An overview of the Crotone Basin (central Mediterranean): tectonics, geohazards and geoenergy implications

Giacomo Mangano[1,2], **Massimo Zecchin**[2], **Dario Civile**[2] & **Salvatore Critelli**[1]

[1]Department of Environmental Engineering, University of Calabria, Arcavacata di Rende, CS, 87036, Italy.
[2]National Institute of Oceanography and Applied Geophysics – OGS, Sgonico, TS, 34010, Italy.

GM, 0000-0001-9860-1899; MZ, 0000-0003-2912-8457; DC, 0000-0002-2809-0015; SC, 0000-0001-7325-0228.

Rend. Online Soc. Geol. It., Vol. 68 (2026), pp. …-…, 5 figs. https://doi.org/10.3301/ROL.2026.06

Short Note

Corresponding author e-mail: giacomo.mangano@unical.it

Citation: Mangano G., Zecchin M., Civile D. & Critelli S. (2026) - An overview of the Crotone Basin (central Mediterranean): tectonics, geohazards and geoenergy implications. Rend. Online Soc. Geol. It., 68, XX-XX, https://doi.org/10.3301/ROL.2026.06.

Guest Editor: Sara Criniti

Submitted: 27 October 2025
Accepted: 22 December 2025

SOCIETÀ GEOLOGICA ITALIANA ETS
FONDATA NEL 1881 - ENTE MORALE R. D. 17 OTTOBRE 1885

ABSTRACT

The Neogene–Quaternary Crotone Basin on the Ionian side of the Calabrian Arc, represents one of the most tectonically complex and resource-rich forearc basins in the Central Mediterranean governed by contractional and strike-slip tectonics. Integration of seismic interpretation, well-log correlation, and burial and thermal modeling provides new insights into the interplay between tectonic deformation, gravitational processes, and petroleum system development. Results demonstrate that the Rossano–San Nicola Fault Zone (RSFZ) has exerted since the Late Tortonian, dextral transpressional and transtensional activity along this shear zone and governed the emplacement of the Cariati Nappe, the differentiation between the Cirò and Crotone areas, the formation of a NW-oriented positive flower structure and structural highs both onshore and offshore. The RSFZ also influenced the onset of large-scale gravitational instability, providing the tectonic framework for the subsequent development of the Crotone Megalandslide. The c. 1500 km^2 extended Crotone Megalandslide is interpreted as a long-lived, gravity-driven collapse translating above a Messinian evaporitic detachment. Its paroxysmal phase during the Late Zanclean–Piacenzian was triggered by renewed transpressional uplift along the RSFZ, whereas subsequent quiescence and reactivation phases correspond to major geodynamic reorganisations of the Central Mediterranean— Gelasian subsidence linked to the opening of the Marsili back-arc basin and Middle Pleistocene uplift of the Calabrian Arc. These transpressional tectonics-driven gravitational processes strongly modulated the petroleum system of the Crotone Basin. Burial and thermal modeling indicate that Triassic–Lower Jurassic and Aptian–Cenomanian source rocks entered the gas window during Miocene–Pliocene subsidence, while the emplacement of mass-transport deposits enhanced heat flow and overburden. Proven Serravallian and Tortonian reservoirs were incorporated within compressional domains of the megalandslide, where structural folding and Messinian evaporitic seals created effective traps.

KEYWORDS: Crotone Basin, strike-slip tectonics, Crotone Megalandslide, Petroleum System Modelling, Calabrian Arc.

INTRODUCTION

The Neogene–Quaternary Crotone Basin, along the Ionian margin of Calabria (southern Italy), has developed as a forearc depocenter in response to the southeastward migration of the Calabrian terranes—an arcuate nappe stack composed of ophiolitic and continental crust— under setting of NW-directed subduction of the Ionian lithosphere, slab rollback, and Tyrrhenian back-arc extension (e.g., Bonardi et al., 2001; Malinverno & Ryan, 1986; Sartori, 1990; Patacca et al., 1990; Gueguen et al., 1998; Critelli, 1993, 2018; Critelli & Martín-Martín, 2022, 2024; Martín-Martín et al., 2023) (Fig. 1). Its tectonic evolution has been marked by the fragmentation of the Calabrian terranes in several blocks bounded by NW- and WNW-trending shear zone (e.g., Van Dijk et al., 2000; Mattei et al., 2002; Cifelli et al., 2007; Tansi et al., 2007; Tripodi et al., 2013, 2018) (Fig. 1), which influenced the partitioning of the basin in three sectors, one of this hosts the largest gas-producing in the Italian territory (e.g., Zecchin et al., 2020; Mangano et al., 2024). It also experienced the effects of a large-scale gravitational collapse and the emplacement of allochthonous units, the so-called Cariati Nappe in the N sector (e.g., Massari & Prosser, 2013; Minelli et al., 2013; Ceramicola et al., 2014, 2024; Muto et al., 2014, 2017; Zecchin et al., 2018; Mangano et al., 2020, 2023a, b).

Therefore, the Crotone Basin constitutes an important geological province, as it represents a well-exposed Neogene–Quaternary structural-stratigraphic archive of regional tectonic significance alongside a natural laboratory for marine geohazard assessment and hosts valuable natural resources such as

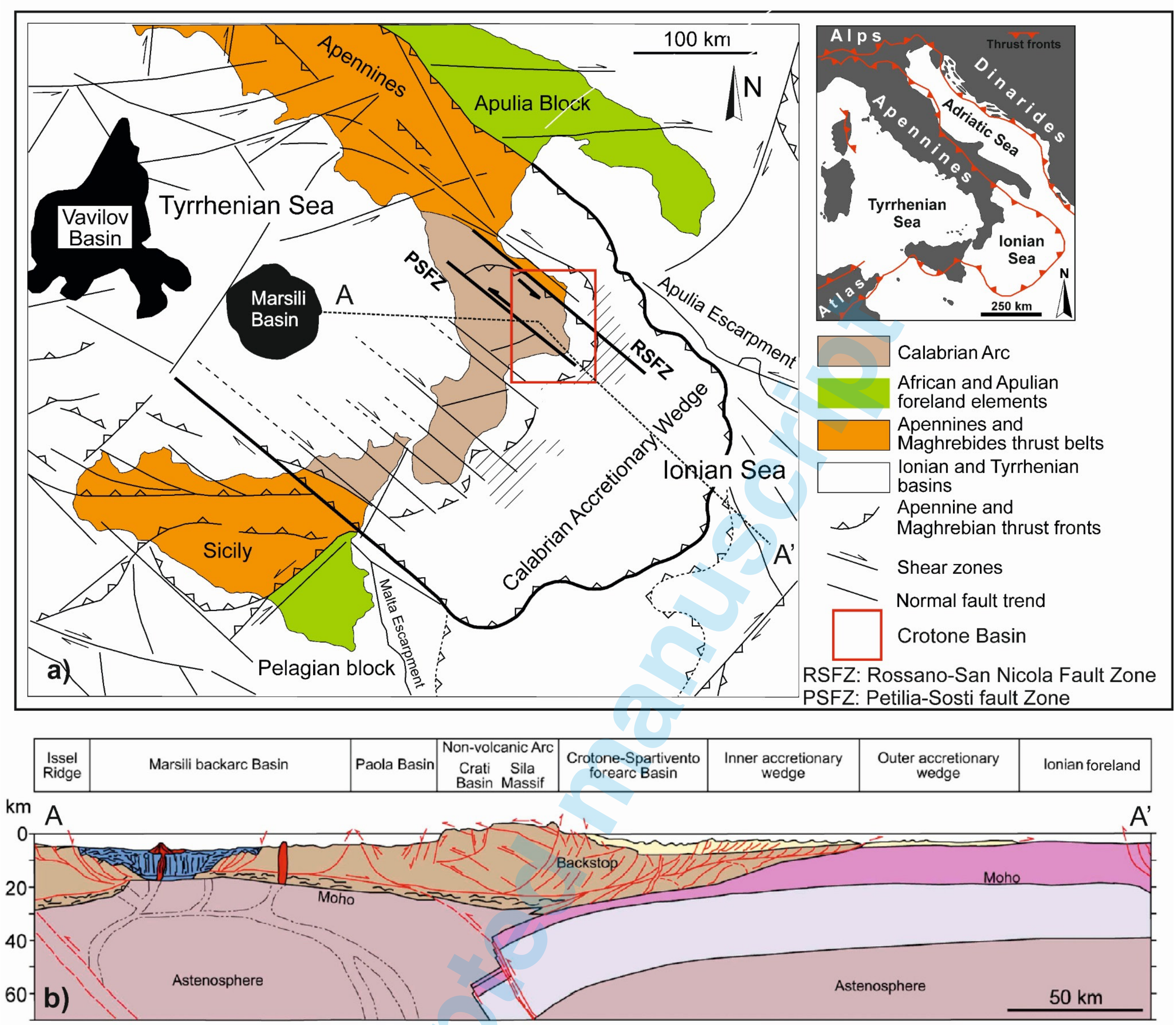

Fig. 1 - a) Structural map of the Calabrian Arc, located between the southern Apennine chain and the Maghrebide thrust belt (modified from Van Dijk and Okkes, 1991). The Vavilov and Marsili back-arc basins are shown within the southern Tyrrhenian Sea. The main fault zones, including the Rossano–San Nicola (RSFZ) and Petilia–Sosti (PSFZ), are indicated. b) NW–SE cross-section through the Calabrian Arc (see transect A–A' in panel a) illustrating the main structural features (modfied from Van Dijk et al., 2000). The Crotone Basin, forming the northern depocenter of the Crotone–Spartivento Basin, represents a forearc basin overlying the Sila Massif.

hydrocarbons, salt, and sulfur, making it of both academic and economic interest (e.g., Zecchin et al., 2020 and reference herein). In this context, recent 3D modelling efforts have further refined the subsurface framework of the basin, revealing marked thickness variations, erosional truncations, uplifted pre-Messinian surfaces, and a fault-controlled horst-and-graben architecture consistent with regional tectonics (Falsetta et al., 2024a, b).

The aim of this manuscript is to provide an integrated overview of the Crotone Basin as a key geological system in the Central Mediterranean, combining insights from recent studies on tectono-stratigraphic architecture, active marine geohazards, and petroleum system development (e.g., Zecchin et al., 2018; Mangano et al., 2020, 2021, 2022a,b, 2023a,b, 2024). By synthesizing seismic and stratigraphic evidence, this work brings together the structural-stratigraphic asset of the basin along with the ongoing gravitational processes and the stratigraphic configurations that controlled hydrocarbon generation and trapping across the Neogene–Quaternary.

GEOLOGICAL SETTING

The Crotone Basin lies along the Ionian side of the Calabrian Arc, forming part of the Calabrian accretionary wedge, and is bounded by two major shear zones: the Rossano–San Nicola Fault Zone (RSFZ) to the north and the Petilia–Sosti Fault Zone (PSFZ) to the south - UTM Est 660000–730000 e UTM Nord 4200000–4260000 (e.g., Van Dijk, 1994; Van Dijk & Okkes, 1991; Van Dijk et al., 2000; Civile et al., 2022; Tansi et al., 2007; Critelli & Martín-Martín, 2022; Mangano et al., 2023a) (Fig. 1). Its tectono-stratigraphic evolution is attributed to the rollback of the northwest-dipping Ionian slab, accompanied by recurrent episodes of slab tearing and retreat (e.g., Faccenna et al., 2001, 2004; Rosenbaum & Lister, 2004; Barone et al., 2008; Critelli & Martín-Martín, 2022). Since the Late Serravallian, the Calabrian Arc has migrated southeastward after separating from the Corsica–Sardinia Block (e.g., Bonardi et al., 2001; Critelli & Martín-Martín, 2022, 2024; Martín-Martín et al., 2023), and its evolution was punctuated by transient collisional events between adjacent plates (e.g., Amodio Morelli et al., 1976; Bonardi et al., 2001; Butler et al., 2004; Iannace et al., 2007). During this migration, forearc propagation was accompanied by the opening of oceanic sub-basins (Vavilov and Marsili) in the Tyrrhenian domain, inducing progressive tectonic subsidence along the Ionian margin (e.g., Zecchin et al., 2020; Campilongo et al., 2022).

The structural evolution of the Crotone Basin was strongly controlled by the long-lived activity of the RSFZ and PSFZ, which governed sediment distribution and shaped the present-day morphology (e.g., Critelli, 1999; Critelli et al., 2014; Bonardi et al., 2001; Zecchin et al., 2012; Massari & Prosser, 2013; Zecchin et al., 2015, 2020; Civile et al., 2022; Mangano et al., 2022a, b; Criniti et al., 2023; Mangano 2024). Initial subsidence during the Serravallian led to the accumulation of continental conglomerates above the Serravallian Unconformity (SU; e.g., Zecchin et al., 2020; Falsetta et al., 2024a, b), while coeval uplift along basin margins produced the regional Tortonian Unconformity (TU). During the Tortonian, a major transpressional phase along NW-trending structures drove the emplacement of the Cariati Nappe—an Oligocene to Tortonian tectono-stratigraphic unit in the northern sector (e.g., Muto et al., 2014, 2017) (Fig. 2).

Following Zecchin et al. (2020), the term Crotone Basin is used in its broader sense to include the Crotone (to the S) and Cirò (to the N) onshore areas and the offshore domain (Fig. 2) that evolved together until the late Tortonian–early Messinian, after which they followed distinct tectono-sedimentary trajectories. During the Messinian evolution was marked by alternating transpressional and transtensional episodes and by the effects of the Messinian Salinity Crisis (e.g., Borrelli et al., 2021, 2022; Zecchin et al., 2013a,b, 2020). The hundred-meter sea-level fall exposed large parts of the basin and produced the Intra-Messinian (IMU) and upper Messinian (UMU) unconformities (Zecchin et al., 2020; Borrelli et al., 2021, 2022). In the Early Pliocene (Zanclean), renewed subsidence accompanied the onset of ocean spreading in the Vavilov sub-basin and led to the development of the Zanclean Surface (ZS) associated with transgressive conditions (e.g., Massari & Prosser, 2013; Zecchin et al., 2018, 2020; Mangano et al., 2020, 2021, 2022a, b, 2023b). This phase also marks the beginning of widespread slope instability that culminated in the development of the Crotone Megalandslide, a large-scale gravitational collapse affecting both onshore and offshore sectors. The megalandslide was triggered by renewed transpressional movements along the RSFZ during the Zanclean–Piacenzian transition, which uplifted the basin shoulder and increased slope gradients (e.g., Minelli et al., 2013; Zecchin et al., 2018; Mangano et al., 2020). Its evolution was later influenced by regional uplift and continued deformation throughout the Pleistocene, contributing to the complex geomorphology of the basin and playing a central role in fluid migration pathways (e.g., Mangano et al. 2020, 2021). From the Late Pliocene to the Pleistocene, the basin recorded successive phases of subsidence and uplift associated with the opening of the Marsili back-arc basin and the deceleration of slab rollback (e.g., Zecchin et al., 2012, 2015, 2020). Major unconformities such as the Early Pleistocene (EPSU) and Mid-Pleistocene (MPSU) surfaces attest to these cyclic tectonic reorganisations, followed by regional uplift that produced a staircase of marine terraces along the coastal sector (e.g., Gliozzi, 1987; Zecchin et al., 2004). All these processes, coupled with long-term subsidence and episodic uplift, created the thermal and structural conditions necessary for the generation and trapping of hydrocarbons, developing the Crotone Basin into one of the most important gas provinces in Italy, currently contributing significantly to the national gas supply (e.g., Roveri et al., 1992; Mangano et al., 2023a).

DATA AND METHODS

This study integrates 2D/3D seismic reflection interpretation, well-log correlation, and one-dimensional burial and thermal modeling to reconstruct the tectono-stratigraphic and petroleum evolution of the Crotone Basin. Seismic and well data provided by ENI Natural Resources were interpreted using Petrel® software (Figs. 2 and 3). Key reflectors and unconformities were identified through the analysis of reflector terminations, facies variations, and amplitude contrasts, and correlated with stratigraphic and structural markers from well data and geological maps. Fault geometries and kinematics were constrained to define the architecture of the Rossano–San Nicola fault zone and their relationship with major tectonic and gravitational features, including the Crotone Megalandslide. Burial and thermal histories were modeled using PetroMod®. Calibration was based on stratigraphic ages, lithologies, paleowater depths, and heat-flow data from regional studies (e.g., Critelli, 1999; Zecchin et al., 2020). These models constrained source-rock maturation and heat-flow evolution linked to Miocene–Pliocene tectonic subsidence and gravitational loading.

THE ROSSANO-SAN NICOLA FAULT ZONE

The Rossano-San Nicola Fault crosses the NE boundary of the Crotone Basin and is part of the major NW- and WNW– ESE-trending strike-slip fault zones generated as a result of the SE migration of the Calabrian Terrane since the Middle Miocene (e.g., Van Dijk, 1994; Van Dijk and Okkes, 1991; Van Dijk et al., 2000; Muto et al. 2014) (Figs. 1 and 2). Seismic reflection data document that the RSFZ is composed of a NE-oriented flower structure that accommodates both transpressional and transtensional deformation, expressed through three main tectonic elements: Fault 1, Fault 2, and Thrust 1 (e.g., Mangano et al., 2024) (Fig. 3).

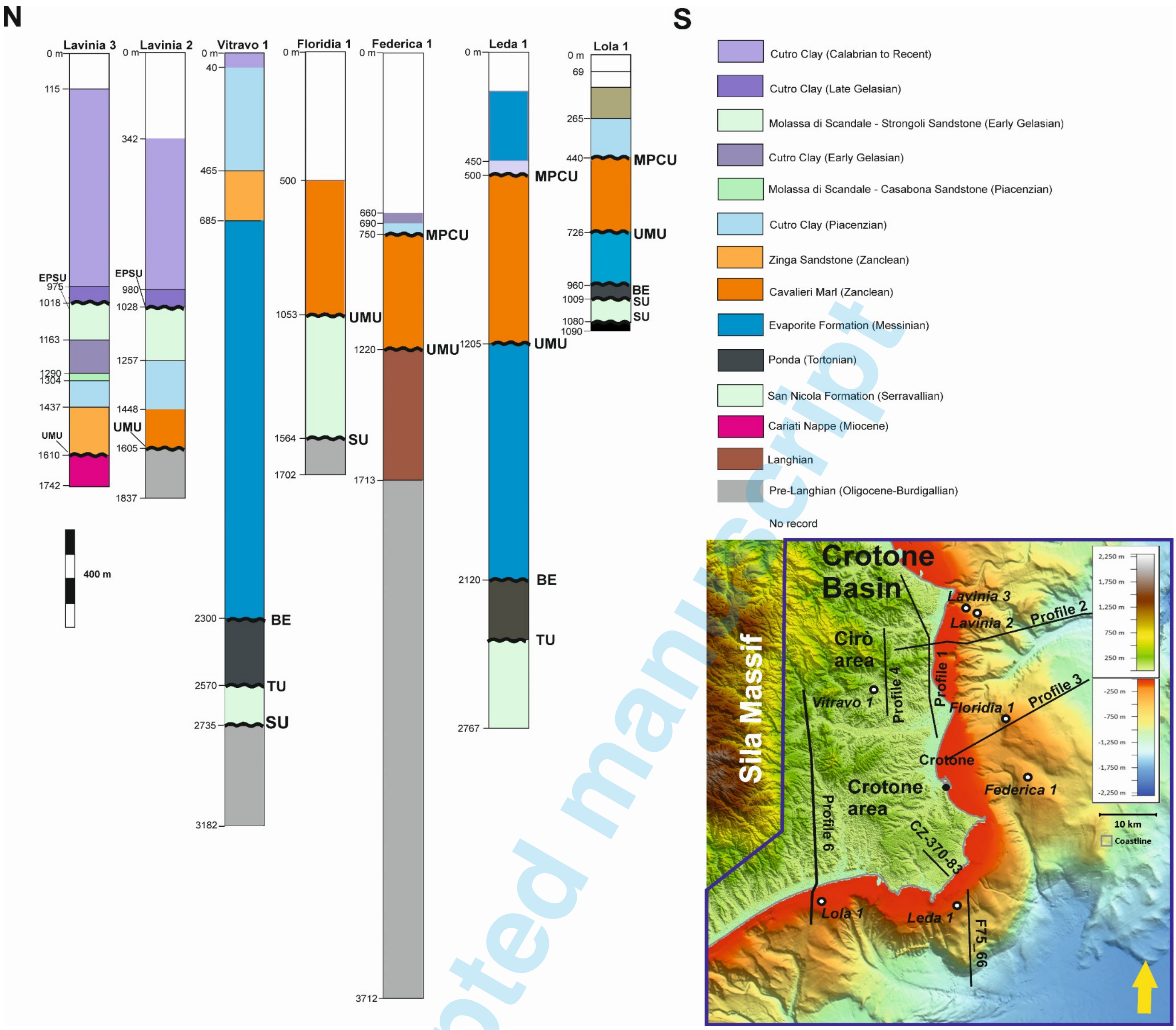

Fig. 2 - Well data were provided by ENI Natural Resources. The locations of wells and seismic profiles are shown in the lower right-hand corner of the figure. Due to data confidentiality of the data, the location of Profile 5 is not shown.

Fault 1 corresponds to a northeast-dipping fault plane with southwest-verging kinematics, affecting the sedimentary successions of pre-Langhian to Quaternary age (based on the available wells) (Fig. 2 and 3a, b, d). Its fault plane crops out by cutting through the Cariati Nappe and continues in the subsurface beneath it (Figs. 2 and 3a, b, d). To the south, the NW-oriented Fault 2 and the W-oriented Thrust 1 define transpressional domains, dissecting pre-Langhian to Messinian units (based on the available wells - Fig. 2) as well as the major unconformity surfaces, such as the SU, the TU and the BE (Fig. 3a, b, d). Both Fault 2 and Thrust 1 are located in the subsurface of the Crotone area, where Fault 2 is truncated by the basal shear surface of the Crotone Megalandslide, indicating a later stage of gravitational collapse superimposed on the pre-existing tectonic framework (Fig. 3a). Notably, the frontal tip of the Thrust 1 lies just ahead of the Messinian succession, without intersecting it (Fig. 3a). The geometric relationships between Faults 1 and 2 suggest linkage at depth to a steep, subvertical master fault, from which upward splaying fault strands produce the positive flower geometry (Fig. 3b). The RSFZ also comprises two major offshore fault segments, named here work Fault 3 and Fault 4 (Fig. 3c). These structures dip to the northeast and are deep-rooted along the eastern offshore sector where they disrupt seismic reflectors within the pre-Langhian to Serravallian succession (Fig. 3c, d). Their activity is not excluded to have generated a prominent structural high defined by the UMU, and the development of older structural culminations capped by the SU (Fig. 3c). The orientation of Faults 3 and 4 is consistent with that of the onshore fault array forming the RSFZ, highlighting the tectonic continuity between the inland domain and the adjacent offshore area (Fig. 3d). Lastly, the Zanclean to recent deposits are deformed and dissected by a set of N-, NE-, S-, WSW- and ENE-dipping high-angle transtensional

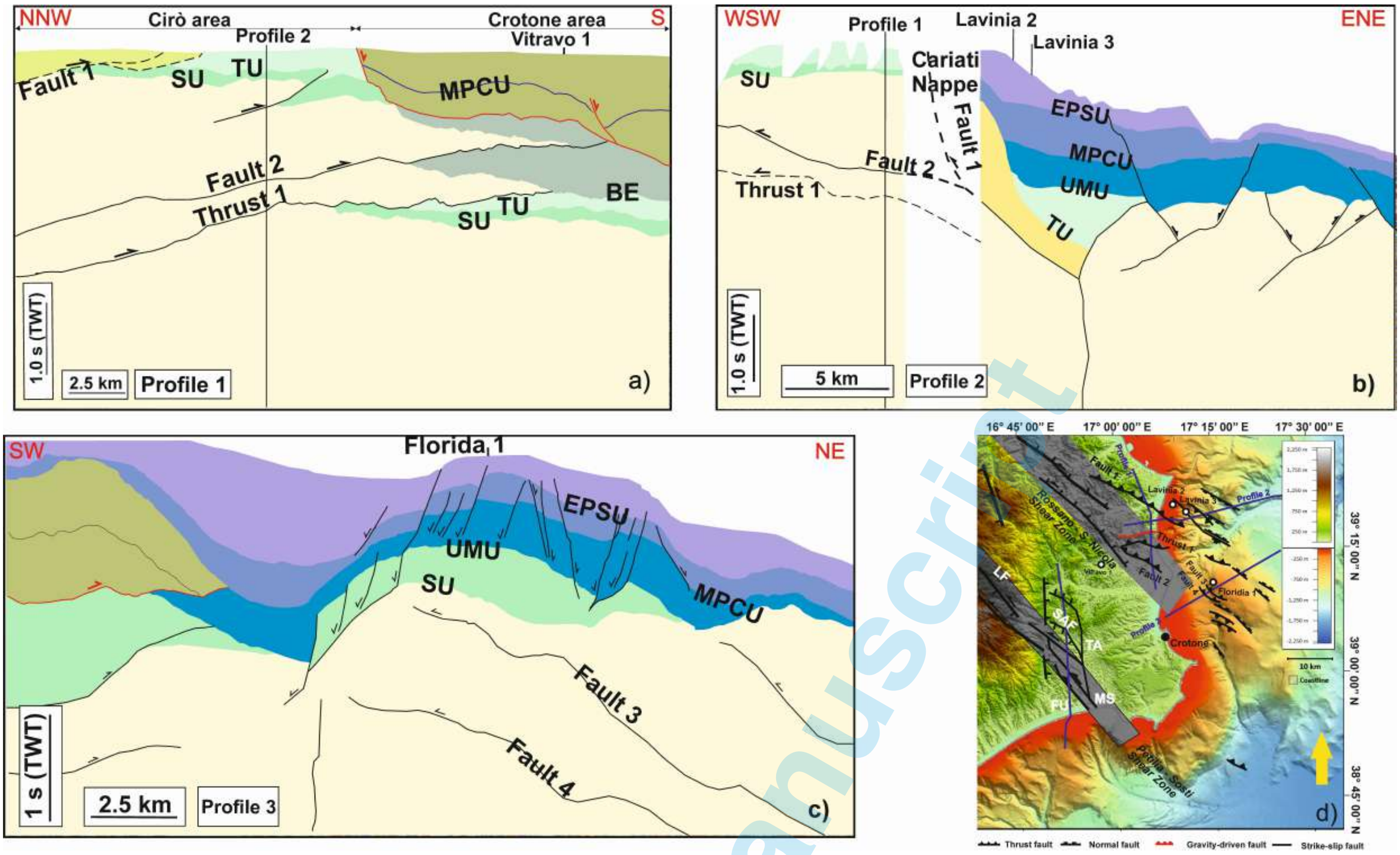

Fig. 3 - Interpreted seismic profiles 1–3 illustrating the main seismic–stratigraphic units bounded by unconformities. Black lines indicate faults. Abbreviations: SU – Serravallian Unconformity; TU – Tortonian Unconformity; BE: Base of Messinian; UMU – Upper Messinian Unconformity; MPCU – Middle Pliocene Unconformity; EPSU – Early Pleistocene Unconformity. The locations of the seismic profiles are shown in the lower right-hand corner of the figure. LF – Lake Fault; SAF – Sant'Antonio Fault; TA – Tacina Fualt; FU – Monte Fuscaldo Fault; MS – Marcedusa-Steccato Fault.

faults that define small-scale depocentres. and exhibit the same orientation as the outcropping NW-oriented structural segments of the RSFZ (3c, d).

THE PETILIA-SOSTI FAULT ZONE

The NW-trending Petilia–Sosti Fault Zone (PSFZ) is an active, approximately 130 km long fault system that intersects the southwestern sector of the Crotone Basin (e.g., Van Dijk, 1994; Massari & Prosser, 2013; Zecchin et al., 2020; Civile et al., 2022). It comprises several fault segments characterised primarily by strike-slip kinematics. The main fault segments include the Lakes Fault within the Sila Massif, and the Tacina, Marcedusa–Steccato, and Fosso Umbro faults in the southwestern part of the Crotone Basin (Fig. 3d).

Portions of the Fosso Umbro and Marcedusa–Steccato faults extend offshore, where they have driven the southeastward migration of the Crotone Megalandslide (e.g., Zecchin et al., 2018). The PSFZ records a complex tectonic evolution since the Middle Miocene, marked by alternating sinistral and dextral transpressional and transtensional phases associated with the geodynamic processes accompanying the southeastward migration of the Calabrian Arc.

At present, fault segments affecting the Sila Massif show predominantly normal faulting with a minor left-lateral component. In contrast, the southwestern onshore–offshore portion of the Crotone Basin exhibits a more complex geological setting dominated by gravity-driven movements with a dextral component, which facilitated the continued southeastward motion of the Crotone Megalandslide.

Seismological data indicate that several significant earthquakes, occurring in 1638, 1744, and 1832 with magnitudes (Mw) ranging from 5.7 to 6.8, are spatially associated with the trace of the PSFZ (e.g., Civile et al., 2022).

THE CROTONE MEGALANDSLIDE

The Crotone Megalandslide is a large-scale, gravity-driven mass movement, encompassing approximately 1500 km^2 across both the onshore and offshore sectors of the Crotone Basin, and involving an up to ~1.6 km thick a sedimentary succession (e.g., Zecchin et al., 2018; Mangano et al., 2020, 2021). It is interpreted as a seaward-gliding landmass translating above a low-angle basal detachment developed within Messinian evaporites, which acted as a regional basal décollement surface (Fig. 4b, c, d). The structure exhibits the typical dual-domain architecture of gravitational collapses, comprising an updip extensional sector linked downslope to a compressional toe through the basal detachment (Fig. 4b, c, d).

Seismic and well data indicate that the megalandslide deforms Messinian to Quaternary successions, with SE-dipping

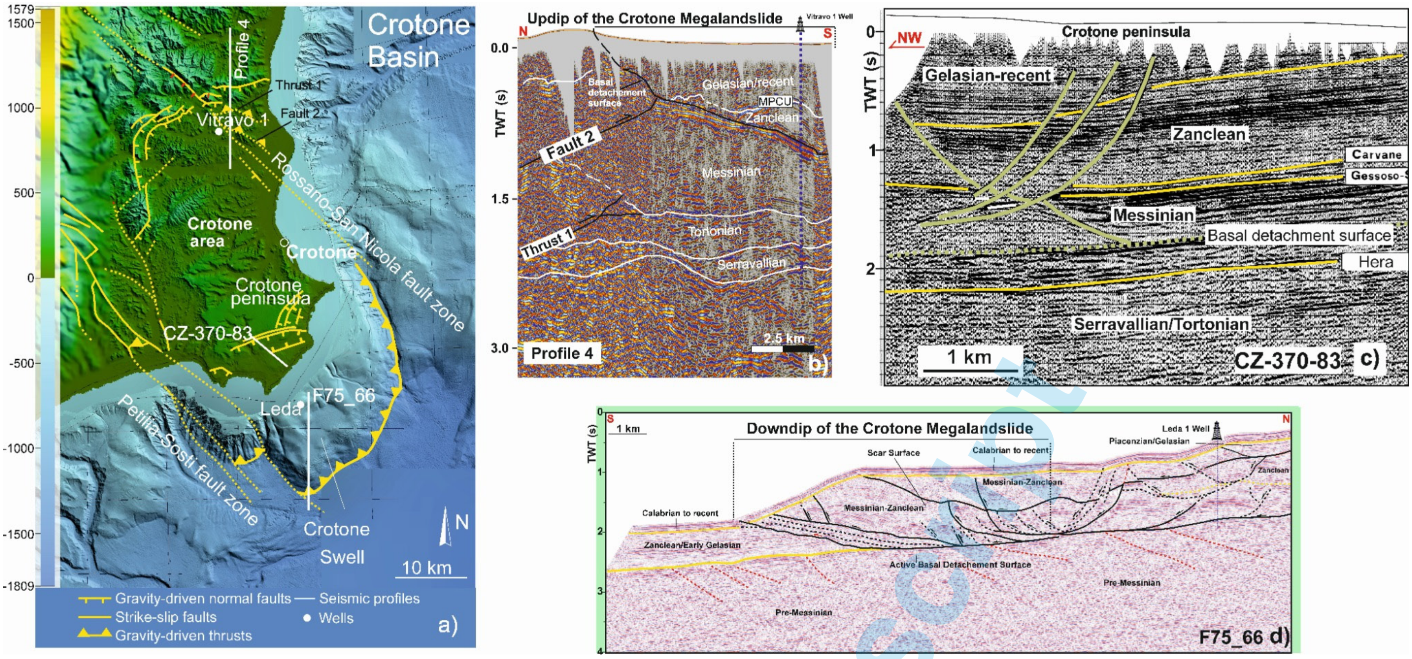

Fig. 4 - a) Digital Terrain Model (DTM) map showing the onshore and offshore sectors of the Crotone Basin and the main structural elements, including the RSFZ and PSFZ. Normal faults (to the north) and reverse faults (to the southeast, offshore) define the extensional and compressional domains of the Crotone Megalandslide. b) Seismic Profile 4 showing the subsurface structure of the updip domain of the Crotone Megalandslide, where the basal detachment surface crosscuts Fault 2. c) Seismic Profile CZ-370-83 (see panel a for location) showing the connection between the basal detachment surface of the Crotone Megalandslide and the listric normal faults cutting through the Crotone Peninsula. d) Interpreted N–Soriented seismic profile F75_66 from the offshore sector of the Crotone Basin (after Zecchin et al., 2018; see panel a for location). The profile highlights the active downdip domain of the megalandslide, where the basal detachment surface intersects the seafloor.

listric normal faults characterizing the landward extensional domain and a SE-verging thrust front marking the offshore compressional sector (Fig. 4b, c, d). In the northern onshore part of the Crotone area, arcuate-shaped listric faults constituting the updip domain display clear evidence of syn-sedimentary activity during the Zanclean and Piacenzian, as indicated by growth strata geometries (e.g., Zecchin et al., 2018) (Fig. 3a). In the downdip domain, represented by the Crotone Swell, Zanclean deposits occur as chaotic bodies overlying a well-defined scar surface and are sealed by Piacenzian to Quaternary sediments (Fig.4a, d). In certain zones of the downdip domain, Zanclean deposits are directly overlain by an undeformed Quaternary drape, with no evidence of Piacenzian deposits (Fig. 4d). Here, the basal detachment surface is observed to intersect the present seafloor towards the S, while landward it seems to be connected to the SE- and E-dipping listric normal faults that dissect the uplifted Pleistocene marine terraces in the Crotone Peninsula (Fig. 4a, c, d). It is also noteworthy mentioning that satellite-based geodetic measurements (GPS and InSAR) document a dense cluster of observation points across the Crotone Peninsula indicating ongoing movements towards the south and east, while no evidence of current activity is recorded N of the Crotone Peninsula (e.g., Zecchin et al., 2018; Mangano et al., 2020).

THE PETROLEUM SYSTEM

The Crotone Basin hosts a gas-prone petroleum system whose trap formation and seal development have been tightly modulated by the Pliocene–Quaternary emplacement of the Crotone Megalandslide on the basin slope. Commercial accumulations cluster near the culminations of contractional structures reactivated in the Pliocene, underscoring the pivotal tectono-stratigraphic control on charge and retention.

Source rocks and maturity

Two main Mesozoic source intervals are implicated. (i) Triassic–Lower Jurassic organic-rich “red beds” (Unit U2); (ii) organic-rich Aptian–Cenomanian shales (Unit U4) are interbedded within thick Lower Jurassic–Upper Cretaceous carbonates (U3–U5) (Fig. 5a). One-dimensional burial models calibrated to exploration boreholes show that Triassic–Lower Jurassic organic-rich “red beds” entered the gas window in the Late Miocene until the present-day, while the organic-rich Aptian–Cenomanian shales reach maturity conditions during the Early Pliocene sustaining gas generation to present (Fig. 5a).

Reservoir, seals and trap developments

Proven reservoirs are hosted within the Serravallian San Nicola Formation, comprising fan-delta conglomerates and sandstones, and within sandy intervals of the Tortonian Ponda Group, developed into shelf to slope settings (e.g., Roveri et al., 1992; Zecchin et al., 2020). In the slope domain, Ponda Group reservoir units are encased within the Crotone Megalandslide, whereas the San Nicola reservoir interval lies beneath it; both reservoir units are sealed upward by Messinian to Recent evaporites and fine-grained

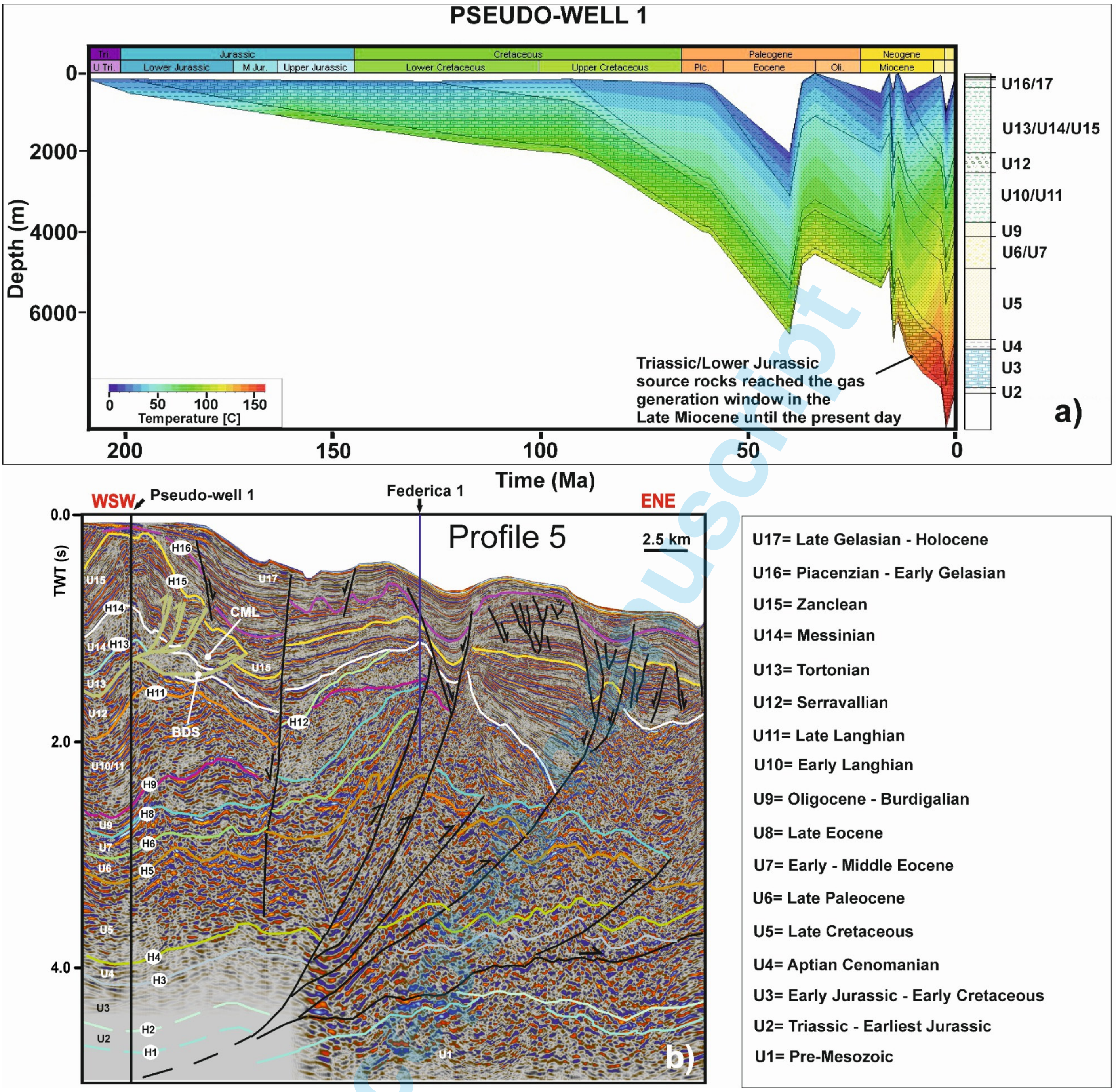

Fig. 5 - a) PetroMod® temperature model for Pseudo-well 1 illustrating the effects of seal (Units U13–U16) and reservoir (Units U11 and U12) intervals within the gas-bearing field. The Triassic–Early Jurassic Unit U2 reached its maximum burial depth during the Piacenzian and has maintained suitable conditions for gas maturation up to the present day. b) Interpreted 2D multichannel WSW–ENE seismic Profile 1 illustrating the seismic–stratigraphic framework of the pre-Crotone Basin deposits (Units U1–U11) and the overlying Crotone Basin succession (Units U12–U17). CML: Crotone Megalandslide

silty strata (Fig. 5b). The Messinian evaporites provide an effective regional top seal, overlain by thick Zanclean–Quaternary clay-rich successions — the Cavalieri Marl and Cutro Clay — that drape the slope and, together with the Crotone Megalandslide, form a composite sealing package (Fig. 5b). These fine-grained units plus evaporites reach more than 1.5 km in aggregate thickness beneath the compressional toe of the Crotone Megalandslide (Fig. 5b). The basin provides a documented case in which a large mass-transport-complex itself constitutes the principal top seal to a producing gas accumulation, with anticlinal traps at both Serravallian and Tortonian reservoir levels sealed by Messinian evaporites and Pliocene–Pleistocene marls/clays.

DISCUSSION

The results of this study highlight the Crotone Basin as a key geological province in the Central Mediterranean, where the interaction between tectonic, gravitational and stratigraphic processes has profoundly shaped basin evolution and resource potential. The basin is unique in combining an exceptionally well-preserved Neogene–Quaternary stratigraphic record with ongoing large-scale gravitational deformation and a proven gas-prone petroleum system. These elements emphasize the dual academic and economic significance of the Crotone Basin, which serves both as a natural laboratory to investigate forearc dynamics and as the largest gas-producing district in Italy.

The role of the Rossano-San Nicola and Petilia-Sosti Fault Zones

The Rossano-San Nicola Fault Zone

The Rossano–San Nicola Shear Zone (RSFZ) emerges as a fundamental element in deciphering the tectono-stratigraphic evolution of the Crotone Basin and its role in the broader framework of Central Mediterranean geodynamics. Its activity controlled differential uplift, subsidence, and sediment distribution, providing a coherent explanation for debated issues such as the emplacement of the Cariati Nappe, the contrasting stratigraphic architectures between the Crotone and Cirò sectors, and the timing of large-scale gravitational collapse. The recognition of a positive flower structure associated with the RSFZ is the key to integrating these processes into a unified tectonic model. The RSFZ has begun to shape the structural architecture of the Crotone Basin since the late Tortonian, when the Cirò area experienced a dextral transprensional regime that promoted the emplacement of the Cariati Nappe (Fig. 3a, b, d). The deformation was accommodated by the activation of a southwest-verging transpressional fault (Fault 1), which cut through the Serravallian-Tortonian succession (Fig. 3a, b, d). This fault is interpreted to merge at the depth with a NW-oriented positive flower structure, whose geometry and position coincide with that of the RSFZ (Fig. 3a, b, d). The evidence indicates that the late Tortonian tectonic phase marked the onset of the RSFZ-controlled deformation, establishing the structural partitioning between the uplifted Cirò area and the coeval depocenter to the S (Fig. 3a). During the Messinian, the RSFZ-related activity persisted through the expulsion of a S-verging thrust (Thrust 1) that uplifted the Cirò area while generating an E–W-oriented depocenter in the Crotone area, where up to 1600 m in thickness Messinian evaporites accumulated (Fig. 3a). This is documented by the presence of a N-dipping reverse shear surface beneath the Cirò area (here named as Thrust 1), whose frontal tip is found just ahead of the Messinian succession (Fig. 3a). This interpretation also found further reinforcement in the model proposed by Hancock (1985), according to which dextral transcurrement deformation along 140° faults promotes the formation of E-W reverse tectonic structures. In effect, the Messinian in the Crotone Basin records evidence of right-lateral reactivation of the NW-striking fault system, accompanied by the growth of E-W-oriented anticlines that attest to a coeval tectonic regime (Massari and Prosser, 2013). The Messinian RSFZ-related activity is also demonstrated in the offshore sector, where structural highs capped by Lower Pliocene sediments directly overlie Tortonian and Serravallian units. Indeed, the Faults 3 and 4 lie beneath these structural highs and are interpreted as deep-rooted components of flower structures (Fig. 3c, d). Their orientations closely match that of the onshore fault segments composing the RSFZ (Fig. 3c, d). After a phase of extensional/transtensional tectonics activity along the RSFZ documented by Zanclean depocenters delimited by NW-oriented faults segment, the RSFZ-related transpressional tectonics was expressed along Fault 2 which was also responsible by the triggering of the Crotone Megalandslide. This is documented by the fact that the basal shear surface of the Crotone Megalandslide lies beneath the lobate shaped deposit and seems to be connected to the outcropping listric faults of Pliocene age, a typical architecture that defines the updip domain of the large gravitational collapse (Fig. 3a). At the regional scale, both the Late Messinian and the Pliocene transpressional activity related to the RSFZ is interpreted to reflect the transient coupling and collision between the NE Calabria and the Apulian margin (Massari & Prosser, 2013). Following theses phases, the studied area was affected by events of both contractional–transpressional (early Gelasian) and transtensional (late Gelasian onwards) associated to contraction relates to the deceleration of Calabrian Arc migration and the termination of Vavilov spreading, while subsequent tectonic subsidence corresponds to the opening of the Marsili back-arc basin and continued SE-ward migration of Calabria (e.g., Zecchin et al., 2020 and reference herein), reflected by NW-trending depocenter affecting Upper Pliocene to recent units (Fig. 3b, c).

The Petilia-Sosti Fault Zone

Tectonic activity along the PSSZ faults began in the Messinian with right-lateral transtension, mainly along the Fosso Umbro Fault (e.g., Massari & Prosser, 2013). This movement produced a N100–110° oblique sinistral fault system and a NE–ENE extensional system that bounded sub-basins filled with post-evaporitic shallow-water and continental siliciclastic deposits of the Petilia–Policastro Formation (Massari et al., 2010). In the latest Messinian, the Fosso Umbro Fault experienced right-lateral transpression, inverting previous extensional structures and generating local SW-verging thrusts (Massari & Prosser, 2013). This tectonic phase produced the upper Messinian Unconformity (UMU; e.g., Zecchin et al., 2013a,b, 2020), linked to contractional-transpressional tectonics, uplift, and subaerial exposure (e.g., Van Dijk, 1990, 1991; Massari et al., 2010; Muto et al., 2014). It likely reflects the initial collision and temporary coupling of the NE Calabrian Arc with the Apulian margin (e.g., Massari & Prosser, 2013). A subsequent extensional–transtensional phase caused dextral transtensional motion along the PSSZ faults, controlling the deposition of the upper Messinian Carvane Group and the Zanclean deep-marine Cavalieri Marl (e.g., Massari et al., 2010; Massari & Prosser, 2013; Zecchin et al., 2012, 2020). During the mid-Pliocene, renewed right-lateral transpression under NNE-directed shortening produced SW–SSW-verging thrusts and diapiric gypsum-bearing breccias along restraining bends of the Tacina, Fosso Umbro, and Marcedusa–Steccato faults (e.g., Massari et al., 2010; Massari & Prosser, 2013). This regional event uplifted the Crotone Basin and triggered the activation of the Crotone Megalandslide affecting part of the Messinian–Pleistocene succession of the basin (e.g., Minelli et al., 2013; Zecchin et al., 2018; Mangano et al., 2020).

Offshore, the Crotone Megalandslide forms a prominent structural high known as the Crotone Swell (e.g., Zecchin et al., 2018), which is bounded by the offshore continuation of the NW-trending Fosso Umbro and Marcedusa–Steccato faults. The Fosso Umbro Fault marks the SW limit of the Swell, juxtaposing the Messinian–Zanclean succession of the sliding Crotone Basin against Zanclean–Piacenzian deposits of the Squillace Gulf. The Marcedusa–Steccato Fault divides the megalandslide into two lobes with different deformation styles: the western lobe shows compressional structures typical of slide toes, whereas the eastern lobe displays gravity-driven extensional and compressional features (e.g., Zecchin et al., 2018). These faults guided the SE-ward movement of the entire landslide toward the Ionian Sea.

During the Early Pleistocene (~2.1 Ma), a phase of tectonic subsidence occurred (e.g., Capraro et al., 2006; Zecchin et al., 2012, 2020), coeval with the opening of the Marsili back-arc basin and a ~20° clockwise rotation and SE-ward migration of the Calabrian accretionary wedge (Sagnotti, 1992; Mattei et al., 2004). This event changed the PSSZ kinematics to left-lateral strike-slip, with sinistral transtension along the Tacina and Marcedusa–Steccato faults forming a subsiding trough (e.g., Massari & Prosser, 2013). A later, late Calabrian (1.2–1.1 Ma) transpressional phase caused sinistral compression along NW-trending faults of northern Calabria (Pollino Shear Zone), accompanied by reduced spreading in the Marsili basin (Nicolosi et al., 2006). Paleomagnetic data indicate counterclockwise rotation of different Crotone Basin blocks, separated by left-lateral motion along the Rossano–San Nicola and Fosso Umbro faults (e.g., Speranza et al., 2011; Massari & Prosser, 2013). In the mid-Pleistocene, transpression was replaced by dextral transtension along NNW–NW-trending en echelon faults of the PSSZ, forming rhomboidal pull-apart sub-basins (e.g., San Mauro, Foresta, Troiani, Marcedusa) bounded by NE–NNE extensional faults (Massari et al., 2010; Massari & Prosser, 2013). Recently, these sub-basins have been affected by NE–NNE listric normal faults accommodating SE-directed gravity sliding along Messinian evaporites within a NW–SE extensional regime (e.g., Massari & Prosser, 2013).

The Crotone Megalandslide as a large gravitational driver

The emplacement of the Crotone Megalandslide represents the most striking gravitational phenomenon recorded in the basin, affecting more than 1500 km^2 and involving up to 1.6 km of Messinian–Quaternary strata. The dual-domain architecture, with an updip extensional system of listric normal faults linked downslope to a compressional toe, testifies to a long-lived seaward gliding process above a Messinian evaporitic décollement. The onset of sliding during the Zanclean is documented by growth strata in the N Crotone area (e.g., Zecchin et al., 2018; Mangano et al., 2020 - Fig. 4a), and re-activated just after the Zanclean as proven by Zanclean chaotic geometry lying above a scar surface and sealed by Piacenzian/Gelasian sediments (Fig. 4b, d). This event was likely triggered by regional transpressional tectonics, with Messinian salt providing the necessary weak layer for detachment (Fig. 4b, c). The system underwent phases of quiescence during the Calabrian documented by a direct contact between the Zanclean and Calabrian units (Fig. 4c), and reactivation during the Middle Pleistocene, coeval with regional uplift of the Calabrian Arc (e.g., Gliozzi, 1987; Zecchin et al., 2004). The basal detachment surface cutting across the seafloor (Fig. 4d), together with present-day geodetic measurements, confirms that deformation is still active in both the coastal and offshore sectors of the Crotone Peninsula (Zecchin et al., 2018), highlighting the significance of this structure not only for tectono-stratigraphic reconstructions but also for marine geohazard assessment.

At a broader scale, the kinematics of the Crotone Megalandslide reflects the geodynamic evolution of the Central Mediterranean. Its initial paroxysmal phase between the latest Zanclean and early Piacenzian coincided with transpressional tectonics linked to the progressive collision and temporary coupling of the Calabrian Arc with the Apulian margin (e.g., Massari & Prosser, 2018; Mangano et al., 2020; Zecchin et al., 2020). The subsequent slowdown during the Gelasian is consistent with a phase of subsidence associated with the opening of the Marsili back-arc basin, which reduced the regional slope and temporarily stabilised the system (e.g., Massari & Prosser, 2013; Mangano et al., 2020; Zecchin et al., 2020). The Middle Pleistocene reactivation corresponds to renewed uplift of the Calabrian Arc, interpreted as the surface expression of slab retreat, slab break-off, or convective removal processes affecting the subducted Ionian lithosphere. These correlations indicate that the evolution of the Crotone Megalandslide is not only a local gravitational response but also a direct recorder of first-order geodynamic reorganisations in the Central Mediterranean realm.

Petroleum System Evolution

The petroleum system of the Crotone Basin is the direct outcome of its complex tectono-stratigraphic history, in which successive phases of contraction, transtension and gravitational collapse established the conditions for hydrocarbon generation, migration and entrapment. Each of the key elements—source, reservoir, trap and seal—owes its effectiveness to the structural framework imposed by the Rossano–San Nicola Shear Zone (RSFZ) and the broader geodynamic evolution of the Central Mediterranean.

Source rock maturation

The principal source intervals consist of Triassic–Lower Jurassic organic-rich red beds and Aptian–Cenomanian shales deposited during oceanic anoxic events (e.g., Critelli, 1999). Burial history models demonstrate that deepening of these strata associated with Miocene–Pliocene fault activity and enhanced sedimentation rates during Zanclean episodes pushed these units into the gas generation window (Fig. 5a). The emplacement of thick Pliocene mass-transport deposits enhanced overburden and heat flow, prolonging source rock maturation and sustaining gas generation to the present (Fig. 5a).

Reservoir, seal and trap development

Proven Serravallian and Tortonian reservoirs were later deformed within the compressional domain of the Crotone Megalandslide, where structural thickening, folding, and uplift imparted the present-day anticlinal geometries. These deformation patterns, triggered by slide kinematics and mediated by the underlying Messinian evaporites, enhanced reservoir compartmentalisation and created the structural closures observed today. In this context, the compressional sector of the megalandslide plays a fundamental role in establishing the trap–seal configuration by embedding both the reservoir units and the overlying evaporitic and Plio–Pleistocene silty successions. The combined effect of compressional folding and the regional evaporite–mudstone sealing system ultimately ensured efficient hydrocarbon entrapment within both Serravallian and Tortonian reservoirs. (e.g., Bonardi et al., 2001; Mattei et al., 2002; Zecchin et al., 2020).

CONCLUSIONS

The Crotone Basin represents a key geological province in the Central Mediterranean, where tectonic, gravitational and stratigraphic processes interacted to shape its evolution, making it both a natural laboratory and the most productive gas district in Italy.

- The RSFZ exerted a first-order control on the tectono-stratigraphic evolution of the Crotone Basin, governing the emplacement of the Cariati Nappe, the differentiation between the Cirò and Crotone sectors, and the initiation of large-scale gravitational collapse through successive transpressional and transtensional phases from the late Tortonian onward.
- The recognition of a NW-oriented positive flower structure, including Faults 1 to 4, provides a unifying model linking onshore and offshore deformation, demonstrating that RSFZ activity drove alternating uplift and subsidence and modulated sediment distribution throughout the basin's evolution. The PSFZ experienced alternating right- and left-lateral movements since the Messinian, reflecting shifts between transtensional and transpressional regimes. Right-lateral motion dominated from the Messinian to the Pliocene, controlling basin evolution and the Crotone Megalandslide, while in the Early Pleistocene, kinematics switched to left-lateral due to regional rotation and back-arc opening. In the mid-Pleistocene, renewed dextral transtension formed NW-trending pull-apart basins later affected by gravity-driven deformation.
- The Crotone Megalandslide represents a basin-scale gravitational collapse (≈1500 km^2) initiated during the Zanclean along a Messinian evaporitic décollement, whose inception is connected to the RSFZ through Fault 2, reflecting tectonic–gravitational coupling.
- Its evolution mirrors major geodynamic reorganisations of the Central Mediterranean: initiation during late Zanclean–Piacenzian transpression linked to Calabrian–Apulian coupling, quiescence during Gelasian subsidence (Marsili back-arc opening), and reactivation during Middle Pleistocene uplift of the Calabrian Arc.
- The structural framework imposed by the RSFZ and subsequent gravitational deformation controlled source maturation, reservoir development, and trap formation, establishing an integrated tectono-stratigraphic petroleum system.
- Gas generation from Mesozoic source rocks was enhanced by Miocene–Pliocene burial and overburden from mass-transport deposits, while Serravallian–Tortonian reservoir sandstones were incorporated into compressional domains of the Megalandslide, where folding and evaporitic seals created effective structural traps.

ELECTRONIC SUPPLEMENTARY MATERIAL

This article contains electronic supplementary material which is available to authorised users.

ACKNOWLEDGEMENTS

This work has been supported by ENI Natural Resources. Special thanks are due to ENI for making these datasets available for scientific use. Also, we would like to acknowledge Schlumberger for providing Petrel license.

REFERENCES

Amodio Morelli L., Bonardi G., Colonna V., Dietrich D., Giunta G., Ippolito F., Liguori V., Lorenzoni S., Paglionico A., Perrone V., Picarretta G., Russo M., Scandone P., Zanettin-Lorenzoni E. & Zuppetta A. (1976) - L'Arco calabro–peloritano nell'orogene appenninico–maghrebide. Mem. Soc. Geol. It., 17, 1-60.

Barone M., Dominici R., Muto F. & Critelli S. (2008) - Detrital modes in a Late Miocene wedge-top basin, northeastern Calabria, Italy: compositional record of wedge top partitioning. J. Sediment. Res., 78, 693-711.

Bonardi G., Cavazza W., Perrone V. & Rossi S. (2001) - Calabria-Peloritani terrane and northern Ionian sea. In: Anatomy of an Orogen: the Apennines and Adjacent Mediterranean Basins. Springer, Dordrecht, pp. 287-306.

Borrelli M., Perri E., Avagliano D., Coraggio F. & Critelli S. (2022) - Paleogeographic and sedimentary evolution of north calabrian basins during the messinian salinity crisis (south Italy). Mar. Petrol. Geol., 141, 105726.

Borrelli M., Perri E., Critelli S. & Gindre-Chanu L. (2021) - The onset of the Messinian Salinity Crisis in the central Mediterranean recorded by pre-salt carbonate/evaporite deposition. Sedimentology, 68, 1159-1197, https://doi.org/10.1111/sed.12824.

Butler R.W.H., Mazzoli S., Corrado S., De Donatis M., Di Bucci D., Gambini R., Naso G., Nicolai C., Scrocca D., Shiner P. & Zucconi V. (2004) - Applying thick-skinned tectonic model to the Apennine thrust belt of Italy: limitations and implications. In: McClay, K.R. (Ed.), Thrust Tectonics and Hydrocarbon System. AAPG Memoir, 82, 647-667.

Campilongo G., Campilongo E., Catanzariti F., Muto F., Ponte M. & Critelli S. (2022) - Subsidence analysis by mean of DeGloT software: application to the key-case of the miocene-quaternary Crotone Basin (Calabria, S. Italy). Mar. Petrol. Geol., 146, 10596 https://doi.org/10.1016/j.marpetgeo.2022.105964.

Ceramicola, S., Cova A., Forlin E., Markezic N., Mangano G., Civile D., Zecchin M., Fanucci F., Colizza E., Corselli C., Morelli D., Savini A., Caburlotto A., Candoni O., Coste M., Cotterle D., Critelli S., Cuppari A., Depont M., Dominici R., Facchin L., Gordini E., Locatelli M., Muto F., Praegi D., Romeo R. & Tessarolo C. (2024) - Geohazard features of the Ionian Calabrian margin. J. Maps, 20(1), 2349785.

Ceramicola S., Praeg D., Coste M., Forlin E., Cova A., Colizza E. & Critelli S. (2014) - Submarine mass-movements along the slopes of the active Ionian continental margins and thier consequences for marine geohazards (Mediterranean Sea). In: Krastel, S., et al. (Eds.), Submarine Mass Movements and Thier Consequences, Advances in Natural and Technological Hazards Research 37. Springer International Publishing Switzerland, pp. 295-306.

Cifelli F., Rossetti F. & Mattei M. (2007) - The architecture of brittle postorogenic extension: results from an integrated structural and paleomagnetic study in north Calabria (southern Italy). Geol. Soc. Am. Bull., 119, 221-239.

Civile D., Zecchin M., Tosi L., Da Lio C., Muto F., Sandron D., Affatato A., Accettella D. & Mangano G. (2022) - The Petilia-Sosti Shear Zone (Calabrian Arc, southern Italy): an onshore-offshore regional active structure. Mar. Petrol. Geol., 141, 105693.

Criniti S., Borrelli M., Falsetta E., Civitelli M., Pugliese E. & Arcuri N. (2023) - Sandstone petrology of the Crotone basin, Calabria (Italy) from well cores. Rend. Online Soc. Geol. It., 59, 64-70, https://doi.org/10.3301/ROL.2023.10.

Critelli S. (1993) - Sandstone detrital modes in the Paleogene Liguride Complex, accretionary wedge of the southern Apennines (Italy). J. Sedim. Res., 63 (3), 464-476.

Critelli S. (1999) - The interplay of lithospheric flexure and thrust accomodation in forming stratigraphic sequences in the southern Apennines foreland basin system. Italy. Rend. Lincei, 10(4), 257-326.

Critelli S. (2018) - Provenance of Mesozoic to Cenozoic Circum-Mediterranean sandstones in relation to tectonic setting. Earth Sci. Rev., 185, 624-648.

Critelli S. & Martín-Martín M. (2022) - Provenance, Paleogeographic and paleotectonic interpretations of Oligocene-Lower Miocene sandstones of the western-central Mediterranean region: a review, in the evolution of the Tethyan orogenic belt and, related mantle dynamics and ore deposits. J. Asian Earth Sci., Spec. Iss. X, 8, 100124, https://doi.org/10.1016/j.jaesx.2022.100124.

Critelli S. & Martín-Martín M. (2024) - History of western Tethys Ocean and the birth of the circum-Mediterranean orogeny as reflected by source-to-sink relations. Int. Geol. Rev., 66(2), 505-515, https://doi.org/10.1080/00206814.2023.2280787.

Critelli S., Muto F., Zecchin M., Tripodi V., Ceramicola S., Ramella R. & Roda C. (2014) - Note Illustrative Della Carta Geologica d'Italia Alla Scala 1:50.000. F. 562 "Ciro", ISPRA - Servizio Geologico d'Italia, p. 148.

Faccenna C., Becker T.W., Pio Lucente F., Jolivet L. & Rossetti F. (2001) - History of subduction and back-arc extension in the Central Mediterranean. Geophys. J. Int., 145, 809-820.

Faccenna C., Piromallo C., Crespo-Blanc A., Jolivet L. & Rossetti F. (2004) - Lateral slab deformation and the origin of the western Mediterranean arcs. Tectonics, 23, TC1012, https://doi.org/10.1029/2002TC001488.

Falsetta E., Bullejos M., Critelli S. & Martìn-Martìn M. (2024) - 3D modeling of the stratigraphic and structural architecture of the Crotone basin (southern Italy) using machine learning with Python. Mar. Petrol. Geol., 164, 106825.

Falsetta E., Bullejos M., Martín-Martín M. & Critelli S. (2024) - The Messinian evaporite succession of the Crotone Basin, Southern Italy: a Python 3D modelling. Rend. Online Soc. Geol. It., 67-73.

Gliozzi E. (1987) - I terrazzi del Pleistocene superiore della Penisola di Crotone (Calabria). Geol. Rom. 26, 17-79.

Gueguen E., Doglioni C. & Fernandez M. (1998) - On the post-25 Ma geodynamic evolution of the western Mediterranean. Tectonophysics, 298(1-3), 259-269.

Iannace A., Vitale S., D'Errico M., Mazzoli S., Di Staso A., Macaione E., Messina A., Reddy S.M., Somma V., Zamparelli V., Zattin M. & Bonardi G. (2007) - The carbonate tectonic units of northern Calabria (Italy): a record of Apulian palaeomargin evolution and Miocene convergence, continental crust subduction, and exhumation of HP–LT rocks. J. Geol. Soc., 164(6), 1165-1186.

Malinverno A. & Ryan W.B. (1986) - Extension in the Tyrrhenian Sea and shortening in the Apennines as result of arc migration driven by sinking of the lithosphere. Tectonics, 5(2), 227-245.

Mangano G. (2022b) - Mid-Miocene to Recent Tectono-Stratigraphic Evolution of the Crotone Basin (Southern Italy): Impact on Gravitational Collapse and Seabed Morphology. PhD Thesis. University of Calabria, Italy.

Mangano G., Alves T.M., Zecchin M., Civile D. & Critelli S. (2023a) - The Rossano–san Nicola Fault Zone evolution impacts the burial and maturation histories of the Crotone Basin, Calabrian Arc, Italy. Petrol. Geosci., 29(2), petgeo2022-p2085.

Mangano G., Ceramicola S., Alves T.M., Zecchin M., Civile D., Del Ben A. & Critelli S. (2023b) - A new large-scale gravitational complex discovered in the Gulf of Squillace (central Mediterranean): tectonic implications. Scientific Reports, 13(1), 14695.

Mangano G., Ceramicola S., Zecchin M., Brancatelli G. & Critelli S. (2021) - Geohazard-related geomorphic features in the crotone-spartivento basin (southern Italy): an expression of Calabrian Arc kinematics. In: Offshore Mediterranean Conference and Exhibition. OMC, OMC-2021.

Mangano G., Zecchin M., Civile D. & Critelli S. (2024) - Tectonic evolution of the Crotone Basin (central Mediterranean): The important role of two strike-slip fault zones. Mar. Petrol. Geol., 163, 106769.

Mangano G., Zecchin M. & Civile D. (2020) - Large-scale gravity-driven phenomena in the Crotone Basin. southern Italy. Mar. Petrol. Geol., 117, 104386.

Mangano G., Zecchin M., Civile D., Ceramicola S., Donato A., Muto F., Tripodi V. & Critelli S. (2022a) - Mid-miocene to recent tectonic evolution of the punta stilo swell (calabrian arc, southern Italy): an effect of calabrian arc migration. Mar. Geol., 448, 106810.

Martín-Martín M., Perri F. & Critelli S. (2023) - Cenozoic detrital suites from the Internal Betic-Rif Cordilleras (S Spain and N Morocco): implications for paleogeography and paleotectonics. Earth Sci. Rev., 243, 104498, https://doi.org/10.1016/j.

Massari F. & Prosser G. (2013) - Late Cenozoic tectono-stratigraphic sequences of the Crotone Basin: insights on the geodynamic history of the Calabrian arc and Tyrrhenian Sea. Basin Res., 25(1), 26-51.

Mattei M., Cifelli F. & D'Agostino N. (2007) - The evolution of the Calabrian Arc: evidence from paleomagnetic and GPS observations. Earth Planet Sci. Lett., 263(3-4), 259-274.

Mattei M., Cipollari P., Cosentino D., Argentieri A., Rossetti F., Speranza F. & Di Bella L. (2002) - The Miocene tectono-sedimentary evolution of the southern Tyrrhenian Sea: stratigraphy, structural and palaeomagnetic data from the on-shore Amantea basin (Calabrian Arc, Italy). Basin Res., 14, 147-168, https://doi.org/10.1046/j.1365-2117.2002.00173.x.

Minelli L., Billi A., Faccenna C., Gervasi A., Guerra I., Orecchio B. & Speranza G. (2013) - Discovery of a gliding salt-detached megaslide, Calabria, Ionian Sea. Italy. Geophys. Res. Lett., 40, 4220-4224.

Muto F., Spina V., Tripodi V., Critelli S. & Roda C. (2014) - Neogene tectonostratigraphic evolution of allochthonous terranes in the eastern Calabrian foreland (southern Italy). Italian J. Geosci. 133, 455-473.

Muto F., Tripodi V., Chiarella D., Lucà F. & Critelli S. (2017) - Tectono-stratigraphic architecture of the Ionian piedmont between the Arso Stream and Nicà River catchments (Calabria, Southern Italy). J. Maps, 13(2), 332-341.

Patacca E., Sartori R. & Scandone P. (1990) - Tyrrhenian basin and Apenninic arcs: kinematic relations since late Tortonian times. Mem. Soc. Geol. It., 45, 425-451.

Rosenbaum G. & Lister G.S. (2004) - Neogene and quaternary rollback evolution of the Tyrrhenian Sea, the appennines, and the Sicilian Maghrebides. Tectonicas, 23, 1013.

Roveri M., Bernasconi A., Rossi M.E., Visentin C. & Spencer A.M. (1992) - Sedimentary evolution of the Luna Field area, Calabria, southern Italy. In: Spencer, A. (ed.) Generation, Accumulation and Production of Europe's Hydrocarbons II. Eur. Ass. Petrol. Geosci. Spec. Publ., 2, 217-224.

Sartori R. (1990) - The main results of ODP Leg 107 in the frame of Neogene to Recent geology of peri-Tyrrhenian areas. In: Proc. Ocean Drill. Progr. Sci. Res., 107, 715-730.

Tansi C., Muto F., Critelli S. & Iovine G. (2007) - Neogene-Quaternary strike-slip tectonics in the central Calabrian Arc (southern Italy). J. Geodyn., 43, 393-414.

Tripodi V., Muto F., Brutto F., Perri F. & Critelli S. (2018) - Neogene-Quaternary evolution of the forearc and backarc regions between the Serre and Aspromonte Massifs, Calabria (southern Italy). Mar. Petrol. Geol. 95, 328-343, https://doi.org/10.1016/j.marpetgeo.2018.03.028.

Tripodi V., Muto F. & Critelli S. (2013) - Structural style and tectono-stratigraphic evolution of the neogene-quaternary siderno basin, southern Calabrian Arc. Italy. Int. Geol. Rev., 55, 468-481.

Van Dijk J. & Okkes M. (1991) - Neogene tectonostratigraphy and kinematics of Calabrian basins; implications for the geodynamics of the Central Mediterranean. Tectonophysics, 196(1-2), 23-60.

Van Dijk J.P. (2000) - Late Neogene kinematics of intra-arc oblique shear zones: the petilia-rizzuto Fault Zone (Calabrian Arc, central mediterranean). Tectonics, 13(5), 1201-1230.

Van Dijk J.P., Bello M., Brancaleoni G.P., Cantarella G., Costa V., Frixa A., Golfetto F., Merlini S., Riva M., Torricelli S., Toscano C. & Zerilli A. (2000) - A regional structural model for the northern sector of the Calabrian Arc (southern Italy). Tectonophysics, 324(4), 267-320.

Zecchin M., Accaino F., Ceramicola S., Civile D., Critelli S., Da Lio C., Mangano G., Prosser G., Teatini P. & Tosi L. (2018) - The Crotone Megalandslide, southern Italy: architecture, timing and tectonic control. Sci. Rep., 8(1), 1-11.

Zecchin M., Caffau M., Civile D., Critelli S., Di Stefano A., Maniscalco R., Muto F., Sturiale G. & Roda C. (2012) - The Plio-Pleistocene evolution of the Crotone Basin (southern Italy): interplay between sedimentation, tectonics and eustasy in the frame of Calabrian Arc migration. Earth Sci. Rev., 115(4), 273-303.

Zecchin M., Caffau M., Di Stefano A., Maniscalco R., Lenaz D., Civile D., Muto F. & Critelli S. (2013b) - The Messinian succession of the Crotone Basin (southern Italy) II: facies architecture and stratal surfaces across the Miocene-Pliocene boundary. Mar. Petrol. Geol., 48, 474-492.

Zecchin M., Civile D., Caffau M., Critelli S., Muto F., Mangano G. & Ceramicola S. (2020) - Sedimentary evolution of the Neogene-Quaternary Crotone Basin (southern Italy) and relationships with large-scale tectonics: a sequence stratigraphic approach. Mar. Petrol. Geol., 117, 104381.

Zecchin M., Civile D., Caffau M., Muto F., Di Stefano A., Maniscalco R. & Critelli S. (2013a) - The Messinian succession of the Crotone Basin (southern Italy) I: stratigraphic architecture reconstructed by seismic and well data. Mar. Petrol. Geol., 48, 455-473.

Zecchin M., Nalin R. & Roda C. (2004) - Raised Pleistocene marine terraces of the Crotone peninsula (Calabria, southern Italy): facies analysis and organisation of their deposits. Sediment. Geol., 172 (1-2), 165-185.

Zecchin M., Praeg D., Ceramicola S. & Muto F. (2015) - Onshore to offshore correlation of regional unconformities in the Plio-Pleistocene sedimentary successions of the Calabrian Arc (central Mediterranean). Earth Sci. Rev., 142, 60-78