STRUCTURAL SETTING OF PETROLEUM EXPLORATION PLAYS IN ITALY

CASERO P.
Consultant, via Enrico di San Martino Valperga 57 - Rome Italy email caseropiero@libero.it

ABSTRACT: A vast majority of the Italian petroleum resources is genetically linked to the flexuration of the African continental margin. For instance either the source rocks contained in the pre flexural epicontinental series reached the maturity window during the flexural subsidence or, alternatively the flexural accommodating flysch series themselves generated and stored the hydrocarbons.

In this paper the petroleum exploration plays of Italy are tentatively classified according to their distribution in individual flexural belts.

A concise description of the geological evolution, followed by the analysis of the most significant fields and related petroleum plays, is provided for each hydrocarbons prone belt, starting from the inner zones outwards.

Plays set in undeformed or poorly deformed foreland areas are also considered. Conclusions on the main petroleum exploration concepts in Italy are finally proposed.

INTRODUCTION

Since the 1950s and increasingly in the last fifteen years, many papers concerning hydrocarbons exploration in Italy have been published. Some of them deal with the entire country (i.e. PIERI & MATTAVELLI, 1986), some others with an individual basin (i.e. NOVELLI *et alii,* 1987), a specific play (i.e. SAITTA *et alii,* 1979), or a single field (i.e. ERRICO *et alii,* 1980). Also the way to consider the matter can vary; some authors propose a classic historical and/or geological review; others, more ambitiously try to discuss the setting of the fields within the geodynamic scenario of the Central Mediterranean area. Numerous papers propose a more specialistic approach based on geochemical concepts (i.e. the correlation of oil/source rock signature), or on mathematical modelling (i.e. thermal/hydraulic conditions), or on sedimentologic criteria. Finally, the more recent works (i.e. ANELLI *et alii,* 1996; LINDQUIST, 1999) embraced the notion of Petroleum System (PS), ie, defining the conditions (e.g reservoir, source rock, maturity, seal, etc.) that must coexist to generate a petroleum accumulation. The notion is obviously a good one, if applied in a genetic sense, which is the sense of the geological evolution of a given area. Otherwise the risk is, as it is often the case, to focus on local field characters without understanding why it is there. In addition, it is quite common to identify a PS with a source rock (i.e. Burano Petroleum System). This simplification cannot be accepted as fields referring to different PS can have the same source rock.

In general the origin of biogenic gas fields is obvious. Often, thanks to the modern techniques (see above) the genesis of oil or condensate fields is also well understood. Nevertheless, in many cases only more or less doubtful hypotheses can be proposed on the source rock distribution and age.

The present paper tries to avoid, as far as possible, to repeat notions already expressed in previous works. It is addressed to general geologists with the aim to provide them with a picture of the regional geological setting of the most significant petroleum fields of Italy, proposing a genetic interpretation of these petroleum occurrencies (i.e. the geological relationships of the source rocks vs. the reservoir/trap). This paper is also the last chapter of a book, that has already helped the reader to become familiar with the regional geological background.

REGIONAL GEOLOGICAL EVOLUTION – SUMMARY

We shall not describe in detail the complex geological evolution of the country, but instead propose a summary for a better understanding of the petroleum geology aspects.

The petroleum provinces of Italy, apart of the still debated Luna field (and its satellites), belong to the North African continental margin. Throughout the Mesozoic and the lower Paleogene the epicontinental sedimentation was predominantly carbonatic resulting from a complex paleogeographic configuration of indenting deeper water basins and open shallow platforms. Inside the latter domains intra-shelf euxinic basins developed, mainly controlled by extensional faulting and climatic conditions.

In general the sedimentation was more continuous, but with low accretion rate, in the deeper waters domains and more discontinuous, with long emersion/erosion periods (Albian, uppermost Cretaceous, Paleogene), and much high rates in the carbonate shelf domains.

During Mesozoic times both extensional tectonic phases (i.e. Middle Liassic) and compressional paleo-inversions (i.e. Lowermost Cretaceous) occurred. Starting from the Middle Eocene onwards (MERLINI *et alii,* 2001) the African continental margin started to be involved in the Alpine orogeny. The flexuration of the margin started from the most external areas and progressed onwards, during the geological times, following sub parallel belts (foredeeps) towards the continent.

The space issued from each flexural phase was accommodated either by the input of large quantities of terrigenous sediments, derived from the erosion of the incipient inverted margin (orogen and former foredeep), leading to the sedimentation of a flysch wedge, or by the sub marine gravitational emplacement of large rock masses detached from the inverted margin sequence (allochthonous nappes). Both phenomena can occur in different segments of the same flexural belt. This is obviously an extremely simplified model. At times the onward displacement of the flexuration is clear and eventually enhanced by the thrusting of the previous belt series (i.e. the Tortonian flexural domain onto the Messinian one).In other cases there are lateral superpositions of depocenters inside the same flexural domain.

Large shallow water sedimentary basins, coeval to each flexural phase, can settle in the syncline depressions on top of the incipient inverted belts (thrust top basins), participating in the final tectonic transport. Behind the orogenic prism, extensional basins can cover large sunken parts of the chain. Today geometry of each individual flexural belt is not easy to be reconstructed, mainly because of the difficulty in dating precisely flysch sediments and because of the post flexural tectonic deformation. In addition, it should be noted that in the Literature the same formation names are often applied to both flexural accommodating and coeval thrust top basin series.

The flexuration is of course not perfectly cylindrical: the width of each belt, in particular, seems to be variable along the belt itself. There is no doubt that the overall rheology of the pre flexural substratum, particularly carbonate shelves vs. deeper platforms, played a dominant role on the hinge line set as well as on the width and the rate of flexuration of each belt. Whatsoever, available data allow to identify and tentatively draw a map of the present day shape of the different flexural belts, from the Lower Miocene to the Middle Upper Pliocene (Plate 1). This paper will not deal with the geodynamic evolution aspects, some of which are still unresolved; nevertheless some observations relevant to the petroleum exploration can be made on this map.

The width of the Messinian and Pliocene flexural belts in the Central and Southern Apennines is greater than in the Northern ones, reflecting either its initial width or different post flexural tectonic shortening. There is no post-Messinian flexuration west of Sicily, in the Sicily channel, and NW of the Casteggio Line, in the westernmost Po Plain. As a consequence, the Apennines can be defined as the segment of the North African margin that underwent the superposition of the Pliocene flexuration/inversion phases onto the Paleogene-Miocene ones, the latter being in common with the Magrebid, Southern Alps and Dinaric chains. Assuming that the flexural belts had originally a continuous and more or less linear trend, they appear to be today tectonically distorted and dissected in some main segments thanks to major transcurrent fault lines.

The flexural history is of great importance with respect to the hydrocarbons generation and accumulation, since: a) about three quarters of the Italian biogenic gas is related to Pliocene foredeep series, b) most of the thermogenic gas and condensate is probably issued from Miocene flysch series, and c) in many oil accumulations the source rock series entered the maturity window during the flexural subsidence**.**

PETROLEUM EXPLORATION PLAYS

Moving from the most internal zones, through the different flexural belts, up to the foreland, the general geological setting will be described first. The most significant petroleum fields belonging to each belt will be then analysed in order to define their play characters. The fields have been selected not necessarily for their economic importance but rather for their geological interest and also on the basis of the quality of the available information (mostly published in the Literature by AGIP geologists), which is often very variable.

The description and the proposed interpretation will be supported by a common stratigraphic chart (Fig. 1) and by dedicated cross sections. These are either geological cross sections or, more frequently, seismic line drawings, mostly issued (and more or less modified) from the Literature. The sections are as long as possible to show the regional setting of the plays. They are assembled in Plates to facilitate the correlation. No recoverable reserves items are provided, for this matter the reader should refer to the relevant literature.

OUTERN CALABRIA MARGIN (OLIGOCENE FLEXURAL BELT?)

General geological setting

The Crotone terrigenous basin extends, to the east of the Calabride crystalline nappe, both on- and off-shore, along the Ionian coast of Calabria (Plate 1). Serravallian coarse grained, deltaic-to-shallow marine series (S. Nicola conglomerates) transgressively onlap, towards the east, a thick Eocene-Oligocene quartzarenitic flysch sequence.

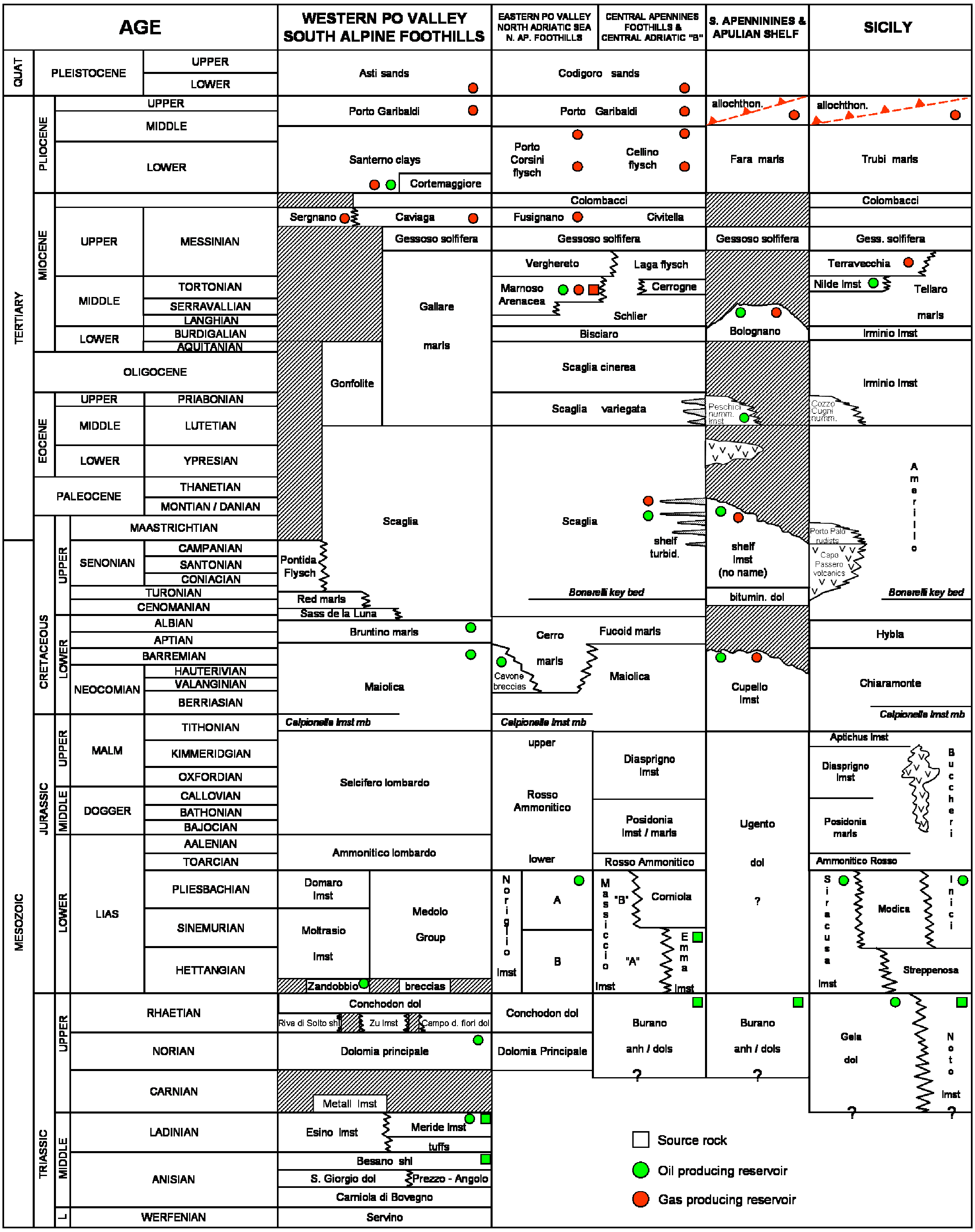


Fig. 1 - Stratigraphic chart of the Italian producing regions

The conglomerates are paraconformably covered by marine, marly/sandy, Tortonian series (Ponda Formation). Affected by late orogenic tectonics (eastward thrust-folding according to ROVERI *et alii,* 1992), these series are more and more eroded toward the east, where they almost disappear due to the combination of onlapping and erosion. The erosional surface in turn transgressed, always from the west, by late Messinian evaporites and lower Pliocene pelagic clays. In connection with the recent Calabria up-lift the Pliocene series, detached from the evaporitic substratum, are locally affected by eastward gravitational mass-slides.

Exploration plays

The important Luna gas fields, and its satellites, were discovered within this complex geological setting. They are the largest gas pools outside the Po Plain and the Northern Adriatic. There are different producing pools, the most important of which is by far the thermogenic dry gas ones (Luna). Issued from an unknown, possibly Tertiary source, situated at great depth, in excess to 5000m (SCHLUMBERGER, 1987) the gas migrated laterally/updip through the porous conglomerate/sandy S. Nicola Formation to be trapped at the top of truncated beds at the crest of the thrust fold, sealed by either the Tortonian marls or Pliocene clays. Minor accumulations of thermal and biogenic gas were also found in sandstone interbeds of the Ponda marls or in lower Pliocene sandy *levels.*

In the recent past an important exploration effort was made, particularly by Agip in the deeper water belt, with the acquisition of a large amount of seismic data and the drilling of several wildcats. No commercial discovery is reported. Nevertheless, one can say that this is one of the very few areas in Italy still poorly explored and evaluated.

INNER EXTENSIONAL BASINS

General geological setting

In connection with the opening of the Tyrrhenian sea, starting from early Miocene, a number of local extensional basins settled on top of different Apennine units along the western margin of the chain (e.g. Viareggio, low Volturno and Paola basins). Most of these basins are located along the coast and in the nearby narrow continental shelf (Plate 1). The age of opening is progressively youngering toward the south. Common characters to the basins are a general westward tilted half-graben setting, westward facies variation from continental/lacustrine to shallow marine, presence of unconformities associated with the on-going Apennine tectonism.

The amount of extension and subsidence and consequently the nature of the sedimentary records are variable.

Exploration plays

Stated in advance that the exploration is quite limited, the sole economic discovery so far is the small Tombolo gas field located in the eastern onshore part of the Viareggio basin. The field produces biogenic gas from several levels of lower Pliocene shallow marine sands, between 1300 and 1700m approx. The trap is a combination of onlap and gentle fold, associated with a main unconformity (SCHLUMBERGER, 1987).

This play is of some potential interest but due to its complexity, the small size of the exploration objects and the rapidly increasing water depth, this interest is probably confined to the onland part of the basins (with the exception perhaps of the Paola basin where the sedimentary record is important).

OLIGOCENE-EARLY MIOCENE FLEXURAL BELT (WESTERN PO PLAIN - SOUTH ALPINE DOMAIN)

General geological setting

The present day buried western South Alpine foothills belt, running roughly from the Garda lake to Vercelli, corresponds to the Oligocene-Lower Miocene flexural belt accommodated by the sedimentation of the thick series of the Gonfolite flysch (Plate 1). Its pre-flexural Mesozoic- Paleogenic substratum is characterized by a Middle Triassic carbonate depositional system articulated in shelf and intra-shelf euxinic basins (FANTONI *et alii,* 2002). During the Jurassic and Cretaceous, extensional tectonism, typically expressed by tilted blocks bounded by listric faults, produced unconformities and strong isopach variations, while compressional events caused limited inversions. Starting from the Middle Miocene the foredeep commenced to be inverted, resulting in a south-vergent thrust fold belt. Coeval thrust top basins developed in syncline trends. In the inner part of the belt a generalized decollement of silici-clastic series from their carbonate substratum occurred. The deformation propagated southward during the Early Messinian, being again accompanied by syncline/erosional thrust top basins infilling.

During the Late Messinian and the Early Pliocene the combination of late tectonic events and relative sea-level changes caused phases of emersions/erosions (canyons, slump scars) and transgression/regression of fluvio-deltaic systems, with deposition of high energy conglomerations and sands. FANTONI *et alii,* 2001, recognize in this time interval 4 sequences at least.

Starting from the Lower Pliocene the Western South-Alpine foothills belt was implicated in the outermost Apenninic flexuration with a regional northward marine trangression. During the Middle Pliocene a last south-vergent tectonic pulse was recorded in a limited sector (Ripalta-Bordolano trend).

Exploration plays

Within the above described geological setting two main families of hydrocarbons accumulations were identified: 1) deep-seated oil, gas and condensate in the Mesozoic pre-flexural substratum, involved in the South Alpine thrust fold belt (e.g.. Malossa field) and 2) shallower gas in the late orogenic clastics.

The major Malossa field produced $30x10^6$ bbls of condensate and more than $5x10^9$ stm^3 of gas (FANTONI *et alii*, 2002).

The main reservoir is made up of Lower Liassic and Upper Triassic fractured shelf dolomites (Zandobbio and Dolomia Principale). The seal is provided by Jurassic pelagic mudstones. The trap (Plate 2b) is a deep seated (reservoir at 5300m), clearly polyphased, thrust fold. It is part of an asymmetric Late Miocene N/NW-S/SE trending and SW vergent thrust fold (ERRICO *et alii,* 1980). On the other sides the structure is bounded by variously oriented normal faults of Uppermost Jurassic age (MATTAVELLI & MARGARUCCI,1992). The structure is interpreted as originated by the compressive Neogene reactivation of part of the Jurassic rift faults. Yet the published seismic data (CHIERICI *et alii,* 1979) and the age of the eastern faults (Latemost Jurassic v. Lower Jurassic rift phase) suggest rather a pale-oinverted structure reactivated along its south-western flank in the South Alpine phase (Plate 2b). Geochemical analyses have shown that the source rock of the Malossa gas-condensate is represented by the Rhaetian Argilliti di Riva di Solto Formation (RIVA *et alii,* 1986). Hydrocarbon generation occurred at a depth of over 7000m (CHIARAMONTE & NOVELLI, 1986) that was reached during to the Oligocene-Early Miocene flexuration. The kitchen was in the north-east (the source rock is absent in the Malossa area) and the migration was lateral up-dip. Minor oil accumulations (Seregna, Canonica, S. Bartolomeo) were found in a similar geological setting.

A good number of small and average gas accumulations (Sergnano, Brugherio, Romanengo etc.) was discovered along a curved belt east of Milan, roughly fitting with the South-Alpine foothills folds. The gas, of biogenic origin, is reservoired in Upper Messinian, late orogenic conglomerates and sands (Sergnano Formation).

The traps (Plate 2c) are mainly a combination of sedimentary and erosional features, subsequently (Middle Pliocene) involved in the late orogenic gentle folding. Other biogenic gas accumulations (Ripalta, Bordolano, Caviaga, etc.) were found further to the south in the most external South Alpine front. The reservoir is made up of Upper Messinian sands (Caviaga sands), a distal equivalent of the Sergnano gravels.

The traps are fine thrust folds, resulting from a Late Pliocene reactivation of Messinian structures (Plate 2c). A special case is the Cornegliano field where the southernmost Alpine fold has been "captured" and reinvolved in the outernmost Apenninic phase resulting in an diachronous double vergence structure.

The Villafortuna-Trecate field is a light oil (43°API) and gas accumulation of major size (about $200x10^6$bbls and $2x10^9$ stm^3). It is clearly set in a South Alpine thrust and fold domain but we shall see that probably its genesis is not primarily controlled by the Oligocene-Lower Miocene flexurations.

The trap is the culmination of a huge, deep seated, double vergence compressional feature, trending SW-NE, bounded by a high angle/high displacement ramp system to the north-west and by less important reverse faults on the south-eastern flank (Plate 2a). This Alpine compressional structure involves previous Mesozoic extensional features of different sizes (FANTONI *et alii,* 2002). As a matter of fact, the whole trend appears to be issued from a mega structural inversion. Yet in the geological cross-section from FANTONI *et alii* the Jurassic section thins considerably or even disappears on the high. This would probably imply a paleo- inversion phase and a subsequent erosion. However, the main structural expression is a huge Alpine triangle feature with opposite deep and shallow ramps. There are two main reservoirs both made by dolomitized shelf carbonates; the lower one is Anisian (Monte San Giorgio Dolomite) and is sealed by tuffaceous shales (Besano Formation). The upper reservoir consists of three Upper Triassic-Lower Liassic units (Dolomia principale, Campo dei Fiori Limestones and Conchodon Dolomite). The shaly mudstones of the Medolo Group provide the seal (FANTONI *et alii,* 2002).

The hydrocarbons derived from Middle Triassic source rocks (Besano shales and Meride Limestones), present in the structure. According to MATTAVELLI & NOVELLI, 1987, the maturity was attained during Plio-Pleistocene times at great depths (7000m or more). Consequently, it must be assumed that migration took place laterally, updip from the large drainage area situated to the south-east (Ozzero basin).

SERRAVALLIAN FLEXURAL BELT

Due to the severe tectonic deformation and probably to the overcooking of its organic matter, this belt was basically unexplored. The sole Raja-1 dry well was drilled in Tunisian waters in the Sicily Channel.

TORTONIAN FLEXURAL BELT

General geological setting and exploration plays

As said earlier this belt extended more of less continuously along the African margin form Tunisia to Piedmont (Plate 1). It was subsequently inverted, severely deformed and shortened and, finally, disrupted in several segments due to Plio-Pleistocene wrench faulting.

The most prolific segment is by far the Emilia Romagna outern Apennine. In this area several small thermogenic gas and condensate pools were found years ago (Rallio, Pietramala, Castel Dell'Alpi, Podenzano etc.) Some new discoveries have been made recently (e.g. T. Baganza). In this segment the flexuration was accommodated by the underwater gravitational set-in-place of internal allochthonous units (Liguridi or Argille scagliose) on a sandy Serravallian authochthon (Marnoso-Arenacea Formation p.p.)

During the subsequent inversion phase (Messinian) the whole of the allochthonous and authochthonous formations was compressionally deformed. Many thrust fold trends were formed, often with detachment of the Oligo-Miocene clastic section from its calcareous substratum. The hydrocarbons are trapped in the Serravallian sandstones at the culminations of these folds.

Geochemical analysises indicate that the underlying Langhian marine shales are the source rocks (RIVA *et alii,* 1986). The migration is assumed to be lateral updip from a deep kitchen situated south-west of each folds trend. The upper seal is provided by the impervious Argille Scagliose cover. We do not have data on the lateral sealing ability of the frontal ramps – NB: In Petroleum literature, even in the most recent one (e.g. LINDQUIST, 1999) the term Marnoso- Arenacea (PS) is referred to in a very comprehensive sense. In general it includes accumulations linked to the Lower Messinian pre-evaporitic flexural belt (e.g. Cortemaggiore field) or even to the post-evaporitic Fusignano formation flysch (e.g. Cremona South).

In the Latium shelf segment an efficient PS existed, as proved by numerous surface oil seeps (known since the Roman age). Unfortunately the severe up-lift and tectonism have destroyed most of the accumulations. Only the small Ripi field is still active, producing heavy oil (21°API), sulphur rich, from basal sandy levels of the Tortonian flysch. The trap is a shallow north-east vergent thrust-fold, compartimented by faults. An Upper Triassic source rock is doubtfully assumed (ANELLI *et alii,* 1996)

In north-central Sicily the major Gagliano field and its satellites produce thermogenic gas and condensate (55°API) in a geological setting similar to that of the Emilia Appennine. A thick allochthonous nappe of Paleogene-Cretaceous varicoloured clays, of internal origin (Sicilide units) lies on Lower Miocene (Langhian) alternation of shales/quartz-arenites. The whole is involved in south vergent thrust folds. A general detachment from a deep marine calcareous substratum occurs (SCHLUMBERGER, 1987).

The hydrocarbons are stored in different sandstone levels of the parautochthonous Miocene, which in Literature is referred to as Oligo-Miocene Numidian flysch. Because of the position in the regional flexural setting the formation could be much younger.

MESSINIAN FLEXURAL DOMAIN

General geological setting

As mentioned earlier this domain has at present an extremely variable width in its various segments (Plate 1). This may be linked to an original difference in width of the flexed margin but it is certainly also related to a subsequent different orogenic shortening. Within this domain one must separate two flexural belts: the pre-evaporitic inner belt (Terravecchia, Laga, uppermost Marnoso-Arenacea of the Literature) and an outer one (Civitella, Fusignano). The geological evolution between the two belts through the evaporitic episode is not well known. There is definitely an outward shift of the depocenter (more than 600ms of thick confined sand beds of the Civitella Formation) but without the interposition of a synsedimentary ramp front. In the Siciy channel there is no post-evaporitic flexuration.

Pre-evaporitic Messinian flexural belt exploration plays

Again, the prolific segment of this belt is the Emilia Romagna Apennines foothills (e.g. Casteggio, Spilamberto, Marzeno fields). On general terms the exploration plays are similar to those described in the Tortonian belt but with a main difference consisting in the fact that in the foothills belt the upper Messinian and Pliocene thrust top sequences (time equivalent of the successive flexural series) are more or less preserved from the erosion and thus contribute to the Petroleum System. Cortemaggiore is the most important and well documented field (PIERI, 1992).It produces thermogenic gas, light oil (35-40° API) and condensate from sandy reservoirs involved in a large scale, high relief, polyphased thrust fold.

Four main types of traps can be distinguished (Plate 2c): 1.Upper Tortonian? – Lower Messinian turbidites in four-way deep closure thrust folds; 2. Lower Messinian turbidites folded and erosionally truncated; 3. Upper Messinian piggy-back sands onlapping on the inner flank of the fold; 4. Lower Pliocene sands (Cortemaggiore sands) folded and truncated – NB: an Upper Messinian age is attributed to the Cortemaggiore sands but their stratigraphic position upon the Colombacci Formation rather suggests a lowermost Pliocene age.

The seal for the different pools is provided by the alternating shale, by the onlaps or finally by the transgressive clays. Based on geochemical evidences the source is assumed to be the lower "Marnoso-Arenacea" Formation that has a good land plant derived organic content (ANELLI *et alii*, 1996). The deep-seated kitchen is most likely located to the south-west and the migration is lateral updip. The exploration of the large pre-evaporite belt of the Abruzzi area was discouraged by the geochemical analyses which proved the overcooking of the organic matter of the Laga flysch (probably caused by tectonic overloading).

On the contrary, in the western Sicily slightly deformed Lower Messinian flexural belt some minor hydrocarbons accumulations were found.

In the Channel the small Nilde, Narciso and Norma fields (Plate 4b) produced 21 to 39° API, sulphur rich oils (SCHLUMBERGER, 1987). These fields are located, in the foothills of the Tunisian Atlas thrust belt, along the tectonically inverted innermost part of the foredeep. The oil is reservoired in bioclastic, karstified, limestones of Miocene age. The traps are of small size. The source rock is uncertain, possibly Mesozoic (PIERI, 2001). It would seem that the small size of the pools is either due to a low efficiency source or to the limited drainage areas.

In west Sicily the commercial Lippone-Mazara field produces biogenic gas from fine grained turbiditic sands sealed by alternating clays. The trap is a four way closed gentle anticline.

Post-evaporitic Messinian flexural belt exploration plays

A number of predominantly mixed origin gas pools (i.e. Cremona S., Cotignola, Budrio E., etc.) are set along the second fold range of the Po Plain foothills. The multi-pay reservoir is made of turbiditic sands (Fusignano Formation). These are involved in polyphased thrust folds whose outer flank is more or less deeply eroded (Plate 3b). The truncated beds are sealed by transgressive Pliocene clays. For MATTAVELLI *et alii,* 1983 the source rock is of "Marnoso-Arenacea type", while the mixed origin would suggest petroleum generation and migration from the vicinity of the fields. Possibly the Pliocene clays can contribute (biogenic gas).

So far no accumulations were found outside the Po Plain. Nevertheless strong hydrocarbons impregnations are known in the turbiditic sands of the coeval Civitella Formation in the Piceno region.

LOWER PLIOCENE FLEXURAL BELT

General geological setting

This belt runs continuously from the central Po Plain (east of Cremona) to the Taranto gulf. Two main segments, with different geological evolution, can be distinguished; they are separated by Aventino-Sangro Line fault system (Plate 1).

In the Northern Central Apennines arc, whose pre flexural thin series pertain to a deeper platform domain, the flexuration of the margin is accommodated by "normal" flysch infilling. An about 50 km-wide sedimentary wedge is deposited; its thickness ranges from more than 2000m in the trough to few tens of meters in the foreland.

On the contrary, in the Southern Apennines segment, whose pre -flexural thick sequence is of carbonatic shelf environment, the flexuration is accommodated by a submarine gravitational set-in-place of allochthonous nappes of internal origin. The superposition systematically occurs by the interposition of a thin sheet of pelagic marls.

In both cases, of course, the whole of the flysch/allochthon and pre-flexural substratum is subsequently involved in the compressional inversion, often with detachment of the first one.

An isolated segment of the belt exists in Southern Central Sicily (Caltanissetta Basin). Its evolution, similar to that of the Southern Apennines, is still little understood.

Exploration plays

As a general rule the accumulations linked to the Lower Pliocene flexuration are of biogenic gas, within the flysch cover, and of oil in the pre-flexural substratum.

Biogenic gas fields, also of good size, were discovered all along the Northern Central Apennines foothills. They can be referred to two main plays:

1. Multiple turbiditic sand beds at the four way closure culmination of thrust folds,

often with associated back thrusts, of polyphased Pliocene age. Alternating clays of the flysch itself provide both the source and the seal.The migration occurred probably at the end of the Middle Pliocene.The traps can set on different structural trends within the deformed foredeep (Plate 3b and 3c), internal (e.g. Rapagnano, Cellino fields), or intermediate and deep (e.g Grottammare field), or more external (e.g. P.to Corsini Mare, S.Benedetto, S.Marco, etc.). Amplitude anomalies often evidence the gas accumulations on the seismic lines.

2. Erosionally truncated turbiditic sand beds, just below the Middle Pliocene unconformity, at the top of thrust folds of Middle-Upper Pliocene age (e.g. Ravenna, S.Pietro in Casale, Alfonsine, Settefinestre, etc.). The seal is provided by the transgressive Middle Pliocene clays, which probably also contribute as source rocks. As a rule these pools are associated to amplitude anomalies and pull down effect on the seismic lines. The most important oil accumulations in this belt are the Cavone field, with its satellites, in the Emilia Apennines foothills and the "Scaglia calcarea" group of fields in the coastal Central Adriatic offshore.

The Cavone field produces heavy oil (20-23° API), sulphur rich (3-4%) - (NARDON *et alii,* 1991). There are two main reservoirs, Lower Cretaceous calcareous breccias (Cavone Breccias) and fractured Liassic oolithic limestones (Noriglio Grey Limestones). They are sealed respectively by Middle Cretaceous marls and by Middle Jurassic marly limestones. The trap (Plate 3a) is a complex, polyphased, north vergent thrust fold. The structure is narrow, elongated, dissected by faults, and has a very high relief. Its expression was mainly attained during the Middle and Upper (out of sequence) Pliocene phases.

The source rock is uncertain, probably Triassic (ANELLI *et alii,* 1996). Whichever the source, it seems quite evident that it entered the maturity window due to the superposition of Lower Pliocene, flexural, and Middle Pliocene tectonic subsidence in the foothills belt south of the field. From here the oil migrated laterally updip along the inner flank of the fold.

The minor Bagnolo field has a similar geological setting but the reservoir is a Cretaceous shelf limestone, which proves the paleogeographic complexity of the area.

In the Central Adriatic coastal offshore a number of commercial, middle-sized fields (Sarago Mare, Mormora Mare, S.Giorgio Mare, David, Emilio, Piropo, etc.) produce oil and/or gas from Upper Cretaceous-Paleocene resedimented, fractured bioclastic limestones levels, which are intercalated in a dominant pelagic mudstones series (Scaglia Calcarea Formation). These beds are interpreted to come from a nearby carbonatic shelf margin (talus sediments). However, as they have proximal characters (even coarse breccia facies) and are distributed along narrow trends with no evidence of carbonatic shelf in the area, it seems most likely that these resedimented beds come from unstable intra-pelagic ridges that have reached, at times, the photic zone and have been subsequently eroded. The traps (Plate 3c) are double vergence, upthrust like, inversion folds, bounded by high angle faults; being essentially of Middle Pliocene age they probably reactivate old paleoinverted features.

The producing structures lie clearly on a NW-SE oriented trend; this strictly fits with the outer hinge of the Lower Pliocene flexural belt. The seal to the producing levels is provided by the overlying mudstones. The source rock is uncertain, possibly represented by the Upper Triassic Burano evaporitic formation. However, as in Cavone, it seems evident here too a lateral updip migration from a kitchen deeply seated to the SW occurred.

In the Southern Apennines some major oil fields (e.g. Costa Molina, Monte Alpi, Cerro Falcone), among the most important ones in Italy, have been discovered in the inner part of the Lower Pliocene inverted flexural belt. Except for Costa Molina (SCHLUMBERGER, 1987) literature on these fields is scarce.

The oil is reservoired in Lower Miocene and in immediately underlying Upper Cretaceous fractured shelf limestones (Inner Apulia unit). The thickness of the impregnated rocks can exceed 1000m and the oil is density segregated with the depth, both in the individual fields (12.6° API and sulphur rich, at the bottom, to 20° API at the top in Costa Molina) and in the entire area (30 to 42° API in the shallower Monte Alpi field). Involved in a general eastward displacement of the Inner Apulia unit, the traps (Plate 4a) are represented by large scale, high relief, double vergent, faulted anticlines, bounded by high angle faults. They are Middle Pliocene in age and probably issued from the reactivation of old inverted features.

A good upper seal is provided by the Lower Pliocene pelagic marls and by the overlying silty shales of the allochthonous formations. Possibly a lateral seal is also given by the reverse fault planes, as the oil column heights seem to exceed the vertical closures of the structures. The molecular composition of the oils suggest a Triassic carbonatic source rock (MATTAVELLI *et alii,* 1992), probably derived from an intra-shelf euxinic basin. A short distance subvertical migration could occur. It must be Middle Pliocene or younger. Minor oil accumulations, rich in CO_2, were discovered in the seventies, in a similar setting, some 200km to the north (Benevento and Castelpagano fields).

Set in a more external trend of the Lower Pliocene flexural belt the Tempa Rossa field is a major accumulation of heavy, sulphur rich, oil. Here too the oil is density segregated with depth (from 12 to 20° API ?). There are different oil-bearing reservoirs: Lower Miocene packstones, Paleogene Nummulitic breccias, Upper Cretaceous fractured shelf limestones and dolomites. The upper reservoirs, of secondary importance, are missing in the top part of the structure because of erosion or non deposition. The transgressive Lower Pliocene marls provide an excellent upper seal. The trap (Plate 4a) is a huge, high relief, double vergence, inversion thrust fold, with Apenninic trend. As the oil column (more than 2000m proved) exceeds the four way closure, the lateral ramps could be sealing.

The source rock is provided by Cenomanian-Turonian bituminous dolomicrites, that were penetrated by the wells.

Despite this structure being part of a regional trend (CASERO *et alii,* 1991) no further discoveries were made: this is to be related to the great depth of the structures and to the difficulty in acquiring good seismic data.

MIDDLE PLIOCENE FLEXURAL BELT

General geological setting

Starting from the latest Lower Pliocene all along the Northern and Central Apennines foothills the internal part (about two-thirds) of the Lower Pliocene flysch wedge is progressively inverted and thrust folded (Plate 3b and 3d). This orogenic phase reorganize completely the physiography of the basins generating coeval thrust top basins and a new wide foredeep.

Exploration plays

In the first basins some significant fields were discovered (Selva, Ravenna Mare South, S. Pietro in Casale etc.). They produce biogenic gas from shallow marine sands. The traps are gently refolded onlaps on both the inner and outern flank of late Middle Pliocene thrust folds. The most important ones, however, are by far the accumulations of the foredeep basin, perhaps the most prolific gas basin in Italy (i.e. Agostino-Porto Garibaldi, Piadena East, Squalo Centrale, etc.). The biogenic gas is reservoired in multiple turbiditic sandy levels more or less gently folded according to their setting. Both the source rock and the seal are provided by the alternated clays.

In Southern Apennines, in this same time, the front of the allochthonous nappe is thrusted onwards. Because of the presence of the rigid, emerged Apulia Shelf foreland that stops the system, the foredeep is narrower and the substratum more flexed (Plate 4a bis). Nevertheless this foredeep (called Bradanic Trough) is in physical continuity towards the NW with the Central Apenninic one. If the productions from the thrust top are here negligeable, the ones from the foredeep (derived from many tens of small-to-large scale fields) are very important. The gas is almost always biogenic. The reservoir is always made up of more or less proximal turbiditic sands and the seal by the alternating clays. Therefore the different plays are mainly characterized by the trap geometry (SELLA *et alii,* 1988). Many fields (i.e. Candela, Pisticci) produce from multiple sandy levels folded under and truncated by the frontal Allochthonous synsedimentary ramp, others from duplex folds under the same ramp. In the upper producing levels of the major Candela field, light oil (42-58°API) and thermal gas, possibly issued from shaly tertiary rocks, containing terrestrial organic matter, have mixed with the biogenic gas (MATTAVELLI & NOVELLI, 1988). As a rule the structures under, or immediately east, the front of the allochthon, of late Middle Pliocene age, involve the preflexural substratum. In these traps some oil accumulations were found reservoired in fractured Miocene and Upper Cretaceous shelf limestones (i.e. M. Taverna, T. Tona, Strombone, etc.). The density of these oils, probably derived from marine carbonates (PIERI, 2001) is much variable. It would seem that the most internal and deep seated pools contain lighter hydrocarbons (52°API at M. Taverna), the density increasing rapidly towards east (12°API in Pisticci). This fact, correlated with the geological setting of the area, suggests the presence of a deep kitchen under the nappes and a lateral updip migration.

UPPER PLIOCENE BASINS

In the uppermost Middle Pliocene a late Apenninic tectonic pulse generated a regional unconformity. This is evident on the flanks of the thrust top basins but very gentle in the outern basins. In the Northern and Central Apennines foreland basin the Upper Pliocene fine terrigeous series are much less prolific than the Middle Pliocene ones. The biogenic gas pools are mostly found in the transgressive basal levels. The traps (Plate 3b and 3d) are either onlaps, on the flanks of the thrust top basins (e.g. Ravenna field) or, more frequently, draping on previous folds in the foreland basins (i.e. Squalo Centrale, Emma West fields). In the Bradano Trough, on the contrary, because of the closure of the system, more producing situations were found (Plate 4 a bis), such as multiple sandy levels truncated by the frontal allochthonous ramp (Candela levels) or, more commonly, thin sand beds in gentle folds draping or reactivating Middle Pliocene structures (e.g. Reggente, Santa Caterina, Palmori, etc.)

QUATERNARY BASINS

During the Pleistocene an important regional relative sea level fall occurred.

A full set of regressive sandy/clay beds was deposited. In the Northern Adriatic Sea,in the basal sandy levels of this cycle, several biogenic gas pools were found, some of which (Barbara, Ada, Bonaccia) of very large size. The traps are everywhere gentle anticlines, in most cases draping previous features of various origin (e.g. Barbara drapes an isolated carbonate shelf high; Bonaccia an old tilted block).

Amplitude anomalies on the seismic lines are always associated to these accumulations.

In the confined Bradanic Trough several pools exist, in connection with the still living tectonism. Some fields produce from beds truncated by the late reactivation of the allochthon frontal ramp (e.g. Pisticci), others from large folds draping foreland highs (e.g. the major Grottole field, Plate 4a bis).

FORELAND OIL EXPLORATION PLAYS

In Italy some important petroleum systems were found which are fully contained in pre-flexural carbonatic series and do not depend on flexural subsidence.

South East Sicily

During the Upper Triassic a high subsidence, open carbonatic shelf domain extended in the area. The sequence, completely dolomitized (Gela Formation), exceeds probably by far (see the seismic character) the over 4000m penetrated by the wells (e.g. Vizzini1). Towards the south, mainly in the off-shore area, the shelf domain makes abrupt transition to a coeval, equally subsident, euxinic basin domain (Plate 5c).In the basin, confined to the south by the emerged African margin (CASERO & ROURE, 1994) thick series of interbedded, organic rich, mudstones, black shales and silts were deposited (Noto Formation). In lowermost Liassic, through the presence of a regional unconformity, the euxinic environment extended largely to the north on the previous shelf area. The series (Streppenosa Formation), similar in facies to the Noto Formation, decrease gradually in thickness from over 800m, in the south, to 0 in the north (Cammarata/Pozzillo field high). During Middle Lias and Dogger, probably in connection with the activity of tensional synsedimentary faults, the paleogeography appears articulated. To the north, on the Cammarata-Pozillo high trend, comprehensive shallow marine massive series are deposited (Siracusa Formation).These give transition, to the south, to pelagic well bedded, clayey, mudstones sequences (Modica and Buccheri Formations). These sequences, similarly to the Streppenosa Formation, tend to thicken toward the south. Here (Plate 5c) the mudstones leave rapidly place to a thick carbonatic barrier made up by oolitic, algal and pelsparitic limestones (Inici Formation). The facies variation occurs clearly on a NW-SE trend, indipendent from the Upper Triassic Gela/Noto scarp. Since Malm the Ragusa Plateau has become the site of much more uniform and isopachous deeper platform calcareous sedimentation. During lowermost Cretaceous, nevertheless, some compressional paleo inversions occurred. In this setting two main oil plays have been proved.

The Ragusa-Gela fields play

Discovered in the 1950's (KAFKA & KIRKBRIDE, 1960) these fields (Plate 1) have been for a long time the largest Italian oil production. They produce heavy (10 to 20°API) sulphur rich oil. The reservoir is provided by the vuggy and fractured, massive dolomites of the Upper Triassic Gela Formation. The seal is made up of the impervious transgressive Streppenosa shales. The traps are large scale anticlines, probably of polyphased age, bounded by high angle normal faults. Because of the high subsidence of the naftogenic and overlying Mesozoic series, the maturation and migration started probably very early but the main phase of expulsion occurred recently when the Plio-Quaternary subsidence created a general southward dip. So the migration was mainly lateral updip, from south to north, across the facies change scarp. The density of the oils increases in the same direction. In the Cammarata/Pozzillo field, where the Streppenosa Formation is missing, the oil migrated upwards in the Siracusa shelf limestones. Some of the oils (e.g. Ragusa) escaped upwards along the fault planes to the surface where they impregnated outcropping Miocene calcarenites and originated large bitumen accumulations.

Perla Vega fields play

The Inici barrier carbonates produce sulphur rich heavy oils (12 to 16°API) in the Prezioso, Perla and Vega offshore fields (Plate 1). The primary porosity (intergranular and vuggy) is low, substantially but irregularly increased by more or less intense fracturing (SCHLUMBERGER, 1987). The traps are mixed, the closure being assured by the dip on three sides and by the facies change to the NE . On this side a superposed lower Cretaceous compressive event can enhance the closure (Plate 5c). While the lateral seal is given by the Jurassic marls, the Upper one is provided by the condensed pelagic series. In the Literature the source of these oils is assumed to be in the Streppenosa Formation limestones/shales with a resulting upwards migration. As an alternative hypothesis the migration into the reservoir could occur laterally updip from the south from unknown coeval lagoonal carbonates (Emma limestones equivalent? See next paragraph).

Rospo Mare field play

In the north-west nose of the Apulia carbonate shelf (Plate 1) the huge heavy oil Rospo field was discovered in the mid-seventies. The stratigraphic section of this part of the Apulia shelf is made up of Upper Triassic alternated dolomites and anydrites (Burano Formation), thick Jurassic dolomitic series of inner shelf environment (Ugento Dolomites Formation) and Lower Cretaceous mudstones and bioclastic packstones (Cupello Limestones Formation). Seismic and wells data show that the massive shelf series change laterally in facies towards the NE to well bedded mudstones series (Plate 5 a) of deeper water platform and euxinic environment (Emma Limestones). Probably during the early Upper Cretaceous the shelf area emerged, in the meantime gently tilting to the NE, and was deeply eroded, while the sedimentation continued in the deeper platform area. A large topographic high zone, strongly karstified, was identified. During the Lower Miocene the high was progressively transgressed by shallow marine, thin, glauconitic grainstones series followed by Messinian evaporites and Lower Pliocene marls. Heavy immature oil (11°API), sulphur rich, impregnates the karstified Lower Cretaceous limestones on the large paleotopographic high. The oil extends to the west up to the erosional limit of the karstified formation and the oil/water surface sensibly rise in the same direction. A good seal is provided by both the Messinian anhydrites and the Pliocene marls. The source of this oil and the migration way have been long time discussed. It is in general assumed that the source is the oil prone Upper Triassic Burano Formation (ANDRE *et alii,* 1991). The migration should be recent (obviously post seal) and subvertical, along the faults. An alternative hypothesis would be that the source is in the Emma Ls, the migration being lateral updip from the NE (Plate 5a).

Aquila field play

The major, deep water Aquila oil field (over 800m wd) is located in the Jonian sea some 10 km from the slope of the Apulia shelf (Plate 1). Here the stratigraphic series (SCHLUMBERGER, 1987) is made up of:

- -a continuous thick Pleistocene to Oligocene sequence of sands, clays and marls of pelagic environment;
- -Paleocene to Upper Cretaceous pelagic mudstones, with packstones interbeds (Scaglia calcarea formation)
- condensed Jurassic deep water mudstones, unconformably resting on:
- Lower Jurassic shelf margin packstones grainstones and dolomites (Cupello Limestones Formation).

An important oil column (about 130m) impregnates the entire fractured pelagic limestones series. The oil is density segregated from 22 to 36°API. The trap is structural but, in spite of the fact that it is proposed as a simple horst, its interpretation appears questionable on the basis on the few available seismic data. The anomaly (Plate 5b) is definitely a paleo feature, as the pelagic series thin on its top, and also a growing structure which justifies the repeated hiatuses (i.e. lack of lower Cretaceous). The structure is possibly an anticline having a semi mobile evaporitic core that partly flowed during the listric faulting of the shelf margin.

CONCLUSIONS

As a consequence of the geological complexity of the region, the petroleum exploration plays of Italy are extremely variegated. Obviously, most of the accumulations are set in the foreland and foothills domains, while they become less and less preserved moving towards the chain, because of the tectonism.

As a general rule the gas pools are associated to flexural and post flexural PS, while the liquid hydrocarbons ones are linked to pre flexural substratum sources.

Biogenic gas pools were found in:

- thrust top, shallow marine sands in mixed traps;
- foredeep turbiditic multi layers sands, involved in thrust folds, either four-way-dip closed or erosionally truncated;
- foreland basins marine sands in mixed traps (refolded onlaps), stratigraphic traps (onlaps/shale outs) or in structural traps (reactivated thrust folds or drapings.

The source is in the interbedded clays. Thermogenic gas pools are in turbiditic sands involved in polyphased thrust folds in foothills areas. The gas, generated at great depth in the flysch, migrated laterally-updip along the inner flank of the folds.

Liquid hydrocarbons, often associated with condensates and/or thermal gas, are reservoired in pre flexural carbonatic series either in foothills or in foreland domains.

In the foothills belts the traps are thrust folds. The hydrocarbons were generated by intra-shelf euxinic basin series, pushed into the maturity window by the superposed flexural/tectonic subsidence and migrated, as for thermal gas, laterally-updip along the inner flank of the folds. In the foreland the oils are stored in carbonates involved in paleo structures of different nature. They were also generated by intra-self euxinic series that reached the maturity thanks to the recent passive margin subsidence. The oils migrated laterally-updip, across the facies change screen. Despite the strong maturity of the exploration an interesting upside remains, mainly for the complex and deep seated plays. Also, some deep water areas are still poorly understood.

ACKNOWLEDGEMENTS

The Author would like to express his sincere gratitude to the following people for their support and assistance in preparing this paper: F.COSSU and A. DI MARIO, for developing the drawings, with a special mention to A.BRUNI for his supervision of the drawings and his contribution to Plate 1; Prof. C. FACCENNA of University Roma3 for his support; Dr. F. ROURE of I.F.P. – Paris, for text revision. A special word of thanks to T. CARBONARI for revising my English.

REFERENCES

ANDRE' P. & DOULCET A. (1991), Rospo Mare Field – Italy, Apulian Platform, Adriatic Sea. In Treatise of Petroleum Geology, Atlas of Oil and Gas Fields, Stratigraphic Traps II, pp. 29-54

ANELLI L., MATTAVELLI L. & PIERI M. (1996), Structural-stratigraphic evolution of Italy and its petroleum systems. In : Ziegler P.A. & Horvath F. (eds), Peri-Thethys Memoir 2 : Structure and Prospects of Alpine Basins and Forelands. Mem. Mus. Natn. Hist. Nat., 170: 455- 483

CASERO P., ROURE F. & VIALLY R. (1991), Tectonic framework and petroleum Potential of the Southern Apennines. In: Generation, accumulation and production of Europe's hydrocarbons (Edited by Spencer, A.M.) Europ. Assoc. Petrol. Geosci., Spec. Publ., 1, pp. 381-387

CASERO P. & ROURE F. (1994), Neogene deformation at the Sicilian-North African plate boundary. In Pery-Tethyan Platforms (F. Roure, ed.), Editions Technip (Paris), pp. 27-45

CHIARAMONTE M.A. & NOVELLI L. (1986), Organic Matter maturity in Northern Italy : some determining agents. Organ. Geochem., 10, pp.281-290

CHIERICI G.L., VAGHI G.C., TORRICELLI L:, PULGA M., GIACCA D. & BILGERI D. (1979), Exploration and Production in the Very deep Malossa Field. In :10th World Petroleum Congress, Bucharest, 1979

ERRICO G., GROPPI G., SAVELLI S. & VAGHI G.C. (1980), Malossa field: a deep Discovery in the Po Valley,Italy. In: Giant fields of the decade 1968-1988, Am. Assoc. Petrol. Geol., Mem., 30, pp. 525-538.

FANTONI R., MASSARI F., MINERVINI M., ROGLEDI S. & ROSSI M. (2001), Tectonic and sequence stratigraphic framework of Messinian deposits Along the buried Southern Alps margin. Geol. Insubr. 6/1 (2001) pp. 95-108

FANTONI R., BELLO M., RONCHI P. & SCOTTI P. (2002), Po Valley oil play: from The Villafortuna-Trecate field to South-Alpine and Northern Apennine Exploration. EAGE 64th Conference & Exhibition – Florence, Italy, May 2002

KAFKA F.T. & KIRKBRIDE R.K. (1960), The Ragusa Oil Field (Sicily) In: Excursion in Sicily. Petr. Expl. Soc. Libya, Tripoli, pp.61-85.

LINDQUIST S.J. (1999), Petroleum Systems of the Po Basin Province of Northern Italy and the Northern Adriatic Sea: Porto Garibaldi (Biogenic), Meride/Riva Di Solto (Thermal), and Marnoso-Arenacea (Thermal). U.S. Department of The Interior U.S. Geological Survey

MATTAVELLI L. & MARGARUCCI V. (1992), Malossa Field – Italy. In: Treatise of Petroleum Geology, Atlas of Oil and Gas Fields, Structural Traps VII, pp. 119-133.

MATTAVELLI L. & NOVELLI L. (1987), L'origine des hydrocarbures dans le bassin du Po. Mém. Soc. Géol. France, 151,pp.97-106.

MATTAVELLI L. & NOVELLI L. (1988), Geochemistry and habitat of natural gases in Italy. Organ. Geochem., 13,1-3,pp. 1-13

MATTAVELLI L., RICCHIUTO T., GRIGNANI D. & SCHOELL M. (1983) Geochemistry and Habitat of Natural Gases in Po Basin, Northern Italy. Am. Assoc. Petrol. Geol. Bull.,67, 12, pp. 2239-2254.

MERLINI S., NICOLAI C., BURBI L. & MORANDI S. (2001), The Remaining Oil Potential Of Italy. In: Focus on Italy A Supplement to Oil and Gas Investor.

NARDON S., MARZORATI D., BERNASCONI A., CORNINI S., GONFALINI M., ROMANO A. & TERDICH P. (1991), Fractured carbonate reservoir characterisation and modelling: a multisciplinary case study from the Cavone oil field, Italy. First Break, 9, 12, pp.553-565.

NOVELLI L., CHIARAMONTE M.A., MATTAVELLI L., PIZZI G., SARTORI L. & SCOTTI P. (1987), Oil Habitat in the North-western Po Basin. In: Migration of Hydrocarbons in Sedimentary basins: 2nd IFP Exploration Research Conference (Edited by Doligez B.), Ed. Technip, Paris, pp. 27-57.

PIERI M. (1992), Cortemaggiore Field – Italy, Po Plain, Northern Apennines. In: Treatise of Petroleum Geology, Atlas of Oil and Gas Fields, Structural Traps VII, pp.99-118.

PIERI M. (2001), Italian petroleum geology. In: Anatomy of an Orogen: the Apennines and Adjacent Mediterranean Basins, Vai G.B. & Martini I.P.(eds.) Kluwer Academic Publishers

PIERI M. & MATTAVELLI L. (1986), Geological Framework of Italian Petroleum Resources. Am. Ass. Petrol. Geol. Bull., 70, 2, pp. 103-130.

RIVA A., SALVATORI T., CAVALIERE R., RICCHIUTO T. & NOVELLI L. (1986) Origin of Oils in Po Basin, Northern Italy. Organ. Geochem.,10, pp.391-400.

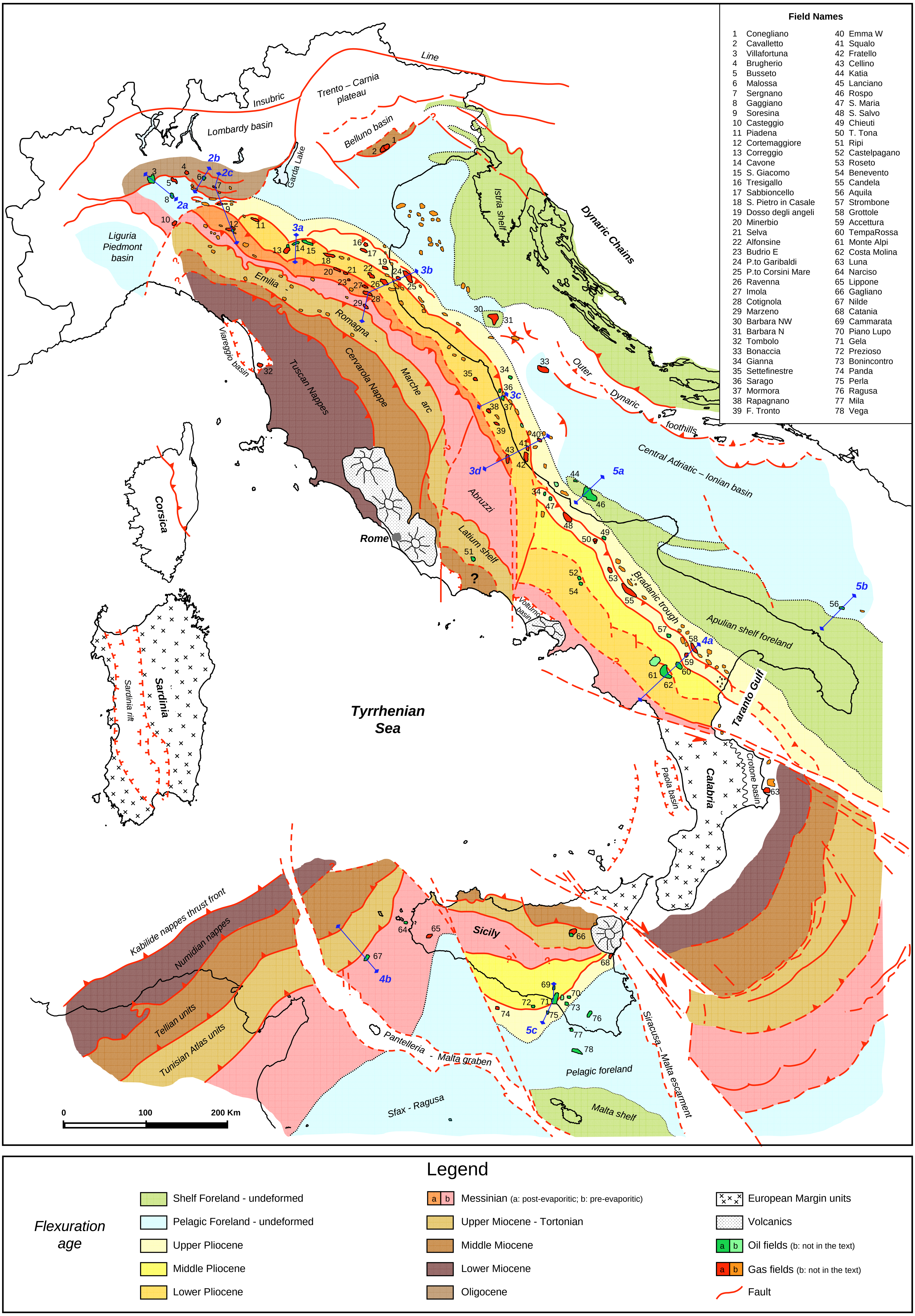
ROVERI A., BERNASCONI A., ROSSI M.E. & VISENTIN C. (1992), Sedimentary Evolution of the Luna field area, Calabria, Southern Italy. In: Generation, Accumulation and Production of Europe's Hydrocarbons (Edited by Spencer A.M.), Euop. Assoc. Petrol. Geosci., Spec. Publ., 2, pp. 217-224.

SAITTA S., D'AMBROSIO, SAVELLI S. & DEL CURTO E. (1979), Exploracion de Trampas estratigraficas en la cuenca del Po (Italia). In: Congreso Panamericano de Ingenieria del Petroleo

SCHLUMBERGER (1987), Well Evaluation Conference, Italia 1987.

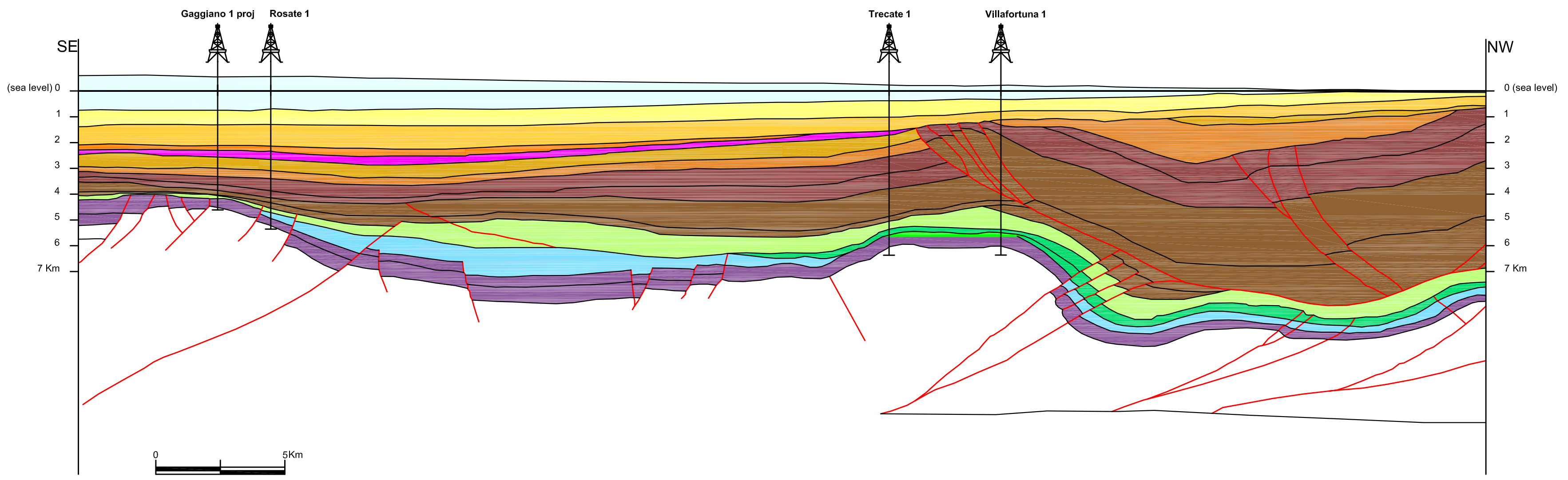
SELLA M., TURCI C. & RIVA A. (1990), Petroleum geology of the "Fossa Bradanica" (foredeep of the Southern Apennine thrust belt). In: Classic Petroleum Provinces (Edited by Brooks J.), Geol.Soc.,London, Spec. Publ., 50, pp.369-378.

ITALY – STRUCTURAL SETTING AND FIELDS POSITION Plate 1



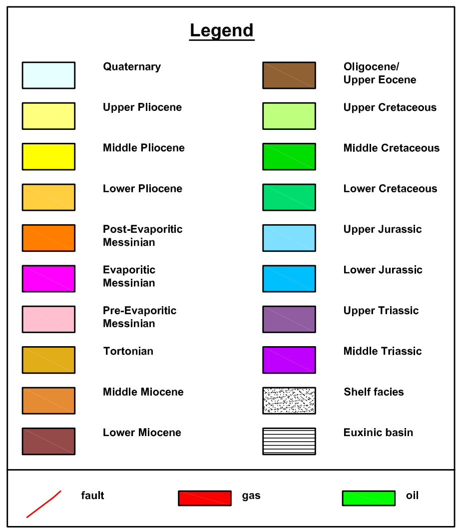
PETROLEUM EXPLORATION PLAYS IN THE WESTERN PO PLAIN

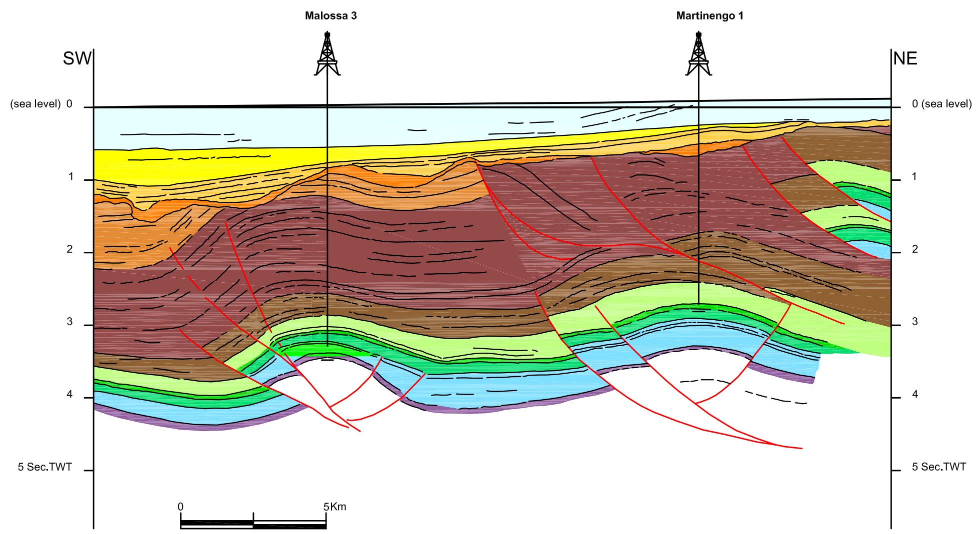
Plate 2



Redrafted after Fantoni et Al., 2002

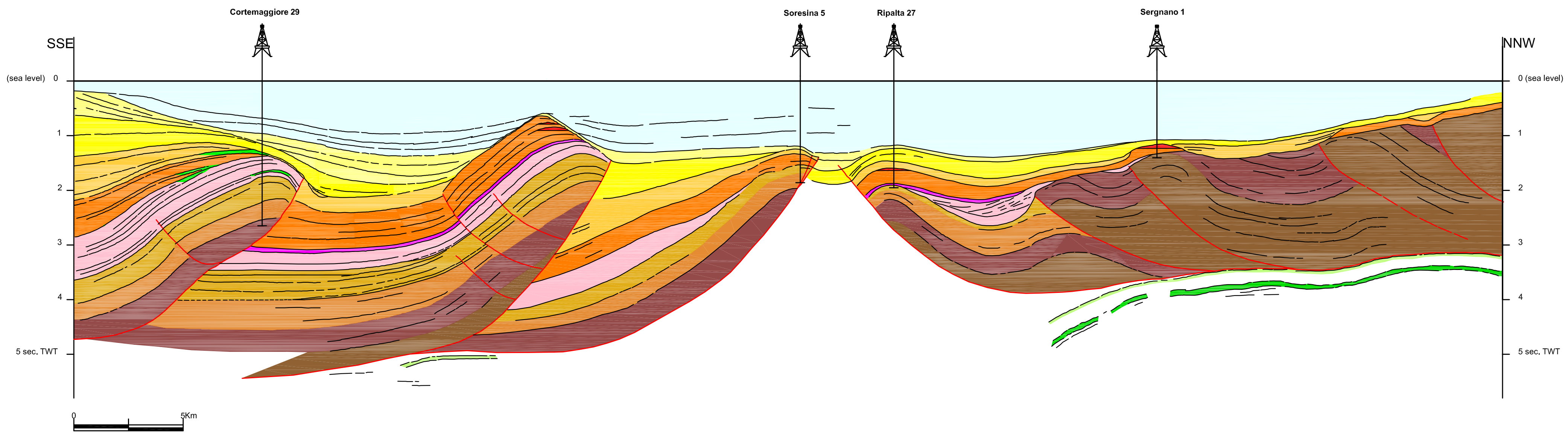
Sect 2a





Re-interpreted from Errico et Al., 1979

Sect 2b

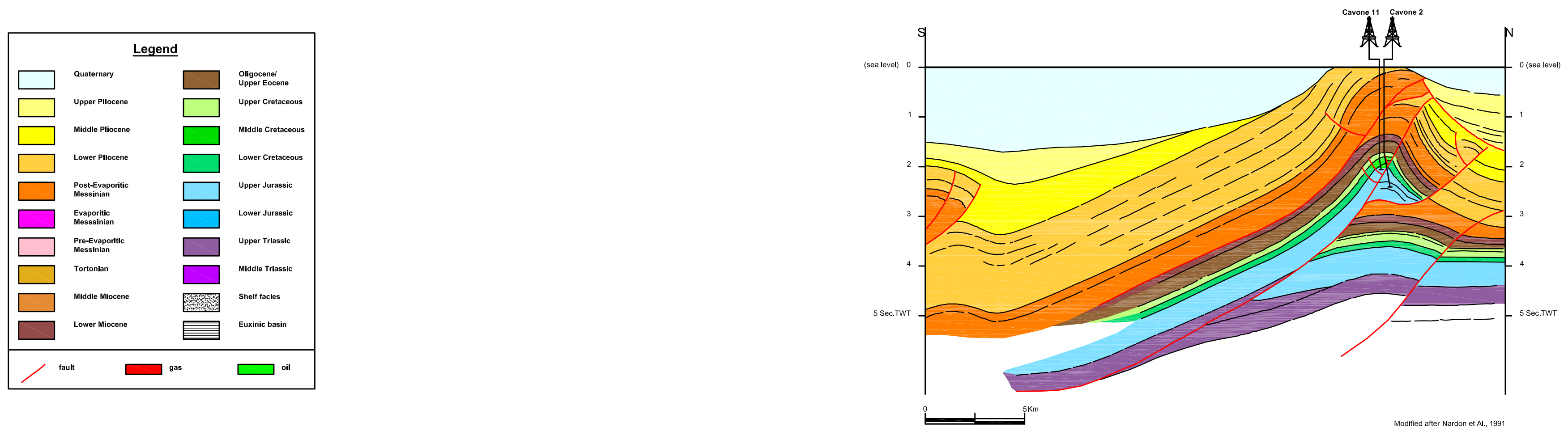


Re-interpreted from different AGIP sources

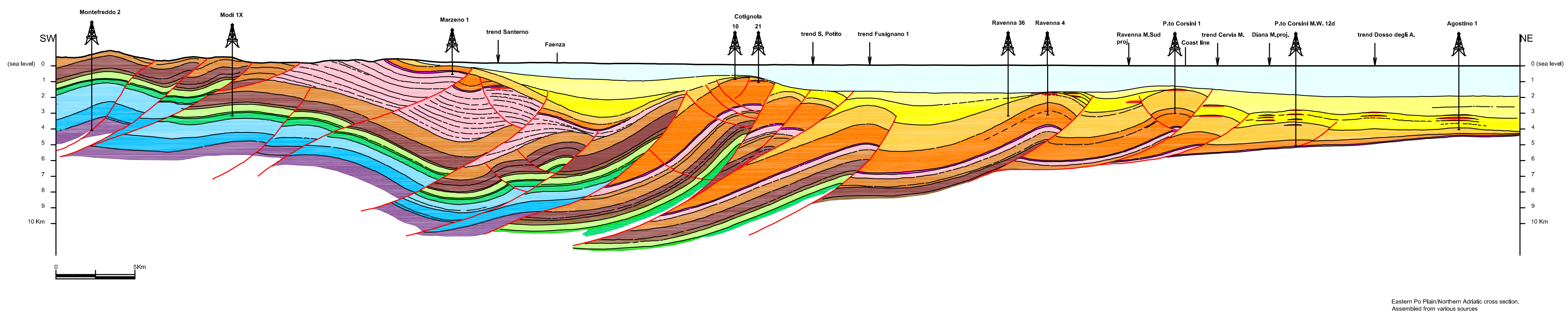
Sect 2c

PETROLEUM EXPLORATION PLAYS ALONG THE PLIOCENE FLEXURAL DOMAIN

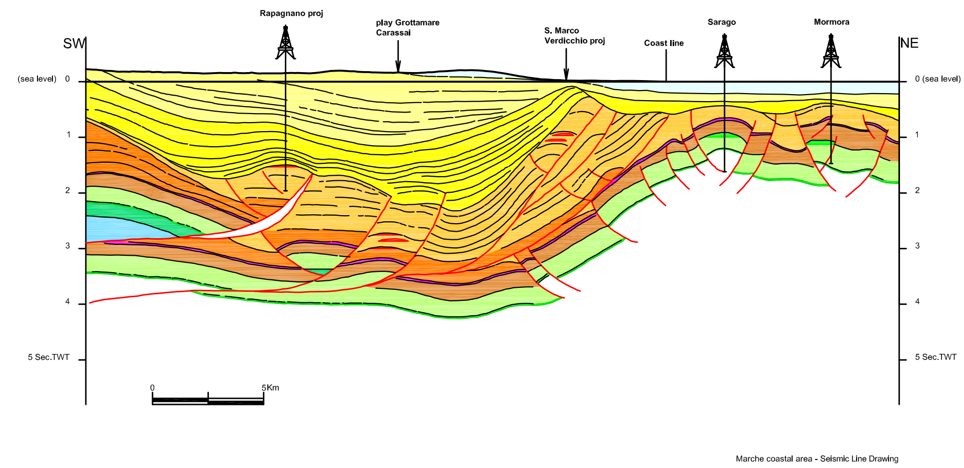
Plate 3



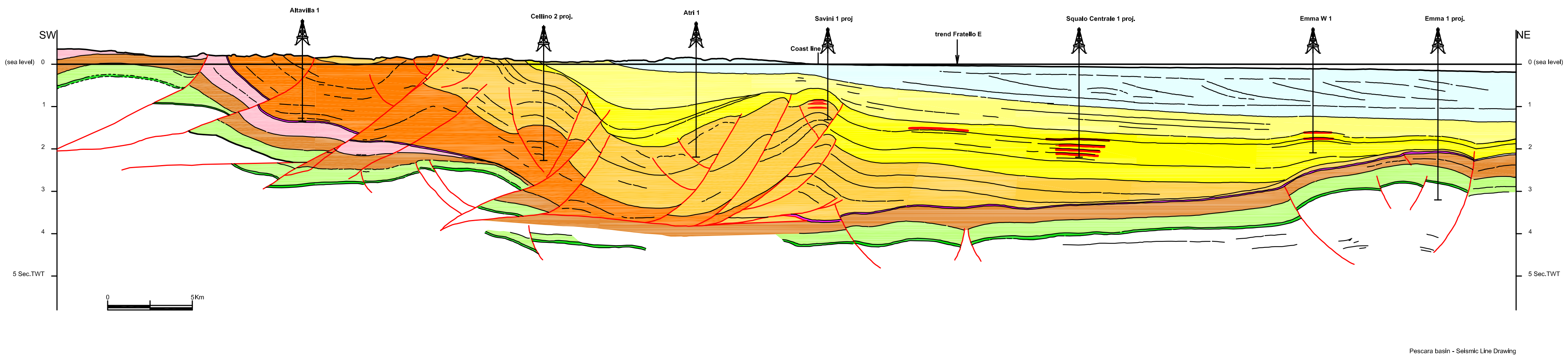
Sect. 3a



Sect. 3b



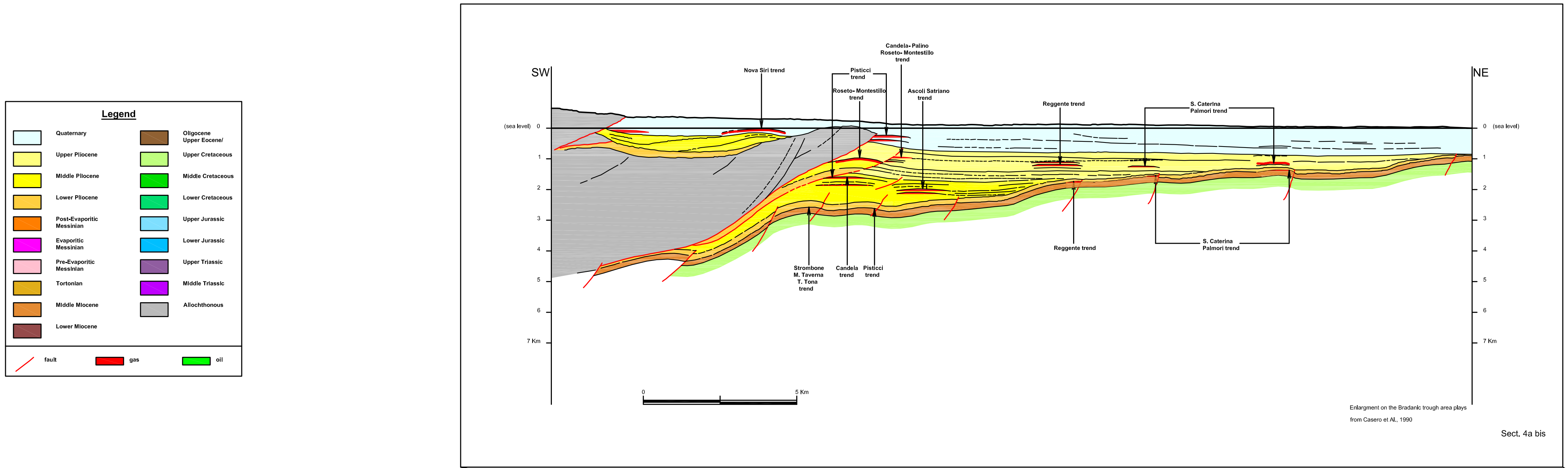
Sect. 3c

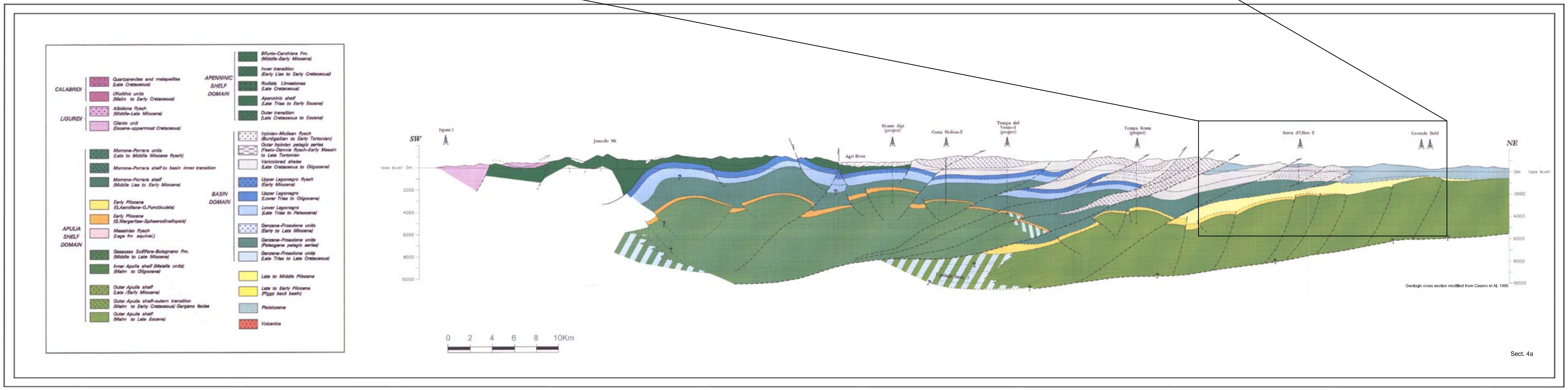


Sect. 3d

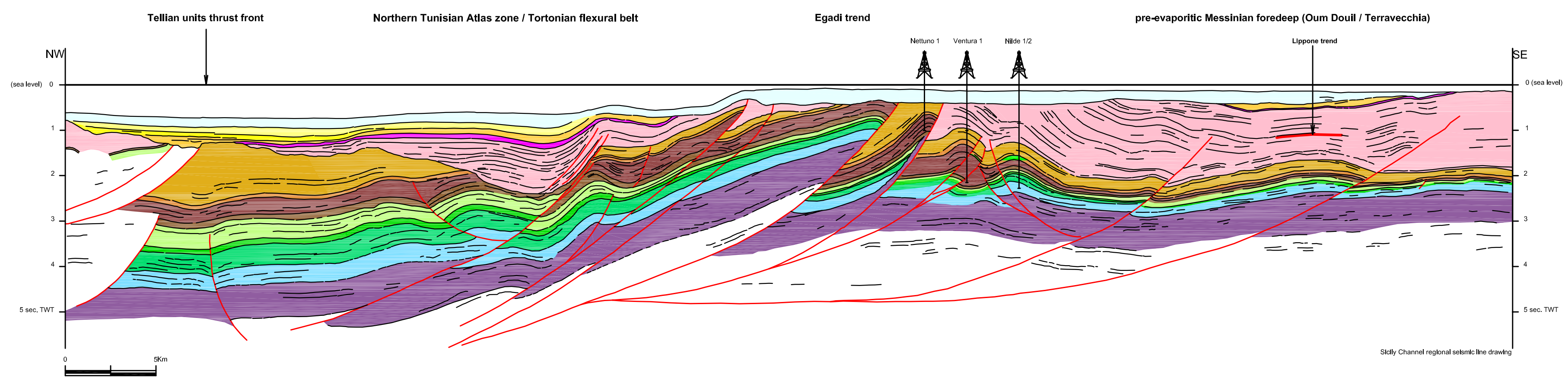
PETROLEUM EXPLORATION PLAYS IN THE SOUTHERN APENNINES

Plate 4



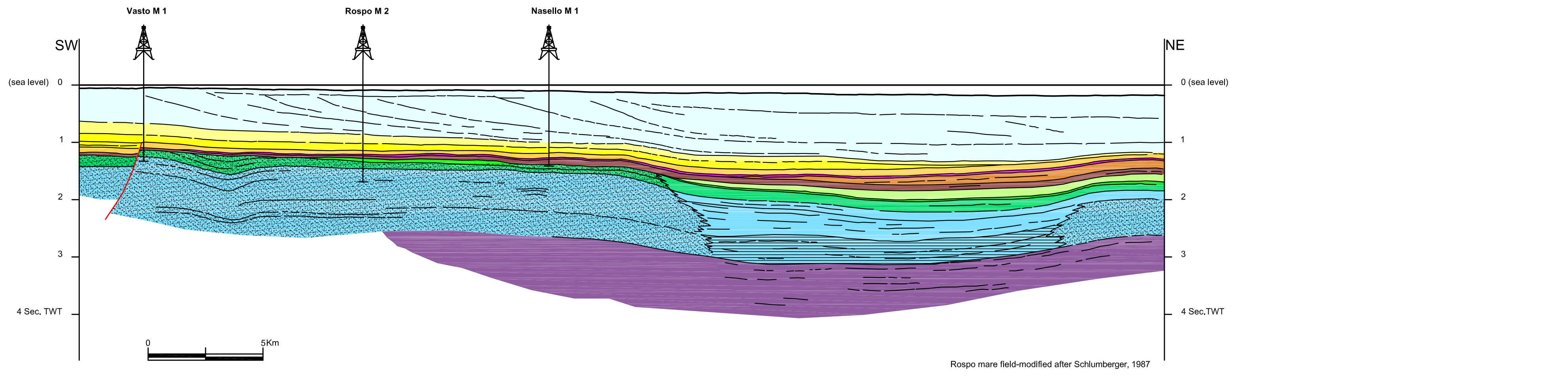


PETROLEUM EXPLORATION PLAYS IN THE SICILY CHANNEL

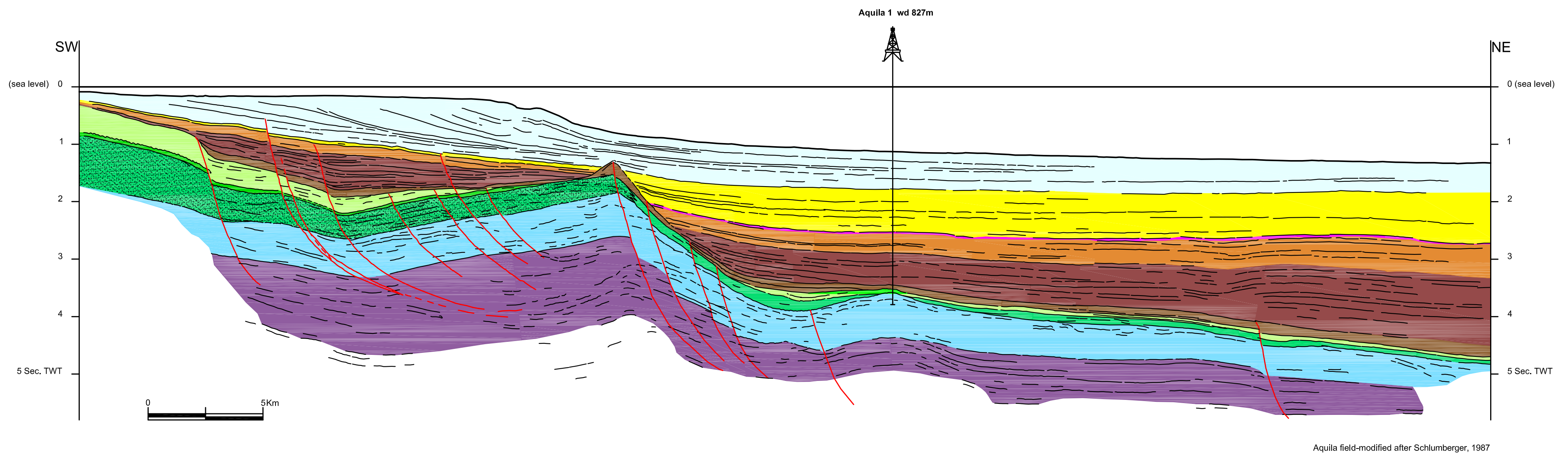


PETROLEUM EXPLORATION PLAYS IN THE FORELAND

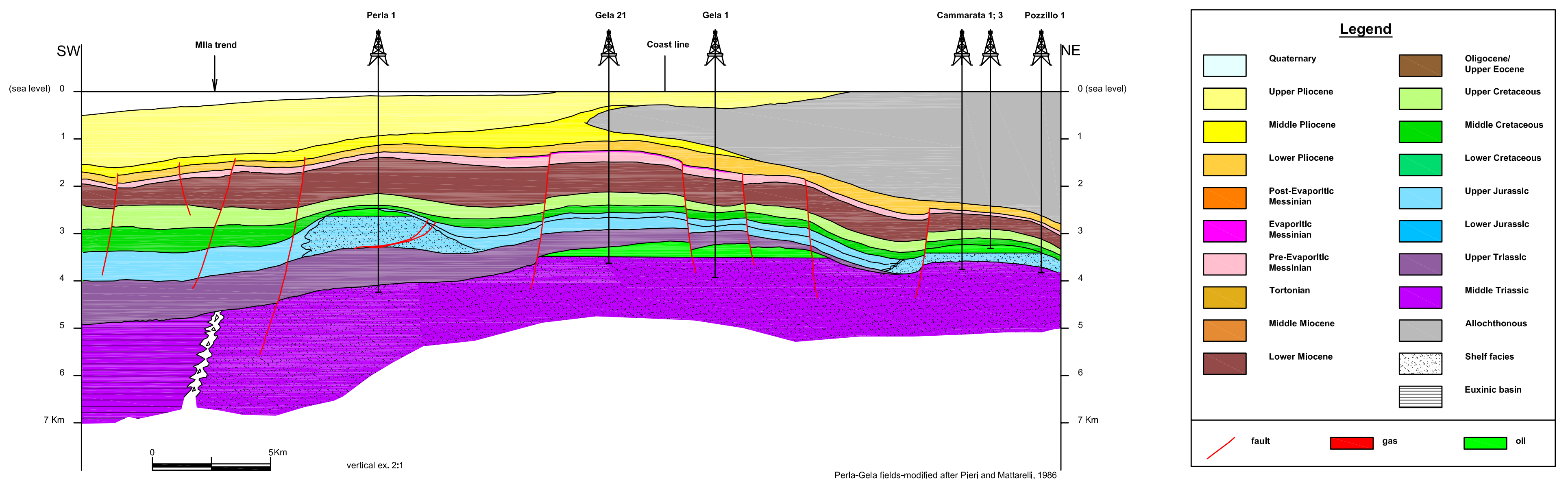
Plate 5



Sect. 5a



Sect. 5b



Sect. 5c