroni[1], Salvatore Miraglia[1], Luca Alfonso Renna[2], and Valeria Scola[1]

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[1]Eni E&P, Via Emilia 1, 20097 San Donato Milanese (MI), Italy (manlio.ghielmi@eni.com)
[2]Eni Petroleum, 1201 Louisiana, Suite 3500, Houston, Texas 77002, USA

Introduction

The Apulian Platform, the main target for hydrocarbon exploration in Southern Apennines (e.g., Val d'Agri, Tempa Rossa and Pisticci Oil Fields; Ferrandina Gas Field), consists of a thick succession of Mesozoic-Tertiary shallow-water carbonates. The Val d'Agri Oil Field, located in the Basilicata Region, represents the major Western Europe onshore oil discovery. Large volumes of subsurface data from wells and seismic acquisition (i.e., explorative and development wells, ditch cuttings, cores, conventional and image logs, 2D and 3D seismic surveys) provided the opportunity to construct a detailed geological model for the Mesozoic and Tertiary succession of the Val d'Agri (VA) and surrounding areas.

Geological Framework

Apulian Platform (AP) is represented by about 7000 m of Mesozoic and Paleogene carbonates. The Triassic succession of the AP is made up of transgressive Ladinian-to-Rhaetian dolostones, anhydrites and halites that unconformably overlie Permian and Scythian siliciclastic deposits. The Jurassic is represented by a thick succession of shallow-water carbonate platform limestones and dolostones. The Cretaceous sequence of AP, the main target in the Southern Apennines, is interpreted as a large-scale carbonate ramp.

Lower Cretaceous is mainly composed of shallow-water, restricted- to open-marine platform dolomitic limestones and limestones. The Upper Cretaceous succession shows an overall transgressive evolution from shallow-water, restricted platform carbonates to shallow-water high-energy, open platform limestones, and finally to deeper marine, low-energy pelagic limestones deposited from Campanian to middle Eocene in a large submarine paleo-high environment.

After a long period of emersion and subaerial erosion, a relatively thin section of Miocene transgressive limestones and evaporites, as well as Pliocene deep-water siliciclastics, were deposited on the AP (these deposits represents the Tertiary sedimentary overburden of the AP).

During Jurassic and Cretaceous the AP represented an isolated wide shallow-water carbonate platform surrounded by deep-water basins: the Lagonegro Basin to the W, the Ionian Basin to the S, the Umbria-Marche Basin to the E and NE. The Southern Apennines formed during Tertiary collision of European and Adria plates. The Ligurian-Sicilian sediments represent the accretionary prism build-up during the oceanic subduction phase responsible for the Ligurian-Piedmont Ocean closure.

The Neogene Apennine deformation phases were related to the continental collision. Large sectors of the Adria foreland were gradually involved in the orogenesis as a consequence of the progressive eastward migration of the Apennine thrust-and-fold belt. In Early Miocene (Burdigalian Phase) the onset of compressive thrusts involving the internal (i.e., western) units took place: the Apenninic Platform (late Triassic-early Miocene), with the Ligurian units on top, began to be thrusted over the Lagonegro Basin (Triassic - early Miocene). In middle Miocene, the Lagonegro units overthrusted, in their turn, the inner margin of the Irpinian foredeep Basin, the site of deep-water turbidite sedimentation.

During late Miocene and Plio-Pleistocene, the western margin and finally the central sector of the AP also underwent gradual deformation. Large sectors of the AP were affected by intense subsidence with the formation of deep-water Messinian-to-Pleistocene Bradanic Foredeep depocenters recording turbidite siliciclastic sedimentation. The AP and the overlying foredeep turbidites were then overthrusted by the Apennine thrust belt, represented by a complex tectonic assemblage of Mesozoic and Tertiary sedimentary units, hereafter referred as Allochthonous Complex, (Mostardini and Merlini, 1986).

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In the VA area, middle Paleocene - middle Eocene is represented by a thin section (30-40 m) mainly consisting of white to light pink fossiliferous micritic limestones (MDST and WKST). These pelagic sediments, unconformably overlying pelagic Campanian-Maastrichtian limestones, were deposited above a wide Apulian submarine paleo-high. An intense tectonic activity affected the area in the late middle Eocene as indicated by intercalations of carbonate breccias and volcanic layers in the AP pelagic deposits. Paleocene-Eocene volcanic rock intrusions along NW-SE, seldom NE-SW, high-angle faults are documented in the VA wells.

At the end of middle Ecene, a dramatic deformational event, related to the orogenesis of the Southern Apennine to the W and of the Dinarides to the E, involved this sector of Adria Plate. The AP was uplifted possibly due to the formation of a crustal bulge in this foreland area. The uplift caused the emersion of most of the platform as confirmed by widespread deep karst and continental “red beds” presence. During the long subaerial exposure, from late Eocene to Miocene, the AP carbonates underwent an important erosion. The erosion was particularly intense in the NW sector of VA area, where the Paleocene-Eocene and Senonian carbonates are completely missing. The deep erosion and the red beds could indicate the presence in this area of a paleo-high related to the late Eocene tectonic events.

During Neogene large sectors of AP were gradually involved in the eastward migration of Southern Apennines thrust belt. While the western-central AP are deeply deformed, the eastern part remained substantially unreformed, with partial cropping out in the Gargano and Salento areas. During Miocene the AP western margin was affected by a rapid subsidence due to the Adria Plate subduction and the tectonic overburden of the growing Southern Apennines. In VA area a tectonic-controlled relative sea-level rise caused the return to marine environment, with deposition of an overall transgressive succession, up to 70m thick, of shallow-water grey bioclastic limestones passing upward to dark fossiliferous phosphatic packstones and wackestones deposited in a moderately deep water, probably shelfal, basin (Carannante, 1982) (Figure 1). The facies and thickness distributions and the coastal onlap outline in the VA area may indicate: (1) the (middle-late?) Miocene basins were probably open towards SE and connected to the Ionian Basin; (2) in VA and Tempa Rossa structural trends, the AP presented a very irregular topography probably related to the presence of large-scale tilted blocks. These deposits are unconformably overlain by Messinian pre-evaporitic coastal bioclastic limestones and syn-evaporitic anhydrites of hyperhaline lagoons (Figure 1). The succession shows an overall regressive trend probably due to the Messinian salinity-crisis base-level falls. The Messinian basin was deepening towards W/SW as indicated by (moving from east to west): (1) the absence of Messinian deposits due to emersion in the Tempa Rossa Trend; (2) the deposition of pre-evaporitic coastal and shallow-marine limestones and evaporites in the VA Trend; (3) a time-equivalent deep-water sedimentation of coarse-grained turbidites in the foredeep in the Castellana Trend. This paleogeographic change was caused by a severe transpressive event, the *Late Tortonian Phase*, responsible for the differential subsidence and tilting toward W/SW of large carbonate units of the AP western margin. Moreover, NW-SE-trending high-angle faults along the margins of the VA trend were reactivated as normal faults with large vertical displacements. A subsequent major tectonic phase, the *Intra-Messinian Phase*, affected the area during late Messinian. This tectonic event was responsible in particular for the eastward displacement of the Allochthonous Complex (AC) over the Castellana Trend. In VA area the sedimentation of calcareous breccias with calcareous or marly matrix, up to 70 m thick, took place. These deposits are missing, for no deposition, in the NW part of VA Trend, as well as in the Tempa Rossa Trend.

The base of the Pliocene is marked in the VA area by a sharp marine transgression. Condensed deep-water fossiliferous marls, named “Basal Marls”, deposited in the central part of the VA Trend (Carubelli et al., 2010). A thick accumulation of low. Pliocene turbidite sandstones and shales of the PL1 Seq. overlay the marls (Patacca & Scandone, 2007). These turbidites of the Volturino Fm., whose thickness ranges between 70 and 600 m, were deposited on VA Trend in a relatively narrow (2-8Km) and elongated (more than 25Km) NNW-SSE-trending foredeep. The inner foredeep margin was represented by the AC front; the external one, by a system of high-angle normal faults cutting through the AP (Figure 2). The succession is mainly made up of thick-bedded sandstone lobes and thin-bedded fine-grained basin plain deposits related to highly-efficient turbidite systems (sensu Mutti et al., 1999) with longitudinal paleocurrents from NNW (Carubelli et al., 2010). The succession, showing an overall coarsening-upward trend, represents the turbiditic infill of the westernmost and oldest Pliocene depocenter of Bradanic Foredeep. A tectonic sequence boundary, related to the AC overthrusting on the foredeep inner margin, subdivides the PL1 Sequence into two smaller sequences named PL1a and PL1b (Figure 3).

During the early Pliocene younger part, a severe transpressive thin-skinned deformation, the *Intra-Zanclean Phase*, was responsible for the rapid overthrusting of the Miocene Irpine Units of the AC on the VA foredeep. The creation of a new and more external foredeep takes place in the Tempa Rossa Trend. The rapid tectonic-controlled burial and the relatively high content in carbonate lithic fragments were responsible for the early and strong diagenesis of the lower Pliocene succession. A thick-skinned tectonics affected the VA area during the latest Pliocene major transpressional event: the *Gelasian Phase.* Older normal faults of the AP carbonates were reactivated as high-angle reverse faults, and the uplift of the VA NW-SE-oriented pop-up occurred. The total throw has been evaluated as over 1300 m. The faulting affected also the overlying lower Pliocene turbidites and the lower part of AC.

After the gradual decrease of the eastward transpressive deformation during the early Pleistocene, the Apulian area underwent a general uplift in middle Pleistocene (Doglioni et al., 1994). The extensional faults cropping out in VA are attributed to this phase.

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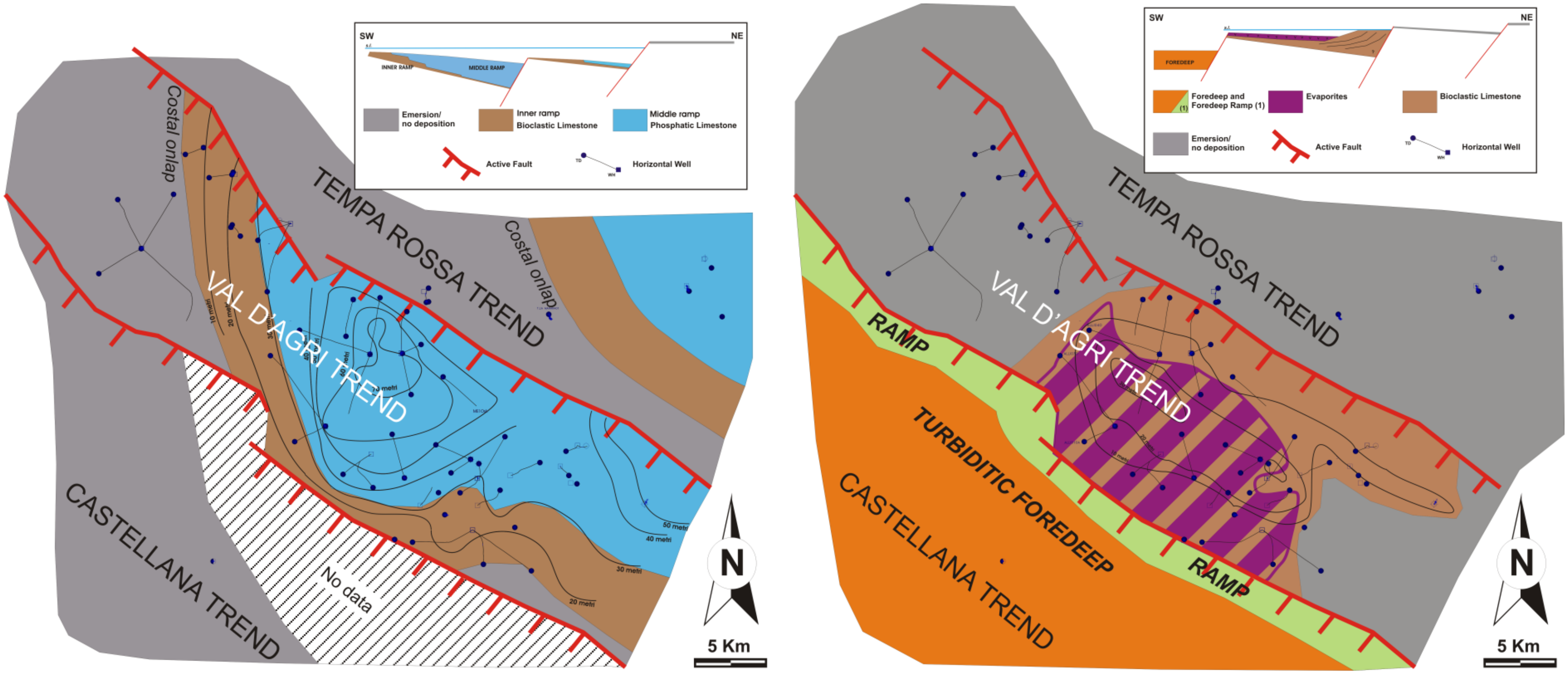

Figure 1. Miocene (on the left) and Messinian (on the right) facies distribution maps in the Val d’Agri area.

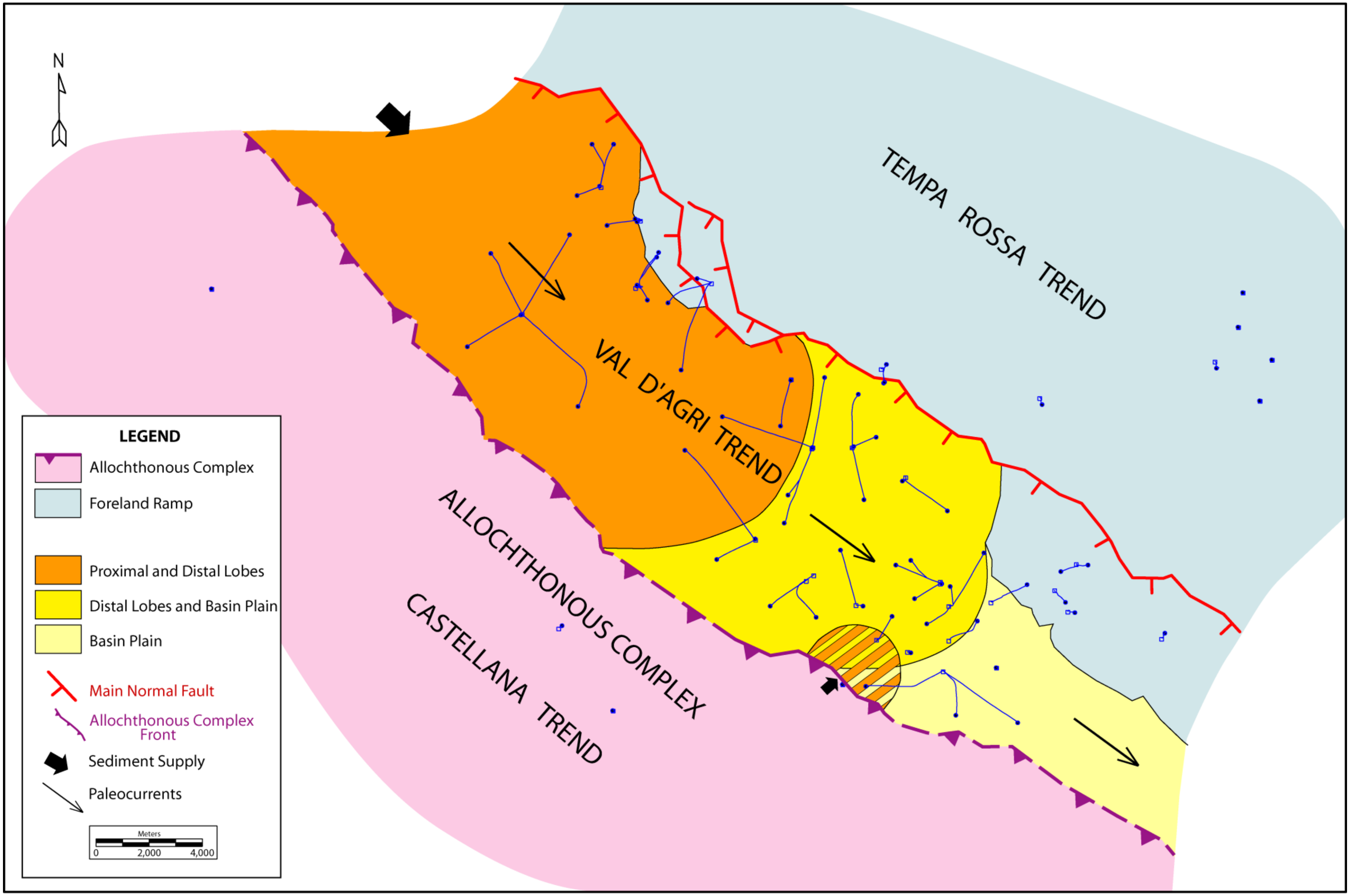

Figure 2. Lower Pliocene facies distribution map (top PL1a Sequence.) in the Val d'Agri area.

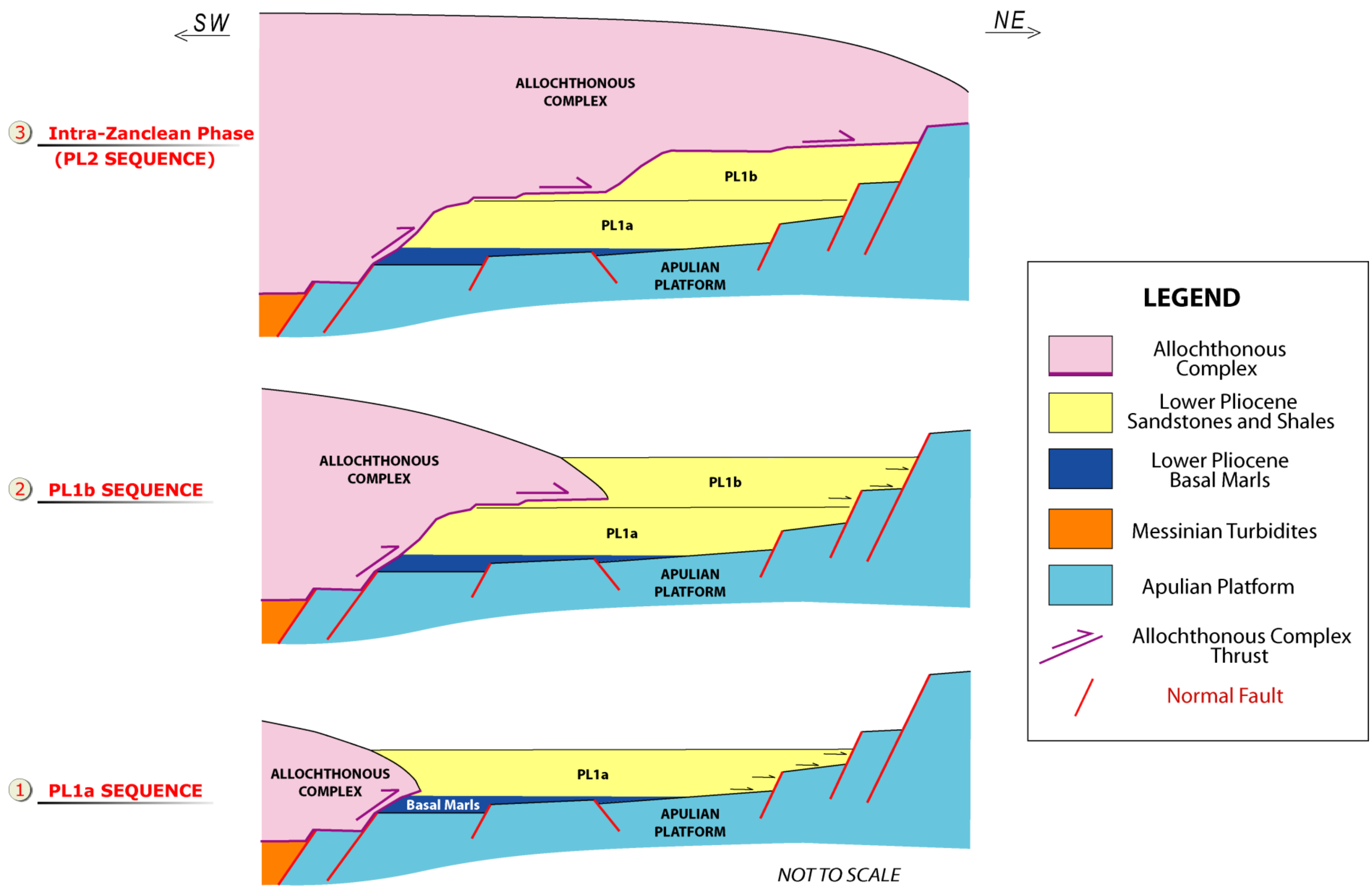

Figure 3. Lower Pliocene tectono-sedimentary evolution of the VA area.