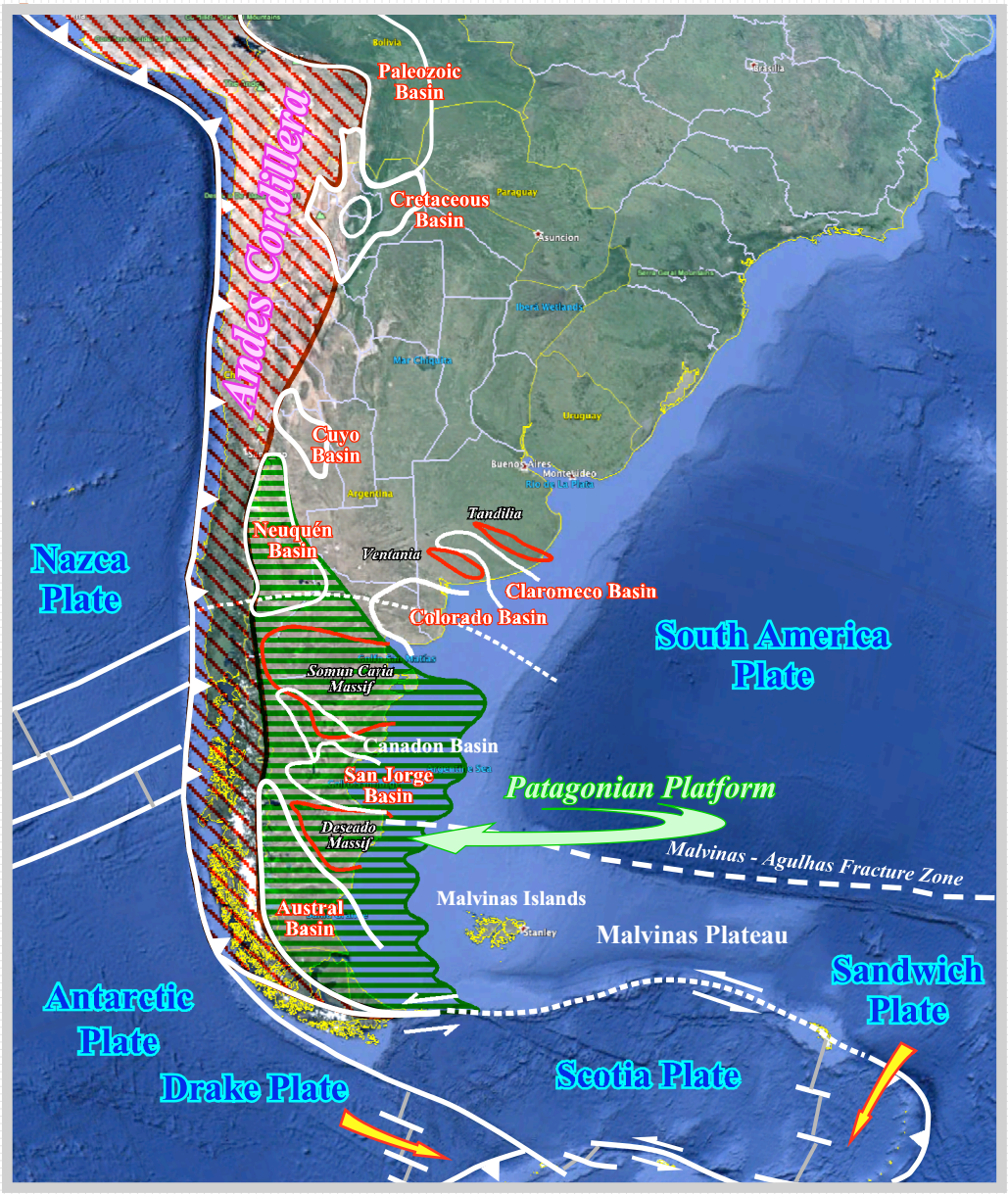
Argentina Sedimentary Basins

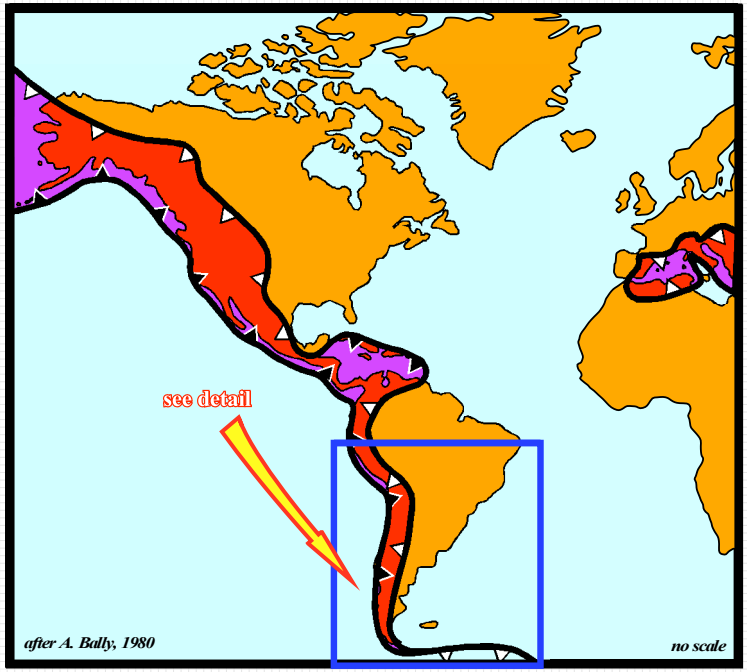
(Cuyo Geographic Basin)

CCramez, 2014

Regional Macrotectonic Features



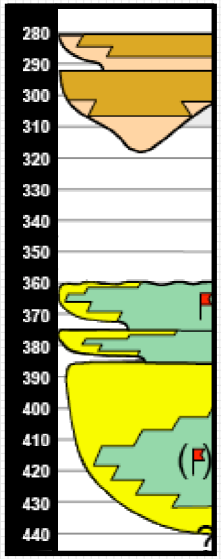
Meso-Cenozoic Megasuture



Subduction B (Benioff)
Subduction A (Ampferer)

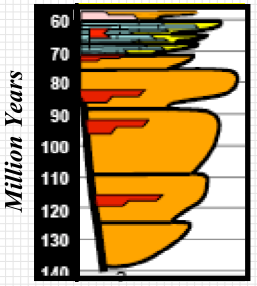
Prolific Argentina Basins

Paleozoic Basin



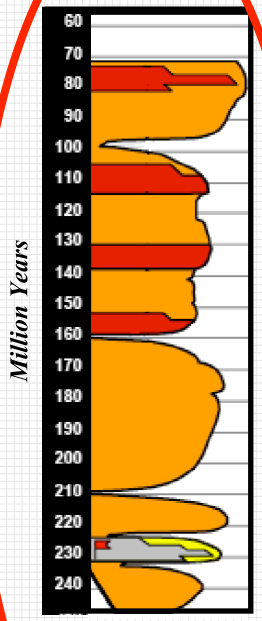
Main Source Rock :
Los Monos Formation,
Lower Devonian
Organic matter type II/I I
to III/IV

Cretaceous Basin



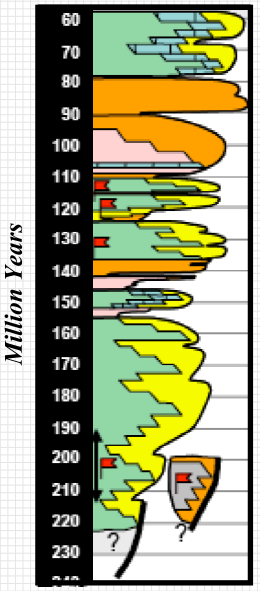
Main Source Rock :
Yacoraite Formation,
Lower Creaceous
Organic matter type I (III)

Cuyo Basin



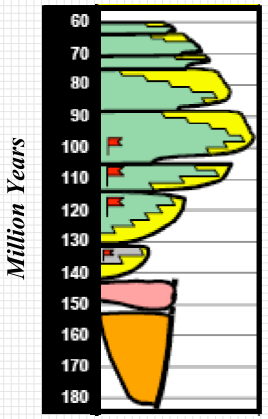
Main Source rock :
Cacheuta Formation,
Middle Triassic
Organic Matter
Type I

Neuquen Basin



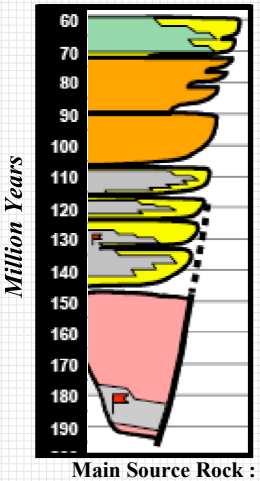
Agrio, E. Cretaceous
type II- II/III)
Vaca Muerta, L Jurassic
type I/II
Los Molles, E Jurassic
type II/III

San Jorge Basin



Main Source Rock :
D-129 Formation,
Early . Cretaceous,
Neocomian
type II(III)

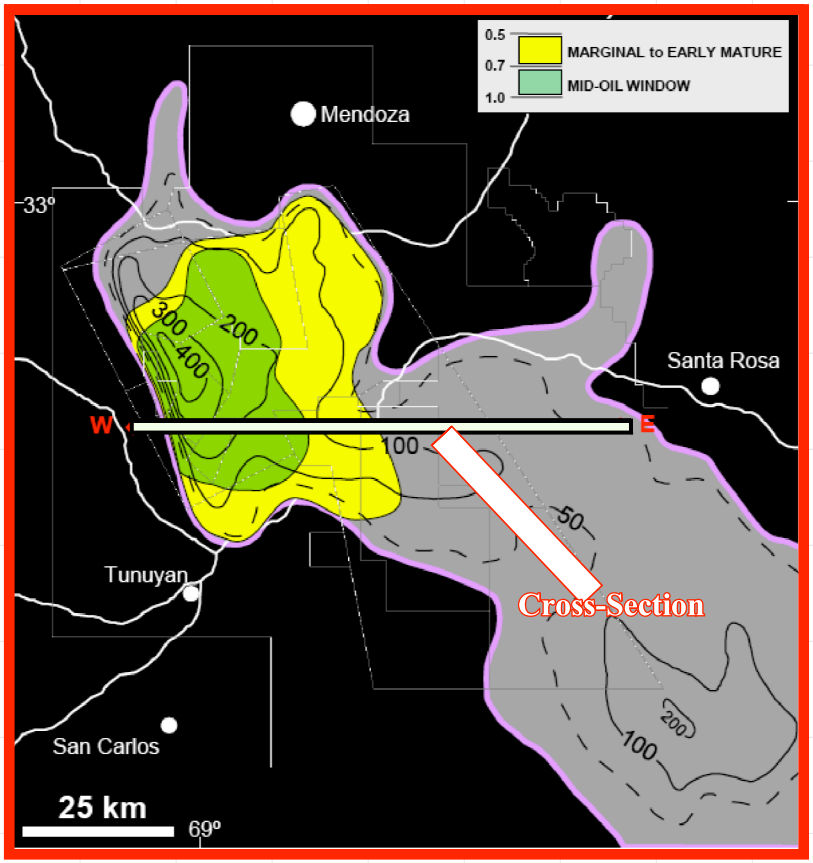
Austral Basin



Main Source Rock :
P. Aike Formation,
Organic matter type II/III
S. Tobifera Formation,
Organic matter type I/III

Cuyo Basin

Cachueta Formation (Triassic)



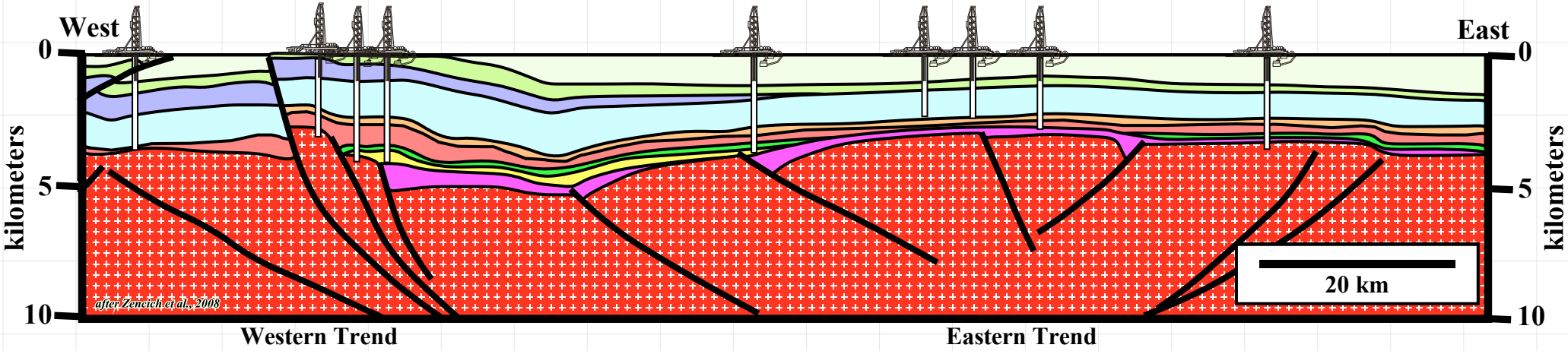
Deposited in deep lakes, with main deposcenters coinciding with the axis of important asymmetric troughs, developed on top of a collapsed Late Paleozoic orogen.

TOC : 3-10 %
Kerogen Type : I
VKA : Algal (Botryococcus-rich)- amorphous, with minor terrestrial contribution.

Source Quality/Maturity :

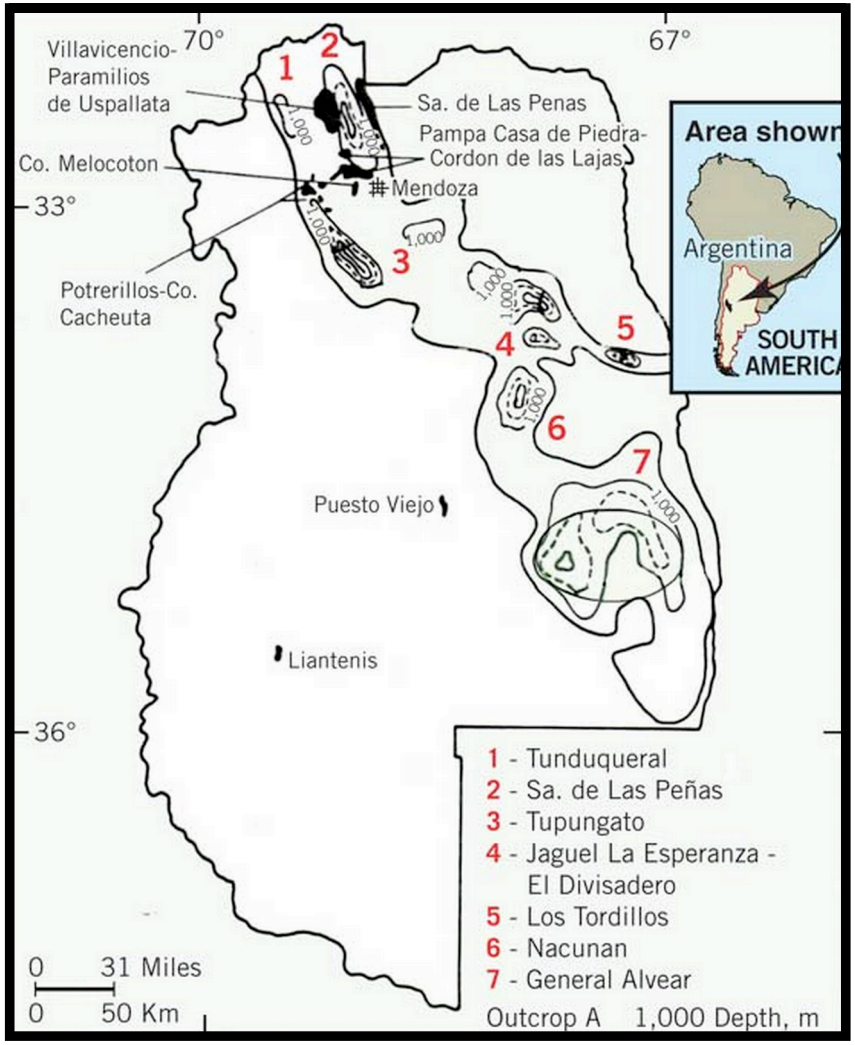
Overall low thermal maturity of the source rock at a basin scale, balanced by an excellent generating capacity of the Tupungato kitchen. Waxy oils, nearly no gas production.

Thickness : 50 to 400 meters



Argentina Cuyo Basin

(depocenters)



modified by Pucci, 2103, after Kokogian et al., 1993

Oil fields in Argentina's Cuyo basin, lying just north of the Neuquen basin, are concentrated in only about 5% of the basin's total areal extent of 42,640 sq km.

Commercial production in the Cuyo-Cacheuta basin began in 1932 with the Cacheuta-1 oil discovery well. However, since 1877 asphalt outcrops were exploited for domestic use.

The Cacheuta subbasin is well known due to extensive exploration carried out by Yacimientos Petroliferos Fiscales and private companies.

This article is a detailed discussion of the Alvear subbasin with an eye to the potential for unconventional hydrocarbons, which can be found at drilling depths of 1.000-2.300 m.

At present no company holds a license to explore for hydrocarbons in unconventional formations in the Alvear subbasin. Licenses are granted by and may be proposed to the provincial authorities.

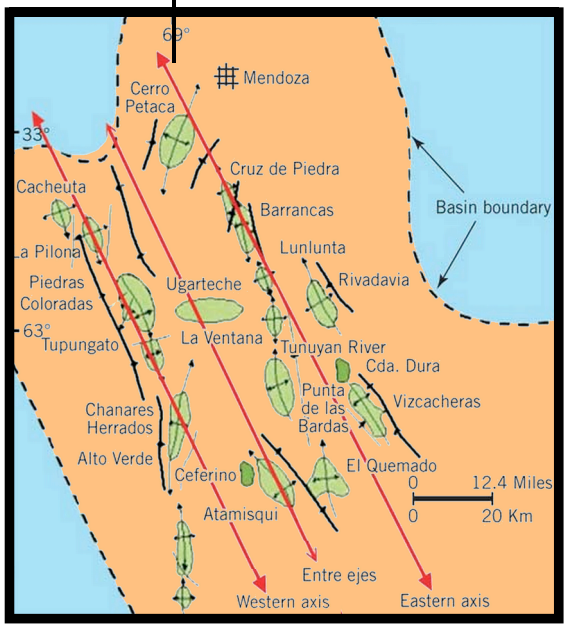
Since the dawn of exploration in the Cuyo basin, 414 wildcat wells have been drilled and seismic acquisition totals 20727 line-km of 2D and 2 704 sq km of 3D.

Much information is available at the office of the secretary of energy of Mendoza Province, but more data such as lithological descriptions and well reports are necessary for a better assessment.

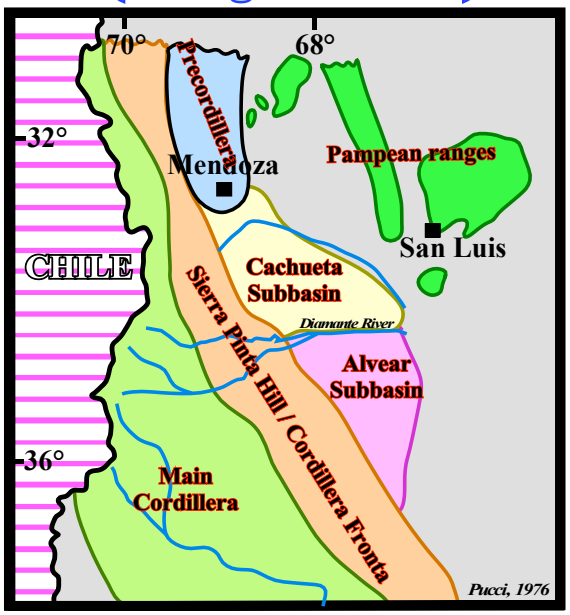
As of December 2011, Cuyo proved reserves were 33 057 million cu m of oil and 715 million cu m of natural gas. As of 2012, cumulative oil production was 195 772226 cu m.1

Argentina Cuyo Basin

(Main fields)



(Geological divisins)



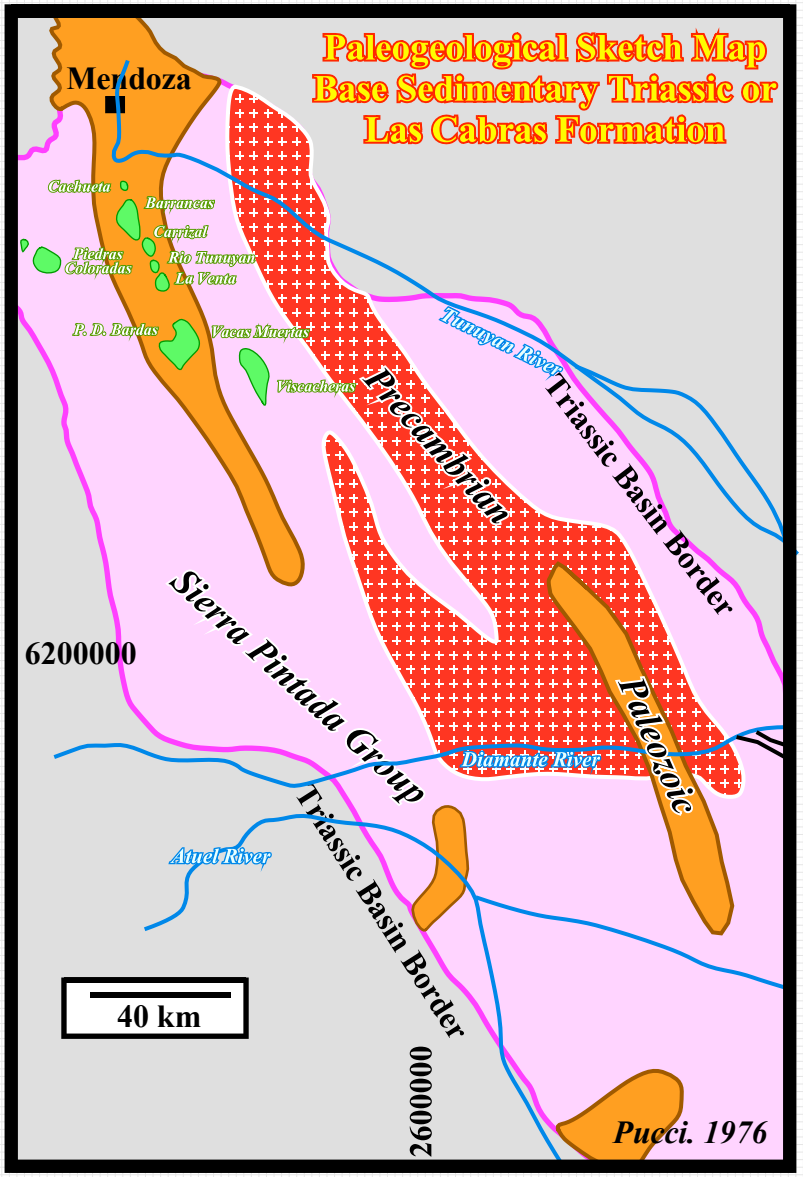
Cuyo Geology

The evolution of the Triassic-Cretaceous Cuyo basin, located in the Precordillera of Western Argentina, was mainly controlled by extensional-transtensional tectonics along northwest-trending structures inherited from Paleozoic sutures, revitalized during the Cenozoic as a foreland basin due to the Andean orogeny current responsible for the structural configuration. The Cuyo basin comprises several subbasins or depocenters ranging in depth from 1,000 m to more than 4,000 m.The Cacheuta-Tupungato depocenter is the only area with oil production. The Cuyo basin is elongated in a NNW-SSE direction and has a taphrogenic origin.The western limit corresponds to two significant orographic systems:(i) the Precordillera and (ii) the Frontal Cordillera. To the southwest it is bounded by the Sierra Pintada system which separates the Cuyo basin from the Mesozoic Neuquen-South Mendoza basin.The eastern boundary includes metamorphics and igneous rocks (Paleozoic and Proterozoic) of the Pampean ranges and Permotriassic volcanic rocks of the Sierra Pintada Group (Choiyoi group). To the north Triassic sediments exceed the boundaries of Mendoza Province and are exposed in a huge sector of the precordillera of the San Juan Province.

The origin, stratigraphy, distribution, and sedimentary environment of each of the formations have been subject to an analysis in several published works in the last decade. Since detailed discussion of stratigraphy is not the main purpose of this article, interested readers are referred to those works. Here only aspects fundamental to understanding the Alvear subbasin's exploration potential are discussed.

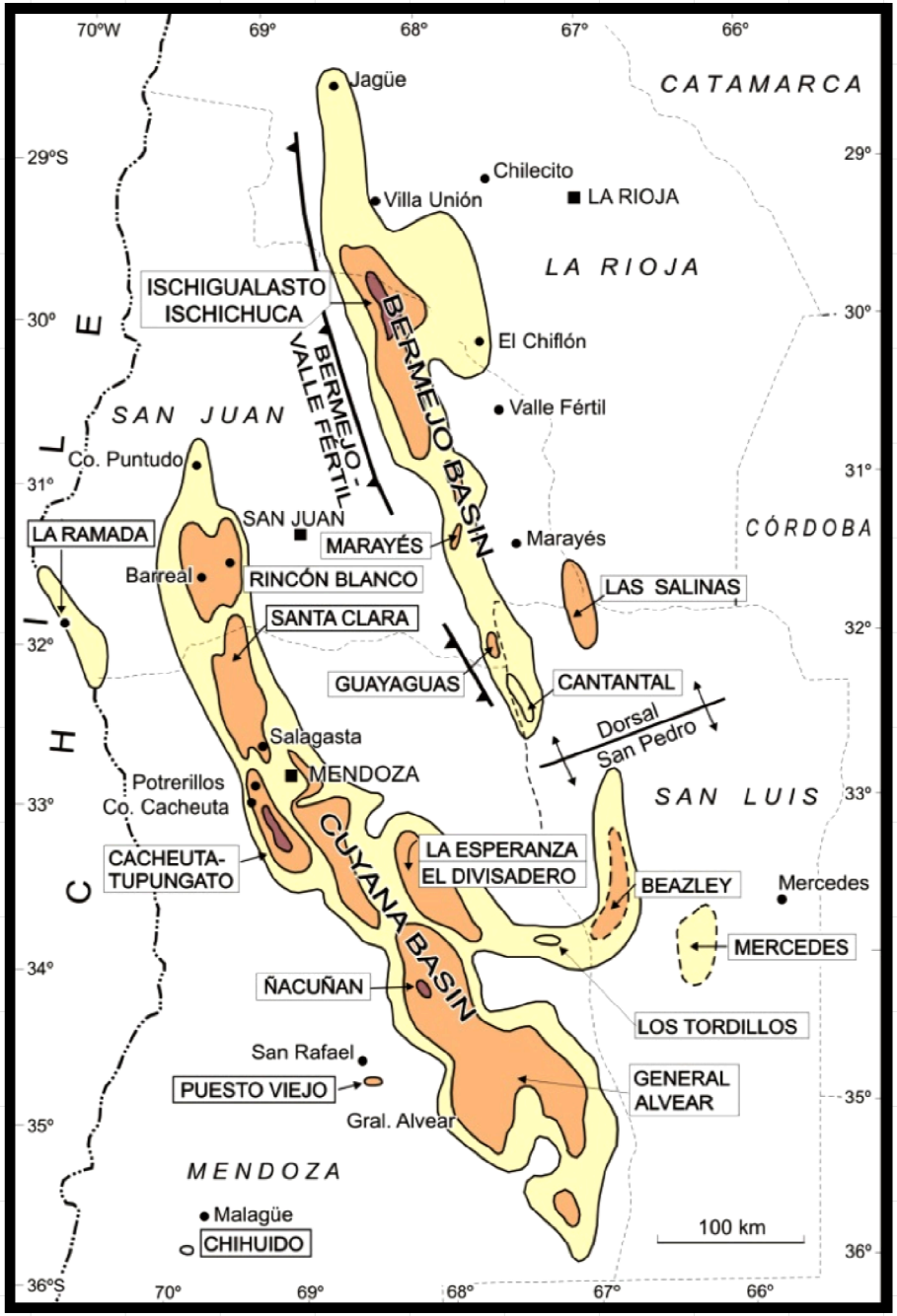
The Cacheuta and Alvear subbasins are mainly subsurface features in which most of the formations found in the subsurface of the Cuyo basin were originally defined from outcrops in the mountains west of Mendoza city.

Argentina Cuyo Basin
(Cachueat & Alvear Subbasins)



The Cacheuta is one of these subbasins, which, in the paleogeological sketch map appears connected to the Alvear subbasin. This connection apparently existed at the beginning of Triassic times, but the precise origins of communication in some sectors seem to have existed in uplifted areas of pre-Triassic units that served as early separation and supply areas.

The separation between the Cacheuta and Alvear subbasins is due to an original paleohigh or dorsal feature at about 34° South Latitude. This high, known as the Rio Diamante dorsal, is located in close combination with the current course of the Diamante River.

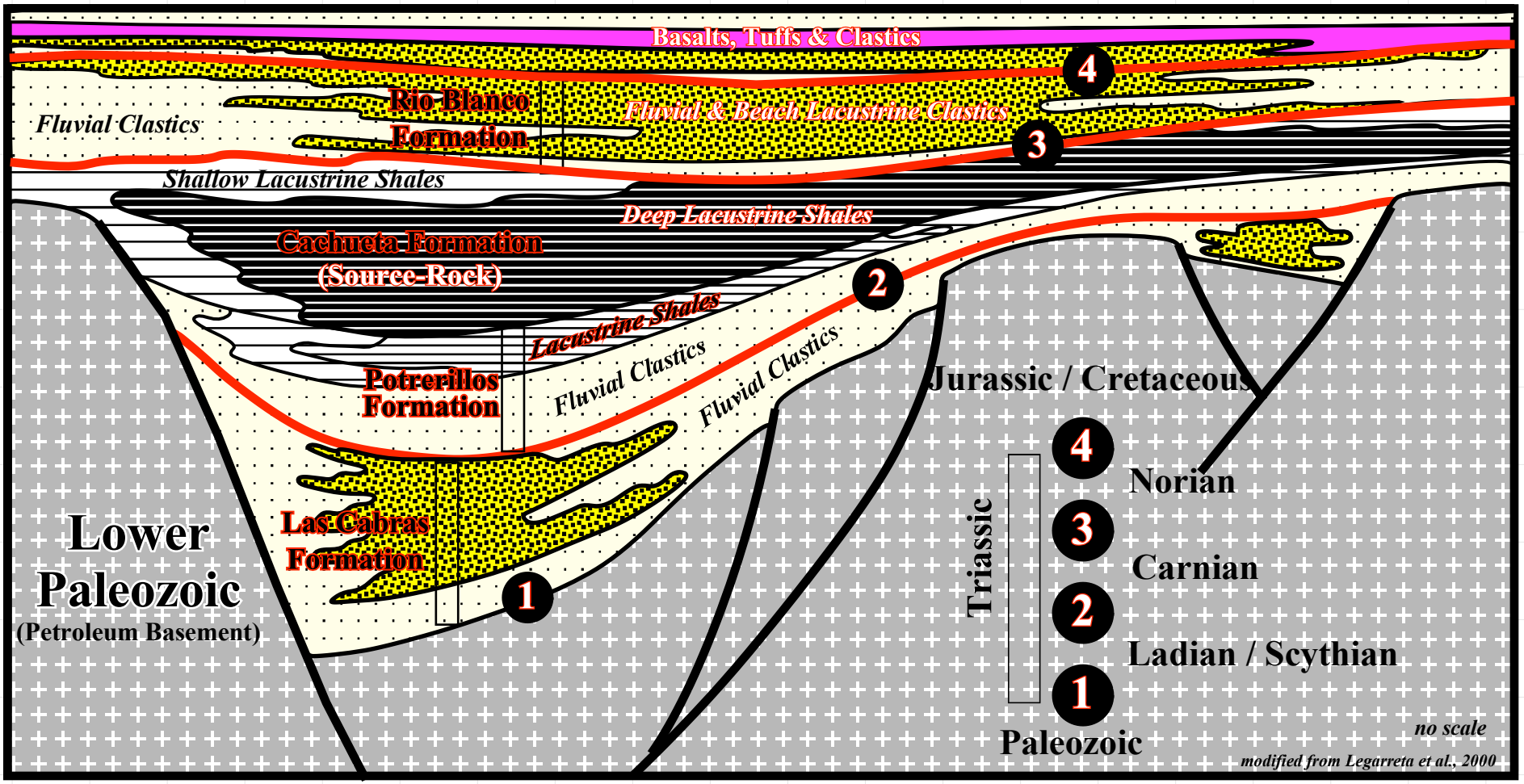


Triassic Rift-Type Basins

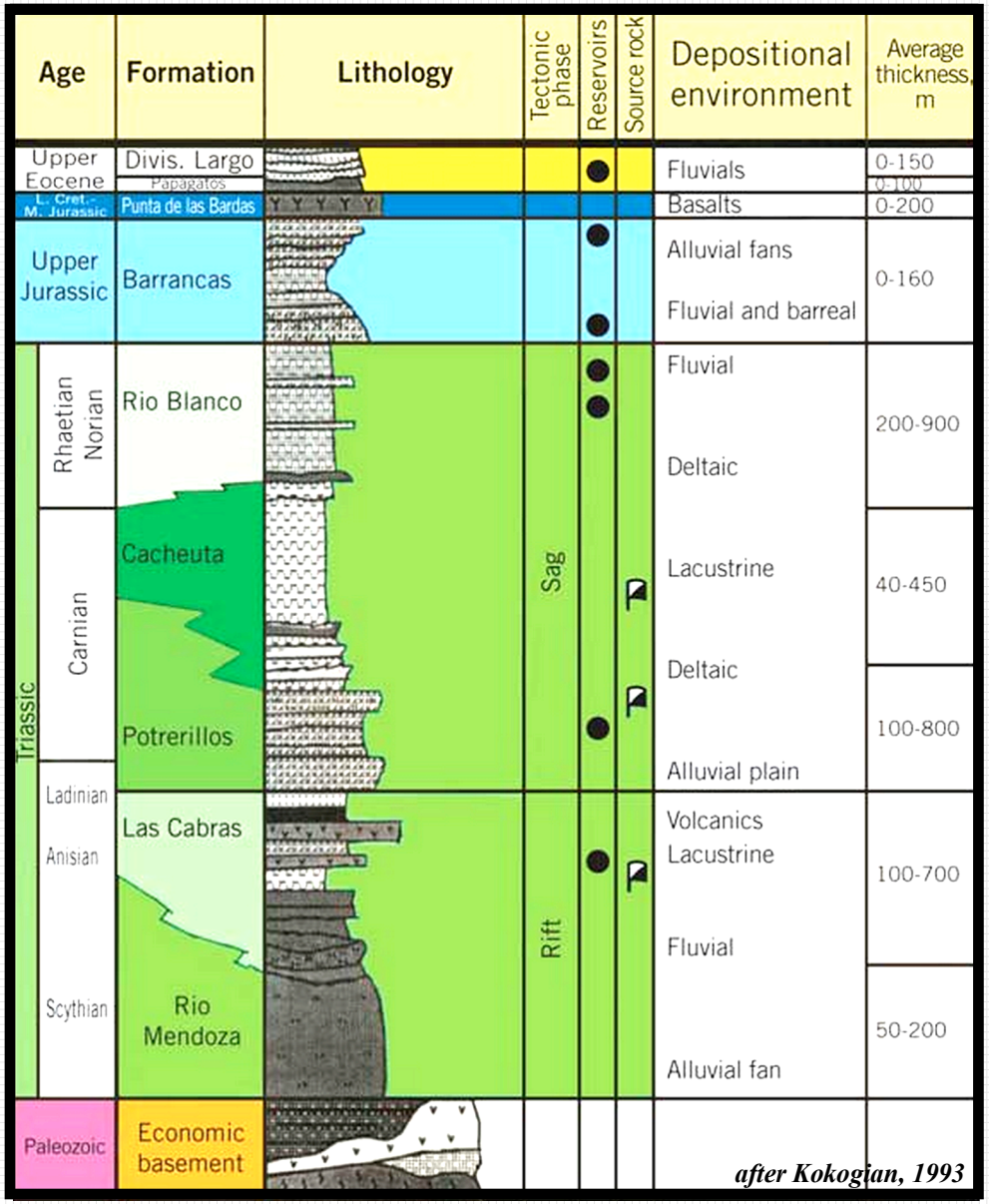
Central Western Argentina

Cuyo Basin

(Major Stratigraphic Units)

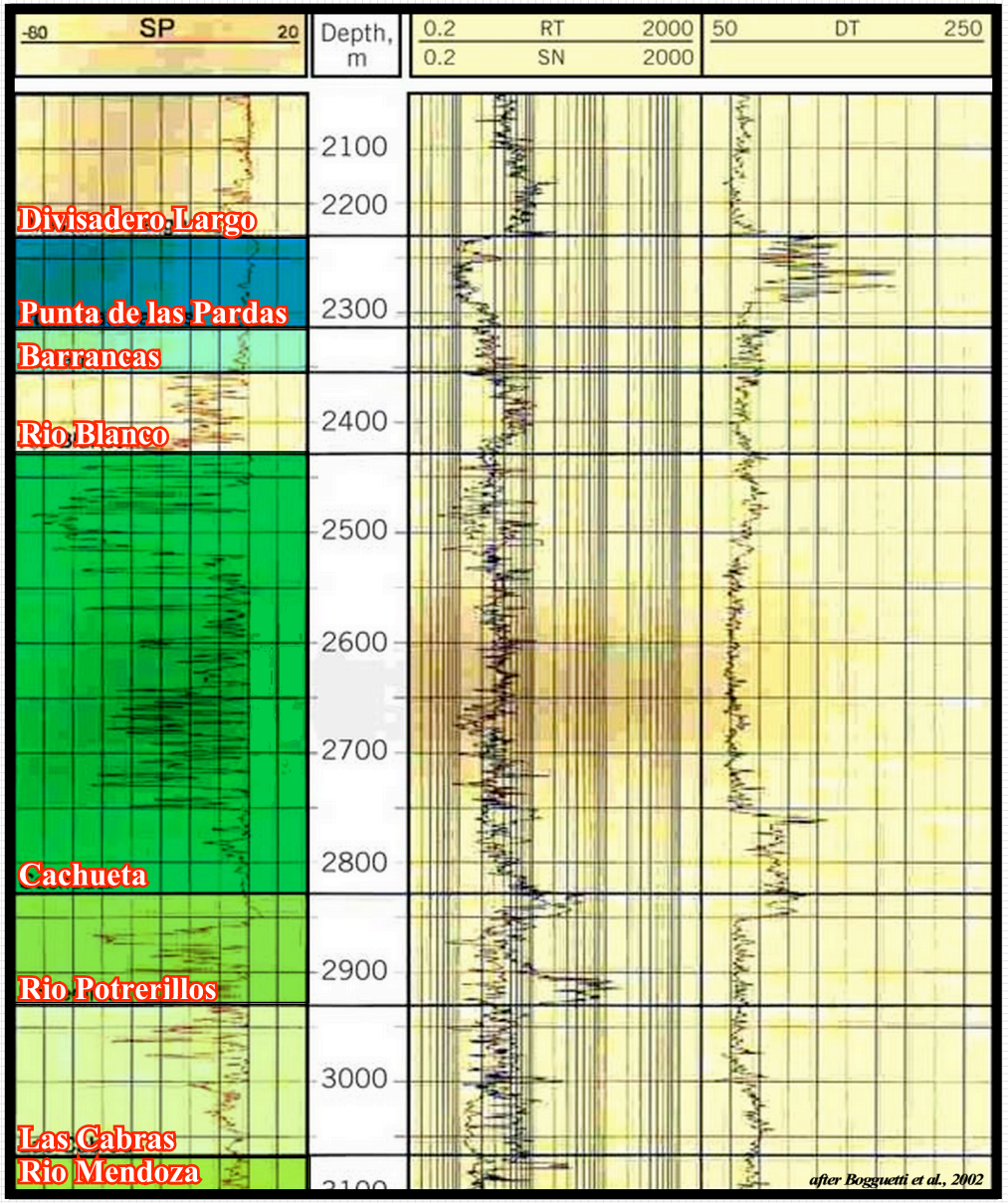


Argentina Cuyo Basin
(Stratigraphic Column)



The stratigraphic column of the Cuyo basin in the Cacheuta-Tupungato depocenter mainly consists of Paleozoic rocks and a Permian-Triassic volcanicclastics complex. The overlying units are composed primarily by Triassic continental sediments and also Jurassic-Cretaceous and Lower Tertiary nonmarine and volcanic rocks).

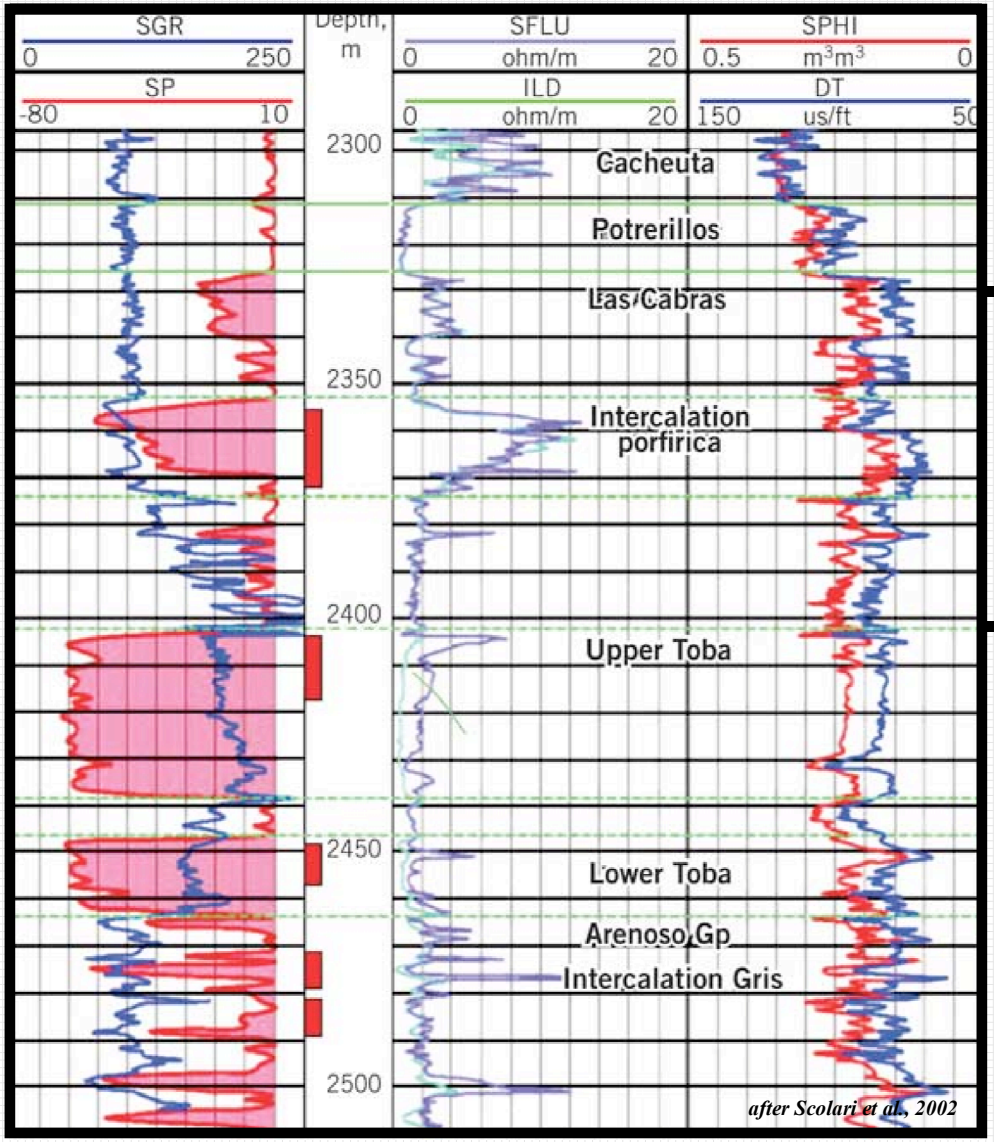
Argentina Cuyo Basin
(Type Electrical Log)



The Triassic section from base to top is made up of the Rio Mendoza, Las Cabras, Potrerillos, Cacheuta, and Rio Blanco formations.The Rio Mendoza formation unconformably overlies volcanic and volcaniclastic deposits of the Choiyoi Group.

Argentina Cuyo Basin

(Las Cabras Formation Type Log)

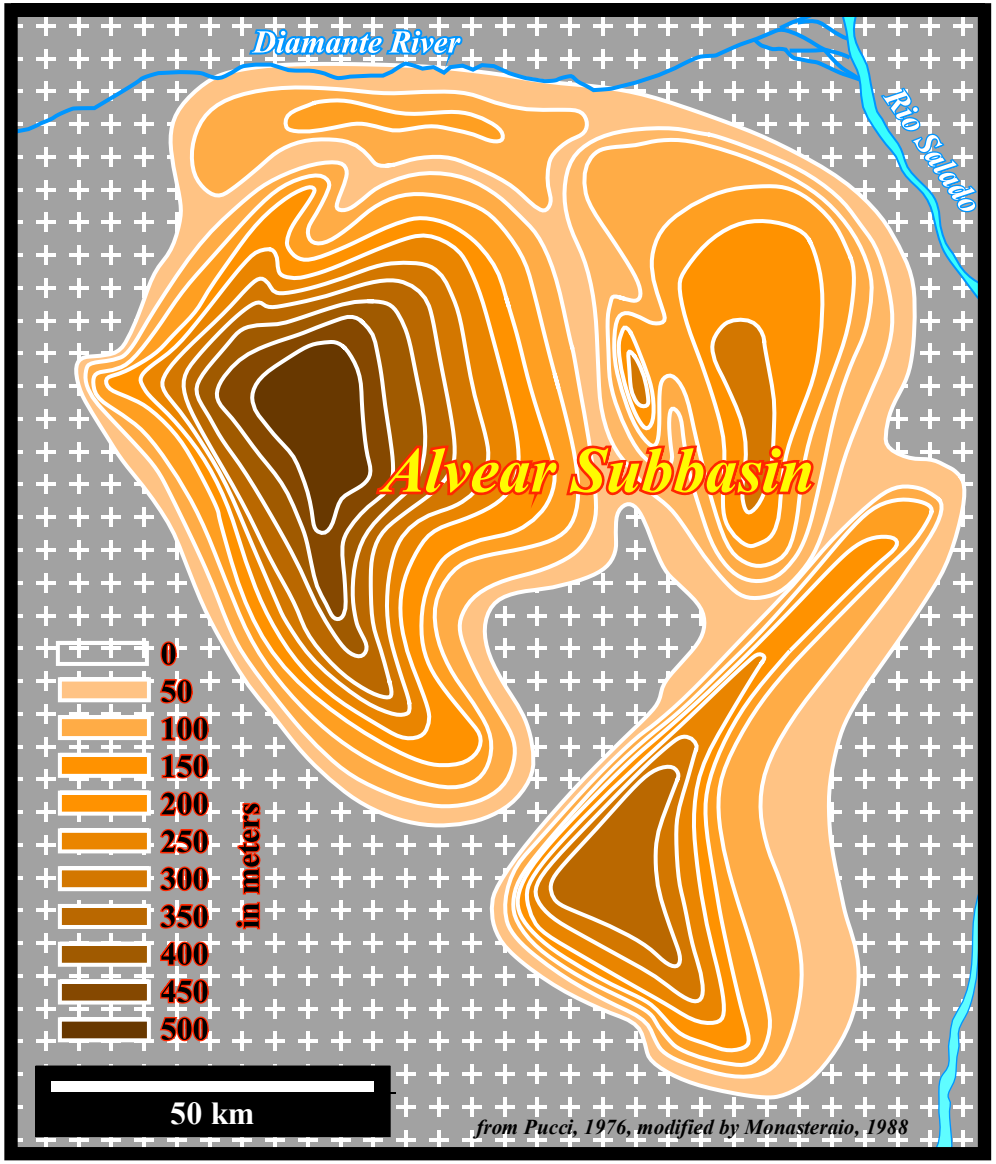


Las Cabras

Overlying Rio Mendoza formation, Las Cabras formation is a thick unit. Its lower part is a mudrich succession with intercalated lenticular bodies of conglomerates and pebbly sandstones. The upper section is a fine-grained succession composed of multicolored mudstones, tuffs, and pyroclastic siltstones.

Argentina Cuyo Basin

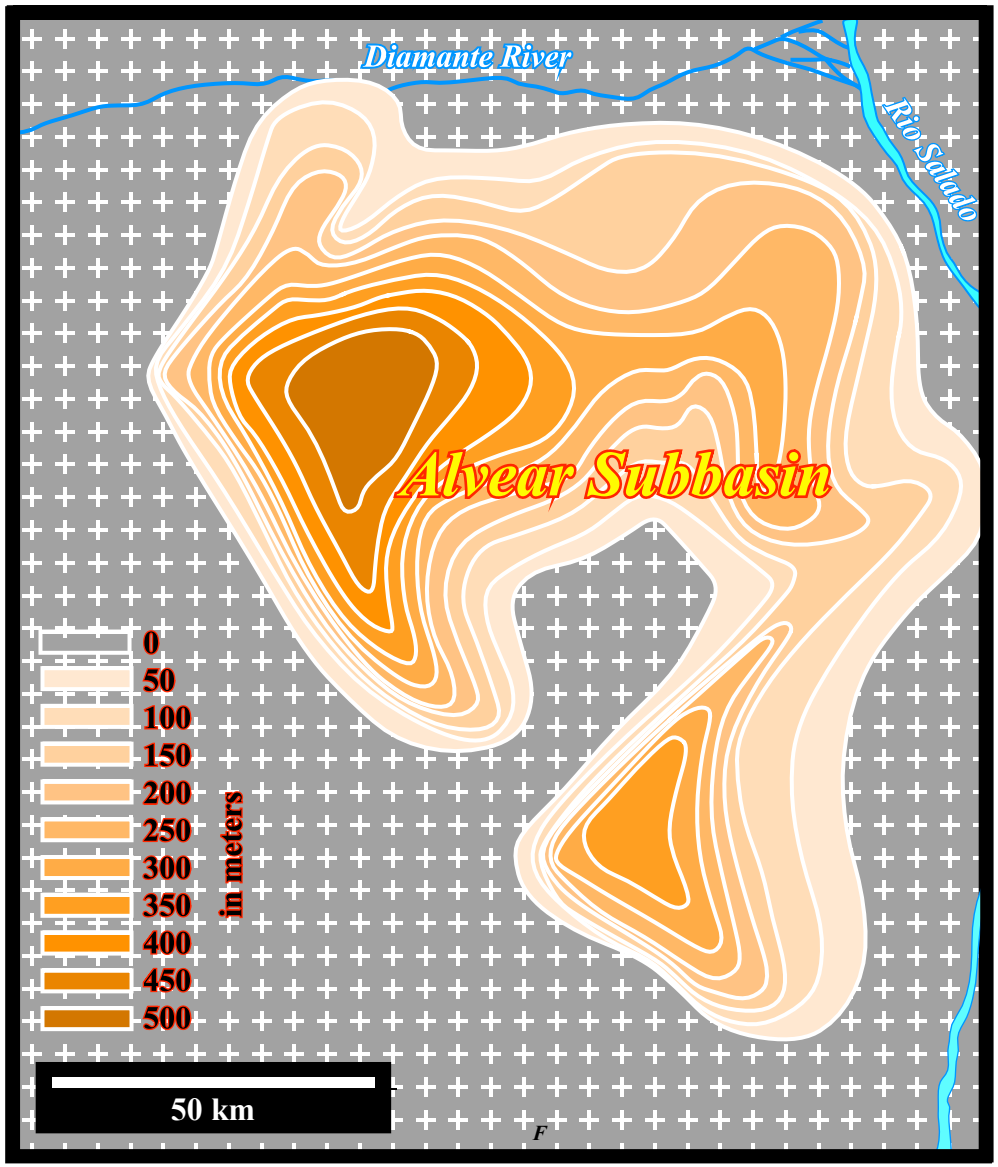
(Potrerillos Formation Isopach Map)



The Potrerillos formation is the thickest Triassic unit and is characterized by cyclic alternations of gravel-, sand-, and mudrich intervals.

Argentina Cuyo Basin

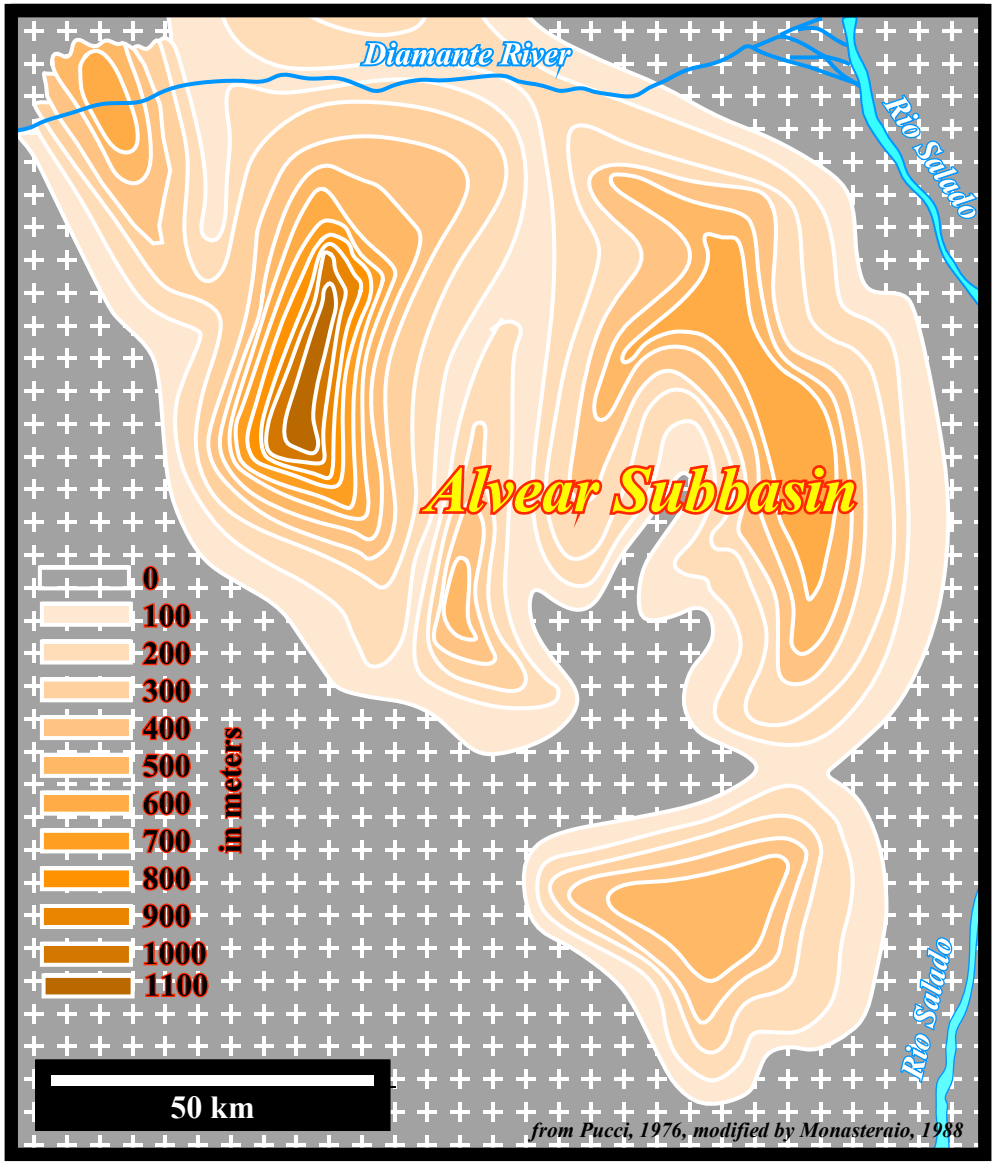
(Cacheuta Formation Isopach Map)



The Potrerillos formations are followed by a succession of black shales of the Cacheuta formation.

Argentina Cuyo Basin

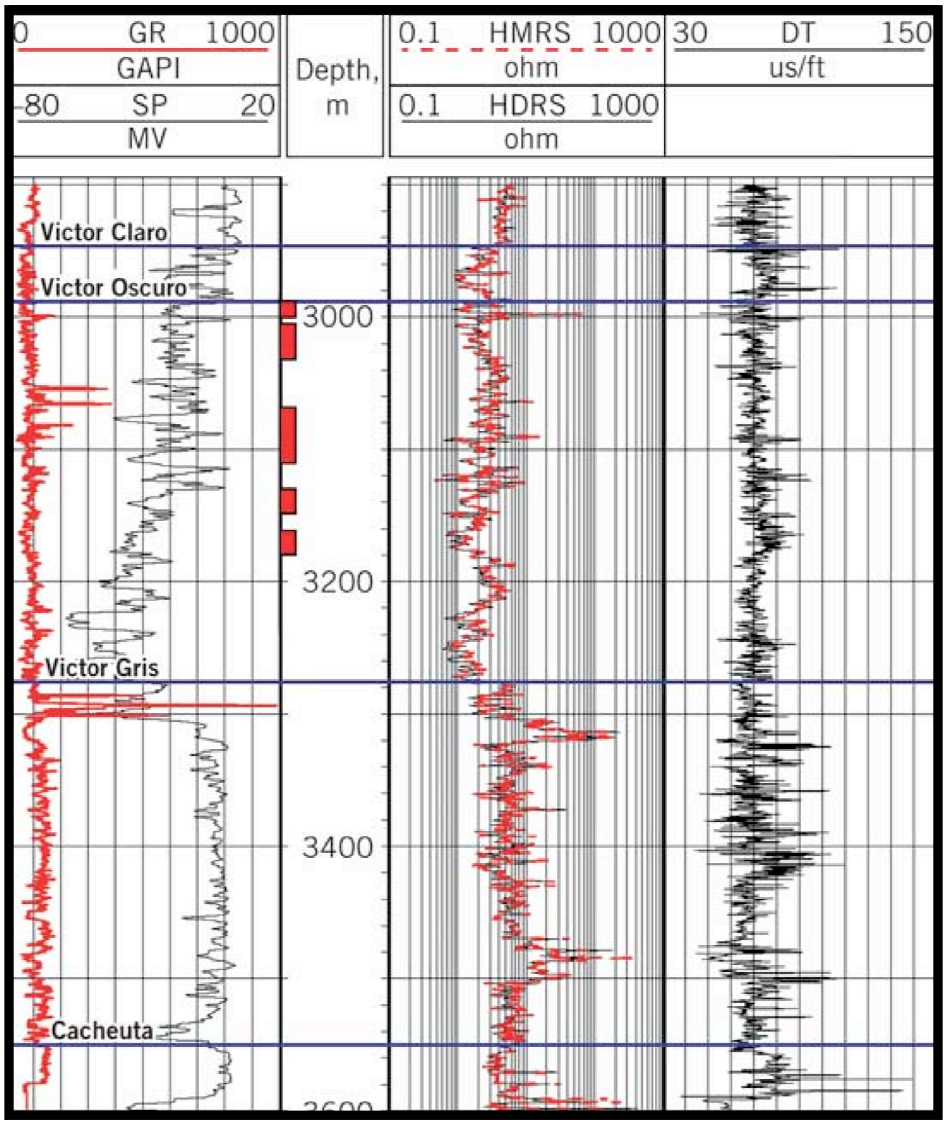
(Rio Blanco Formation Isopach Map)



The Triassic succession ends with the red beds of the Rio Blanco formation composed of fluvial and lacustrine sediments.

Argentina Cuyo Basin

(Rio Blanco Formation Type Log)



With the deposition of the Rio Blanco formation, the Triassic sequence acquired its maximum extent. In addition, the communication between the Cacheuta and Alvear subbasins was restarted. This communication was made mainly from the northwest of the Alvear subbasin, as evidenced by YPF´s Estacion Monte Coman-1 and Alvear West-1 wells.

In the Cacheuta subbasin two anticlinal axes oriented NNW contain the most characteristic surface features. They are the western and the eastern axes. Fields in the western axis contain 12% of the oil production while 88% is from eastern axis fields.

Source rocks

Geochemical analyses recognized only two source rocks in the Cuyo basin.The major proven source rock corresponds to the entire Cacheuta formation and the upper third of the Potrerillos formation . The other corresponds to the bituminous pelites from the informally named “intercalacion gris” (grey intercalation) in the Las Cabras formation.

More than 60 wells and a dozen outcrop sections corresponding to the upper third of the Potrerillos formation and the entire Cacheuta formation were analyzed to obtain total organic carbon values.Analysis of subsurface samples showed average TOC values of 4 wt %. Maximum values varied from 5 wt % for proximal positions to 12% in distal positions of the basin.

TOC values of 0.2-0.9% were found in the Rio Blanco formation. While this last magnitude is appealing, the inertinite found on these levels reduces the possibility of hydrocarbon generation. Regarding the “i ntercalacion gris” (grey intercalation) of the Las Cabras formation, its TOC value is known only by Strelkov and Alvarez. Analytic-quantitative studies are also unknown. In most cases, the amount of organic matter present in the previous column varies in the developing of the sedimentary Las Cabras and Potrerillos formations. Maximum TOC values were established in packages corresponding to lagoons or ephemeral inundations. TOC values are strongly relevant and continuous where they contact with lacustrine deposits of the Cacheuta formation and rapidly decrease when measurements are taken on fluviatile levels of the Rio Blanco formation.

It was possible to define with certainty that the lacustrine pelites interbedded in the upper third of the Potrerillos formation and the thick packages of black shales of the Cacheuta formation, have Type I kerogen, i.e., basically, algal material. The Potrerillos-Cacheuta column exhibits a gradual enrichment of Type I kerogen towards the top of that sequence, while there is an occasional presence of Type II (in middle levels) and insignificant occurrence of some shows of Type III (at the base).

This distribution of the types of organic matter is consistent with the depositional system responsible for such units, as it passes from base to top, from a definitely river system to terms that reflect the inundation of the basin with lacustrine pelitic packages.

The bituminous pelite located in the Las Cabras formation as potential source rock is more uncertain. Indeed, few wells have drilled through the intervals and provided samples for geochemical analysis. However, some correlation with the "grey intercalation" is exposed in outcrops of the Las Cabras.

Geochemical studies on samples indicated that the rocks are potential sources for hydrocarbons due to high organic content and to organic richness in saturated and aromatic hydrocarbons. It is unknown if studies on this unit have been continued or developed. In the Rio Blanco formation, the type of this organic matter is limited to Type III kerogen, with a predominance of inertinite that, usually, corresponds to the second cycle of organic matter, in consistency with the fluviatile system that represents this unit.

Maturity of organic matter was determined by the Thermal Alteration Index (TAI) and vitrinite reflectance. The Cacheuta formation revealed a maturity close to the initial generation of hydrocarbon liquids. Maturity in the west of Cacheuta and Tupungato, most high, is linked with a maximum of generation of oil. More favorable maturity for the generation is measured at deeper levels, corresponding to the upper third of the Potrerillos formation.

The processes of hydrocarbon generation, migration, and accumulation were triggered and controlled by the development of a Tertiary foreland basin that overlapped the Cuyo basin, providing the sedimentary column necessary for source rock maturation during the last 10 million years until the present.

Moderate mature oils (VRE ~0.7-0.9%) were sourced from the Tupungato kitchen to feed the reservoirs of the Eje Oriental (Eastern axis) district, after a long-distance lateral migration from the southeast towards the east through the Barrancas carriers. The Punta de las Bardas formation acted as an excellent quality regional seal. The contour area of Entre Ejes-Rio Hondo to the east sourced early oils (VRE ~0.55-0.7%) that were mostly trapped locally. Jones et al. defined five petroleum systems in the Cacheuta subbasin from a single generator level and five reservoir levels.

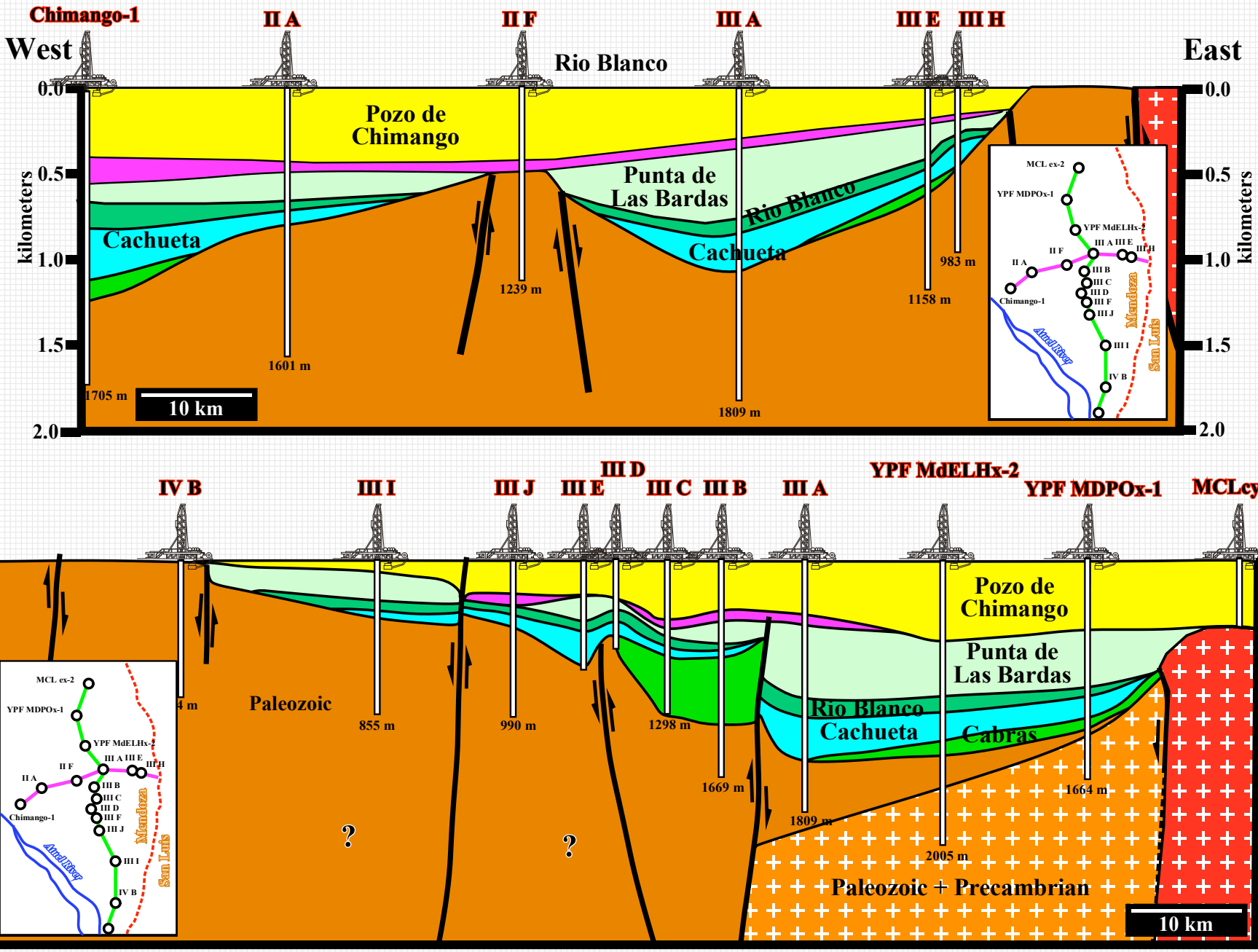
In the Tupungato area source rocks reach the oil generation window approximately at 12Ma while the deepest levels would fall in late phase after 2 Ma. However to the opposite east side, the Rivadavia zone continues immature at present, mainly due to the lower Tertiary subsidence, and left from the Andean front of deformation. The "between axis" area (Entre Ejes area) reaches the generation window at approximately 1 Ma.

To date, the analysis of migration paths has been tentative based on geochemical correlation of maturity and facies of oil-source rocks. Until now no publication or modeling has shown how and when the hydrocarbons generated in the Tupungato depocenter arrived to traps and reservoirs located in the eastern axis of the basin. It should be noted that in the Cuyo basin, almost 88% of the total production of hydrocarbons is yielded on the eastern axis, however the older source rock thicknesses and conditions of generation and expulsion occurred in the western axis. This might be an indication of lateral migration of 20-70 km.

The Triassic and Jurassic units (Barrancas formation) involved in the migration of hydrocarbons are composed of fluvial, braided, meandering, and ephemeral deposits. From the point of view of the primary porosity the main carrier are the clastic rocks of the Barrancas formation and subordinated by the Rio Blanco formation.

Argentina Cuyo Basin

(Alvear Subbasin Cross-sections)

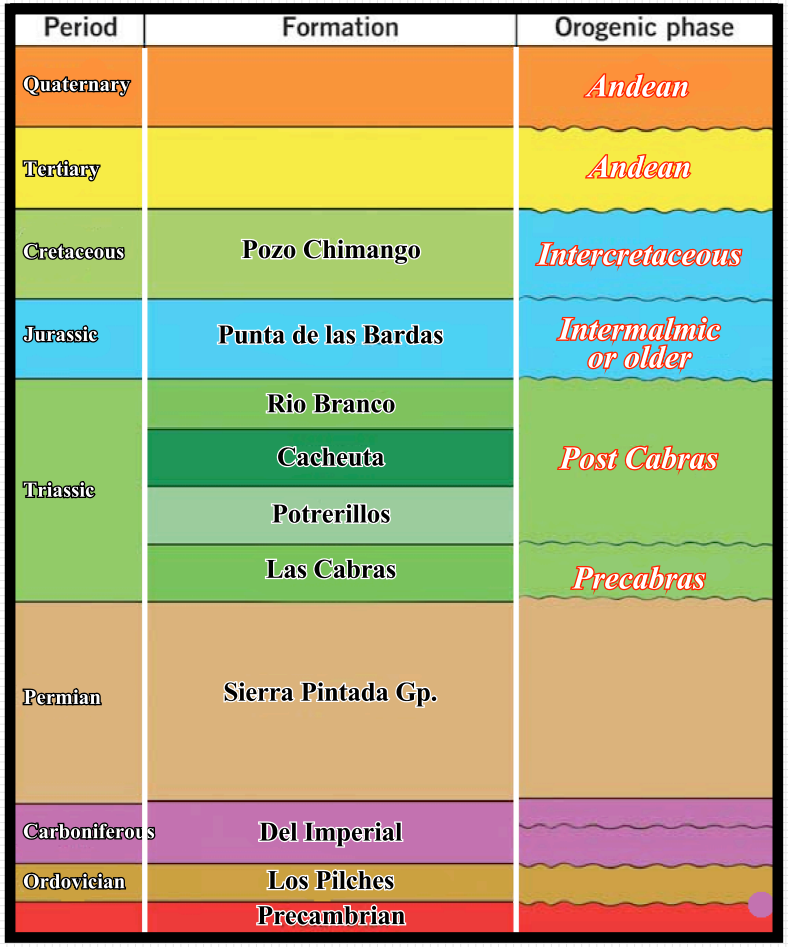


In the Cuyo basin is recognized an important network of subvertical fractures of different magnitude, possibly a reactivation of older deeper faults, that would provide excellent migration paths.

Argentina Cuyo Basin

The reservoirs correspond to rocks of continental origin; those with better petrophysical conditions correspond to the fluvial sandstones of the Barrancas (Jurassic) and Papagayos (Cretaceous) formations. The rest of the accumulations are clastic fluviodeltaic deposits and volcaniclastic of the Triassic Rio Blanco, Potrerillos, and Las Cabras formations Minor accumulations are included in the eolian deposits of the Areniscas Entrecruzadas member (Marino formation) of Tertiary age and the deep sea levels of the Villavicencio formation (Devonian).A detailed description of the exploratory plays of the Cuyo (Cacheuta) basin, associated to the Cacheuta Barrancas (!) oil system as to various hypothetical and speculative systems, can be found in Boggetti et al, 2005.

Argentina Cuyo Basin
(Alvear Subbasin Stratigraphic Column)



The stratigraphic column of the Alvear depocenter, although similar to the Cacheuta-Tupungato, is abridged. The lower layers are common to the Sierra Pintada hills located to the west. The Precambrian consists of the La Ventana formation whose levels, which were drilled by few exploration wells, are made up of granitiferous and micaceous schist rocks. In a sample recovered from the Gulf IV-D well, the radiometric age was found to be 605 Ma. The Cambro-Ordovician Pilches formation, which consists of sandstones, limestone, and shales are affected by gentle metamorphism. The formation is only a subsurface unit, penetrated by the SAOC/IV/B well, and the radiometric dating yielded values of 441 and 534 Ma.

The overlying unit is the carboniferous Imperial formation, whose levels are widely distributed in outcrops of the Sierra Pintada hills and were penetrated in several wells in the depocenter. Essentially, the lithology consists of clayey and conglomeratic reddish and yellowish sandstone with shaly and limolithic intercalations. The carboniferous sediments are overlaid volcanic rocks with some tuffs and few sediments whose conspicuous representatives are very well exposed in the Sanrafaelino-Pampeana geological province, from where derives its identification as the Sierra Pintada Group. Radiometric dating showed values between 200 and 270 Ma indicating a Permo-Triassic age.

Exploratory results

The results of intense exploratory activity, through reflection seismic surveys and the drilling of 51 wells, allow formation of a somewhat optimistic picture regarding the depocenter prospectivity. Several exploration areas were awarded to Gulf Oil, Esso, and YPF. Exploration began in the late 1960s, and as a result of exploratory commitments companies recorded almost 4,000 line-km of reflection seismic and drilled 50 wells (22 by YPF, 26 by Gulf, and 2 by Esso). This stage was completed in 1972. After 20 years with no activity, within the framework of the exploratory "Plan Argentina," the General Alvear block was awarded in 1992 to the consortium comprising Tecpetrol SA and Shell CAPSA. The two companies recorded 800 line-km of 2D seismic and drilled Tp.Mz B x-1, the last well drilled in the Alvear subbasin.

Since the beginning of the exploration it was considered that the dark gray and black shales of the Cacheuta formationare the real source rocks, as in the depocenter located to the north. However, in the Alvear subbasin the amount of organic matter, measured in terms of TOC, is similar to that in the Cacheuta subbasin. The same occurs with the quality or type of organic matter, mainly consisting of algaceous and amorphous material (Type I), with subordinate proportions of Type II herbaceous and woody material.

Therefore, it would fully meet with two of the basic concepts to consider an adequate rich-organic-matter rock. Unfortunately, the exploration carried out by wildcat wells and the analytical work performed on the material recovered from wells, indicate with a high degree of certainty that the evolution or maturity of the organic matter contained in its sediments did not pass all stages that could establish the Cacheuta formation as a source rock for this region. After the deposition of the Triassic sediments, possibly due to the uplift of the San Rafael block, the region remained a high and stable area for long periods. This implied a relatively low rate of post-Triassic sedimentation, with the reduction of the thickness of the rocks overlying the Cacheuta formation.

The second negative element is the very low or almost zero tectonic influence of this sector of the basin during the tertiary compressive movements of the Andean tectonic. Nevertheless, horizontal displacements occurred, related to the fracture system and its relative movement that affected the different taphrogenic phases. Both factors, coupled, lead to a common result which is the insufficient lithostatic load and temperatures to make possible the development of organic matter to hydrocarbons in sufficient quantity to produce commercial accumulations. Analyzing the results of exploratory wells drilled in the depocenter, it appears that only this package of sediments is a potential source rock of the region, at least at the regional level.

The exception is some reduced sector in which the quality of organic matter reaches the "window" of liquid hydrocarbon generation, as verified by the production test of the Ituzaingo x-2 well that yielded 22.2 cu m of oil at levels corresponding to the Potrerillos formation. Three more wells drilled in the vicinity could not confirm the occurrence of hydrocarbons. The critical factor is the low level of maturity of the pelites of Cacheuta, regardless of their high TOC values and the type of the organic matter present.

Hydrocarbon potential

The information provided by the recording of 4,800 line-km of 2D seismic and drilling 51 exploratory wells in the Alvear subbasin allows us to conclude that there are good structural and stratigraphic conditions for the entrapment of hydrocarbons. In the folding structures, structural closures against faults, good reservoirs and seal rocks are recognized. The fundamental structural characteristics of the area consist of a series of blocks delimited by fractures with near-vertical inclinations. Such fractures show signs of differential movement. Few defined structures have been generated by these blocks, not existing in the zone certain evidence of compression movements.

As shown in the cross-sections, the different fractures have been reactivated in different periods, in a game of rise and fall of blocks, showing clear evidence of inversion relief, in relation to different cycles. This fact is very noteworthy, among the pre- and postcabras movements, as it also occurs in the Cacheuta subbasin. However, the results thus far have been discouraging, considered for the oil possibilities of the depocenter. The critical factor, from the point of view of the hydrocarbon potential of the depocenter, is the low maturity level of the pelites of the Cacheuta. The black and dark gray shales of the Cacheuta formation have organic matter in proper quality and quantity to generate hydrocarbons, but its maturity is not sufficient. The lithostatic load and the temperatures did not reach the values to enable the evolution of organic matter to hydrocarbons, as to produce commercial accumulations.

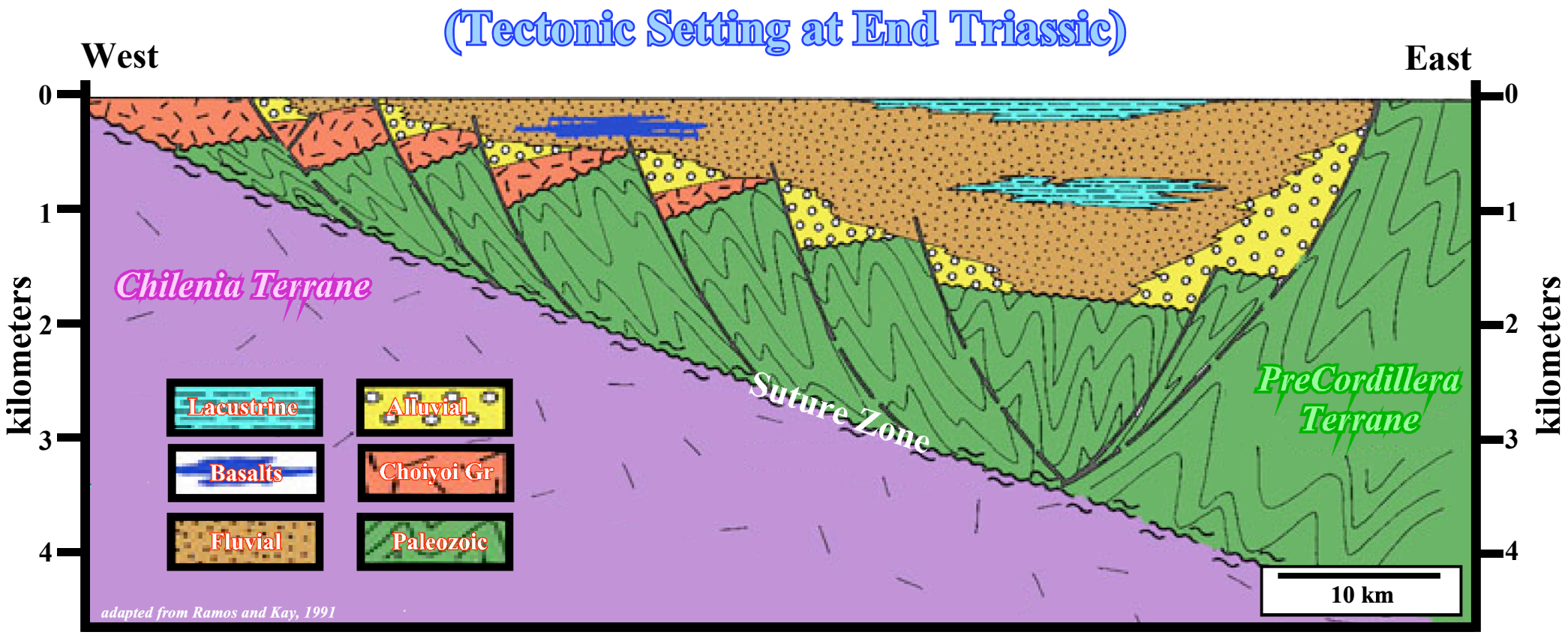
Organic material begins to appear in the gray portion of the Rio Blanco and becomes increasingly abundant with depth. In some wells thin black shale zones similar to the underlying Cacheuta formation, have been seen well above the base of the Rio Blanco. In the north there is a sharp contrast between the gray basal Rio Blanco and the very bituminous black shales of the Cacheuta formation. This lithologic contrast disappears farther to the south as the Cacheuta formation is less bituminous. In the northern part of the Alvear subbasin and in the Cacheuta subbasin the black shale facies extends up into the lower Rio Blanco so the basal contact is gradational. A proposal has been made to place the lower Rio Blanco (Victor Gris) in the Cacheuta formation.

Within most of the subbasin there are few sandstone lenses within the Rio Blanco, and these are generally thin and discontinuous. The only sand that appears to extend over a relatively large area is a 15-30 m thick basal lens that is present in the Nandu and Chimango wells and as far as M/GA/x-1 (Gen. Alvear) well. YPF's M/GA/x-2 well, near the western margin of the basin, has an unusual number of well-developed sand lenses in the Lower Rio Blanco.

The sandstones are loosely consolidated, generally quartzose, and vary from fine to very coarse grained. They are usually very argillaceous and, although logs indicate porosities varying from 20 to 30%, visual examination of sidewall cores suggests that effective porosity and permeability are low. Depending on the quantity and quality of information available (seismic and wells) the Alvear subbasin would not be a true exploration frontier area. However, it is necessary to remark that there are elements of the oil system that cannot be forgeted.

Hydrocarbon potential

The occurrence of oil in the Potrerillos formation, even in noncommercial quantities, shows different exploratory alternatives. Among them are areas of thermal anomalies associated with Cretaceous or recent volcanism enabling the generation in localized areas or migration over long distances by presently unknown carrier beds.



Although extension continued during the Late Triassic to Jurassic, Franzese and Spalletti (2001) have suggested that the Triassic-Jurassic (T-J) extension event should be considered as an independent extensional episode based on different tectonic frameworks for each extensional episode (Lower Triassic, T-J, Upper Jurassic). The T-J extension and bimodal magmatism were the result of margin mechanical interaction between the lithospheric plates at the Gondwana margin. In this setting the cessation of subduction paired with a dextral strike-slip regime at the continental margin caused the collapse of the slab and generation of an asthenospheric window . The Upper Jurassic extensional episode, which developed the Patagonian basins, is directly related to break-up of Gondwana

Composite Seismic Line
Cuyo Basin