ARGENTINA

PETROLEUM GEOLOGY BRIEF

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Petroleum Geology Brief

SUMMARY WITH RECOMMENDATIONS

1. With daily production around 487,000 barrels (77,500 m^3) and reserves in excess of 2.463 billion barrels (391.6 million m^3), Argentina is among the most important oil-producing countries. It also has major reserves of gas (estimated at 31.7 Tcf proved and probable, or 898 billion m^3) and current gas production of 1.24 Bcf/d (35.2 million m^3/d).

2. Sedimentary areas extend from the Andes on the west to the continental rise on the east, but not all of this vast region is prospective; rather, numerous massifs and basement highs separate it into 20 different sedimentary basins of varying size and promise (Fig. 1; Tables I-III). The potentially hydrocarbon-bearing areas cover about 1-1/3 million km^2 onshore and about half a million km^2 offshore. An additional 0.9 million km^2 of basinal area with hydrocarbon potential lies in deep water (more than 200m).

3. The 20 basins can be grouped into:

(a) seven major ones with commercial production (Table II);

(b) two major basins that do not yet have commercial production;

(c) seven small onshore basins, almost entirely unexplored, with no production; and,

(d) four other basins, largely offshore, with no production and very little exploration (Table III).

Most of the production is from Mesozoic reservoirs, predominantly sandstones, in more than 360 different fields.

4. In spite of the fact that Argentina's petroleum industry dates from the earliest years of this century, with more than 24,000 wells drilled, the country has not had the benefits of continuous, well-coordinated exploration and development of its petroleum. Periods of unsystematic and sometimes unsupervised work by small private companies and large international companies have alternated with periods when state organizations, hampered by shortages both of experienced professionals and up-to-date equipment, have tried to bring the industry to full, modern development.

5. At present Yacimientos Petroleros Fiscales (YPF), the government oil company, is dominant in onshore activity, while high-cost and high-risk offshore exploration has been entrusted to major multinationals, through contracts with YPF.

6. Gaps in petroleum engineering work have evidently parallelled the nonsystematic approach to exploration; for as recently as 1979, it is noted that (a) one-third of the natural gas produced was being vented or burned, while 80% of this amount had to be imported, and (b) less than 1% of the recoverable reserves of oil were attributable to secondary recovery operations.

7. As a result of this discontinuous and uncoordinated evolution of the industry, the body of technical knowledge about Argentina's oil and gas—whether geological, engineering, or geophysical—is not up to the level that might be hoped. All of the sedimentary basins, productive or not, have either been incompletely explored or remain unexplored. Their boundaries have not been well-defined, especially offshore, and their hydrocarbon potential has not been adequately appraised, either in terms of probable source and reservoir rocks, or in terms of different trapping mechanisms. Existing well files, in some cases scattered and incomplete, need to be filled out and updated to provide an optimum data base for thorough evaluation of all the basins.

8. Also, fundamental phases of geophysical exploration that were bypassed in many areas need to be carried out with modern equipment. Magnetometry can help define sedimentary limits and depth to basement in many basins, and can delineate important "windows," or thin spots, in the basalt that covers the unexplored Northeastern Basin. In fact, an aereomagnetic survey of the whole country could help complete the delineation of all the onshore sedimentary basins, and, in the process, perhaps reveal unsuspected areas of petroleum potential.

9. The stage of gravity surveying was also skipped in many regions, and some Argentine explorationists are understandably reluctant to go back and do gravity work in areas where exploration has already advanced to the drilling stage; but because of this, gaps will remain in the knowledge of the subsurface structure in places with no wells, or few wells. One new technique that ought to be considered is airborne gravity, which would be especially suitable in areas of difficult access.

10. Finally, there are still many gaps in seismic coverage, even in known prospective areas close to production. Modern seismic surveys could help develop new drillable prospects in those basins with established hydrocarbon potential. Offshore areas, on the other hand, should be systematically explored by private companies through risk contracts.

11. YPF geologists have estimated that an exploration program adequate to Argentina's needs will require at least 200 wildcat wells per year. Properly locating this many wells, while providing adequate geologic support for secondary recovery operations and gas development, will require an adequate "infrastructure" of geology, geophysics,and geochemistry, compiled and interpreted to come up with the best prospects.

OIL AND GAS PROSPECTS

12. The petroleum geology of this large country is so varied that prospects can best be discussed with reference to the individual basins (some

the size of Uruguay) in which the prospects occur. In very general terms, however, we can say that Argentina has excellent potential for major oil and gas discoveries, both onshore and offshore.

MAJOR SEDIMENTARY BASINS

13. As defined by YPF geologists, there are 20 sedimentary basins in Argentina (Table I), of which seven now produce oil (Table II). All of the seven except the Cuyo Basin also have significant gas reserves. Two others that do not have established production (Table III) bring the total of major basins to nine, with an aggregate surface area of more than 1,750,000 km^2 (of which something over 50% is considered prospective).

14. On the basis of calculated remaining reserves (Table IV), the onshore and onshore/offshore basins with the greatest future potential are the San Jorge and Neuquén basins. The other important prospect for the future is the Malvinas (Austral Marine) Basin, which lies entirely offshore; it has no established production at present, but three significant discoveries in the past year or so attest to its potential. The geology of all these basins is reviewed in a later section of this brief.

ONSHORE OIL PROSPECTS

15. Among onshore basins the most prospective are the Neuquén and San Jorge, which still have major potential. Only about 50% of the Neuquén Basin has been explored, and large onshore sectors of the San Jorge Basin remain to be tested. The Austral Basin is also considered highly prospective, although its potential is probably much less than that of the two just mentioned. The Cuyo Basin, on the other hand, has been extensively drilled, and small fields (perhaps with heavy oil) are the most likely future discoveries. Additional information on prospects in individual basins is given in the next major section of this brief.

OFFSHORE OIL PROSPECTS

16. Argentina's potential for commercial production offshore is highly favorable. The country has one of the broadest continental shelves in the world, encompassing 833,000 km^2 out to the 200-meter isobath (this is over 50% larger than the shelf area of the entire Gulf of Mexico). Of this, close to a quarter (196,000 km^2) is considered prospective, and nearly 2/3 of the prospective area lies in less than 100m of water.

17. Although commercial production has not been established offshore so far, 44 wildcats have been drilled on the shelf, with important discoveries recorded in the Malvinas Basin by Esso and Shell. Also, commercial production reaches right down to the coast in both the San Jorge and Austral Basins, whose offshore areas are about 50,000 km^2 and 25,000 km^2, respectively.

18. The four other offshore basins (Table III), totalling very roughly 400,000 km2 in gross area, have been little explored and are considered significantly less attractive than those already mentioned. The total prospective area for the four may amount to 25% of the gross figure just given.

GAS PROSPECTS

19. Argentina is an important gas producer whose real potential is far from realized. In fact, one of the most pressing energy problems for the country is the better utilization of the large volumes of gas now available from the known gas-producing areas. The bulk of the onshore prospects are located in the Neuquén Basin, which has 70% of the proved reserves and 80% of the probable reserves (Table V). The Austral Basin (including the undrilled offshore area) is second in importance; although the Malvinas Basin is considered highly prospective for gas, it is still in the earliest stage of exploration, and its real potential is unknown.

20. Other gas prospects are located in the Northwestern tripartite basin, where recent discoveries should substantially enhance the deep prospects. The San Jorge Basin also has potential for further gas discoveries, both onshore and offshore. Finally, there are the other (undrilled) basins mentioned previously, whose gas potential is entirely unevaluated.

GEOLOGIC FRAMEWORK

REGIONAL TECTONIC SETTING

21. In the broadest sense, the tectonic framework of Argentina has two main elements--the Andean Belt along the western border, and the cratonic area that occupies the rest of the country, including the Atlantic shelf. Upon these two basic elements, post-Paleozoic events have superimposed the many geologic complexities that resulted in the present arrangement of intracratonic and intramontane basins separated by massifs and basement highs.

22. The Andean Belt, in the simplest terms a response to the over-riding of the Nazca Plate of the Pacific by the South American Plate, trends north-south through most of Argentina. However, toward the southern end it turns sharply eastward in the zone of lateral movement between the Antarctic Plate and the small Scotia Plate to the northeast. Although there are a few intramontane basins in Argentina's Andean Belt, nearly all of the productive basins and all the basins with future hydrocarbon potential lie to the east of the Andean Belt.

23. The major portion of Argentina, onshore and offshore, is associated with the old cratonic region that marked the trailing edge of the South American crustal plate. During the Mesozoic this region was affected by tensional movements and downwarping which modified the old craton, creating epicratonic and taphrogenic basins of varying sizes. Cratonic areas that are still prominent today, in places veneered by relatively young sediments, include the Pampean Ranges massif in the northwest; the North Patagonian Massif in the south-central part of the country; the Deseado Massif in the southern onshore area; and its offshore prolongation in the Dungenes High.

STRATIGRAPHY

24. Stratigraphic relations in the older Paleozoic have been worked out for only a few areas of Argentina; in many places, pre-Devonian and even pre-Mesozoic strata are entirely absent (Fig. 2). And, as indicated in the previous section, Mesozoic and Cenozoic sedimentation took place for the most

part in separate basins; the stratigraphy of these is therefore discussed separately in the following sections of the brief. Fig. 2 gives generalized stratigraphic terminology for Argentina according to the principal basins; it also shows clearly the major hiatuses present in different areas.

GEOLOGY OF THE MAJOR BASINS

25. The degree of detail provided for each of the nine basins in the following discussion directly reflects the status of petroleum exploration: for example, considerable detail is available for the San Jorge Basin, with over 4,000 producing wells; whereas almost nothing is known about the Northeast Basin, which has yet to be explored in the subsurface.

Northwest Basin

26. The name Northwest Basin is commonly given to a composite depositional area containing sediments from six different periods of sedimentation. Of these, three are both important enough and sufficiently noncongruent geographically to be considered as separate--but largely overlapping--basins, called the Devonian, Carboniferous, and Cretaceous basins (Table II).

27. Tectonics: The Northwest Basin is limited on the west by the Cordillera Oriental (eastern Andean ranges). The western part of the basin is a fold-belt trending NNE-SSW (Fig. 3), including the sub-Andean ranges and the Santa Barbara System. The sub-Andean ranges are characterized by asymmetric folds overturned to the east; the folding is associated with west-dipping thrusts that slid on Silurian and Devonian shales. By contrast, the Santa Barbara System is marked by east-dipping thrusts and folding.

28. Stratigraphy: Economic basement is formed by Precambrian metamorphic rocks (with some plutonic rocks) and by Cambrian quartzites. As mentioned previously, the sedimentary fill was deposited in six partially overlapping depositional basins:

(a) the pre-Devonian contains a marine sequence of dark shales and light-colored sandstones;

(b) the Devonian, up to 6,500m thick, is a very widespread pre-Gondwana marine sequence of gray shales and quartz sandstones;

(c) the late Paleozoic sequence, mainly Carboniferous of the southern Tarija Basin, contains continental and shallow marine clastics;

(d) the Triassic, less than 200m thick, consists mainly of light-colored supposedly marine sandstones;

(e) Late Cretaceous-Paleocene strata up to 2,000m thick were deposited in two sub-basins, Metan and Lomas de Olmedo, both lying east of the Cordillera Oriental. The highly varied lithology includes continental clastics at the base; evaporites; dark-colored micritic limestones; oölitic limestones; calcareous shales; varicolored marls; stromatolitic banks; and light-colored sandstones; and,

(f) the later Tertiary basin contains a thick fill of continental clastics that can exceed 5,000m of post-Paleocene strata.

29. Petroleum Geology: Of the foregoing sequences, the Devonian, late Paleozoic, late Cretaceous-Paleocene, and later Tertiary are of interest in petroleum exploration. Source rocks include gray bituminous shales in the Devonian and Carboniferous; and in the Cretaceous, gray oolitic limestone and dark gray to black shales. Reservoir rocks include fractured quartzitic sandstones in the Devonian and older rocks. In the Carboniferous, oil and gas are reservoired in sandstones of good porosity. Late Cretaceous reservoirs are calcareous sandstones and carbonates. Hydrocarbons have also been recovered from Tertiary sandstones and conglomerates. Per-well production from the Devonian and Cretaceous basins averages 560 BOPD (90 m3/d), but from the Carboniferous the average is only 45 BOPD (7 m3/d).

Cuyo Basin

30. A taphrogenic basin elongated NNW-SSE, this old producing area is bounded on the west by the Cordillera Frontal of the Andes, and separated from the Neuquén Basin to the southwest by the uplift of the Sierra Pintada. The Cuyo Basin is transected into north and south halves by a major strike-slip fault, the Rio Seco de las Peñas Fault, with right-lateral movement. The prospective area within the basin is some 30,000 km2.

31. Tectonics: A Triassic basin, the Cuyo Basin was formed after the "Permo-Triassic magmatic cycle" associated with the orogenic phase of the Carboniferous Cordilleran geosyncline. Arching of the Pampean slab and transcurrent movements along old faults led to "en echelon" down-dropping of the graben blocks, which have irregular floors, sharp western limits, and more gentle limits on the east. The faulting was reactivated in successive stages up to the Quaternary.

32. Economic Stratigraphy: Into the basin blocks just described, up to 3,700m of petroliferous Triassic sediments were deposited; they are overlain by late Triassic to early Cretaceous basalt of the Punta de las Bardas formation, and up to 3,500m of largely nonprospective Cenozoic sediments. The most important reservoir is the Barrancas formation, youngest unit of the Triassic Cerro Cocodrilo Group. This formation is made up of conglomerates, sandstones, mudstones, and tuffs, deposited in an alluvial environment. The source of the basin's hydrocarbons was probably the black shales of the underlying Cacheuta formation.

33. Petroleum traps in the Cuyo Basin include asymmetric anticlines, closure against faults, and tilted fault blocks. The per-well average production is around 140 BOPD (22 m3/d).

Neuquen Basin

34. The Neuquén Basin, named from the province that it largely occupies, is bounded on the west by the Andes, on the east and northeast by the Sierra Pintada, and on the south by the North Patagonian Massif. The roughly triangular area thus enclosed covers about 140,000 km2, of which about 100,000 km2 is considered prospective.

35. The basin can be subdivided into three sectors:

(a) an Andean back-arc basin to the west, characterized by a complex structural style, with folding that is independent of the basement;

(b) the Neuquén Embayment, considered to be an aulacogen that evolved from a SE-trending Jurassic trench into a Paleocene sineclise. The boundary between these two sectors is the Los Chihuidos Axis, a north- to northeast-trending positive feature about 100km long. The Neuquén Embayment is characterized by simple platform structures—broach anticlinal arches and structural noses;

(c) the northern (Mendoza) part of the basin is much narrower, divided into three north-south trends reflecting the compressive stress regime:

(i) to the west, big, relatively open folds;

(ii) in the center, foothills structure marked by disharmonic folds and low-angle thrusting;

(iii) to the east, a platform of nearly undeformed strata.

36. Stratigraphy: Economic basement in this basin is a complex consisting of (a) metamorphic rocks presumed to be Precambrian in age; (b) Paleozoic marine sediments and granitic plutons; and, (c) Permo-Triassic lavas and pyroclastics. On this basement, continental deposition began in the late Triassic, followed by two Jurassic marine cycles of transgression/regression. The first cycle began with dark-colored marine shales deposited in the axial region of the basin, while continental clastics were laid down in peripheral areas; the cycle ended with evaporites that are limited to the central part of the basin.

37. The second cycle began with low-energy marine clastics grading laterally to littoral deposits, and followed by micritic limestones. The regressive phase of the cycle is characterized by gypsum with local varicolored marls, overlain by littoral and fluvial clastics in the east and by redbeds in the west.

38. On the disconformity that marks the end of this cycle, Late Jurassic conglomerates (continental to littoral) began the next depositional phase in some areas; in other parts of the basin, fine-grained sandstones are present. On these, dark-colored calcareous and bituminous shales were deposited. The regressive part of the sequence includes shallow-water carbonates (oolitic and bioclastic limestones, with intercalations of anhydrite and calcareous sandstone).

39. The next transgressive pulse, in Early Cretaceous time, began with conglomerates, sandstones, and littoral limestones. These are covered by dark shales, in turn overlain by redbeds marking a brief regression. Finally, the

last transgression of the sequence is marked by dark shales, and the regressive phase by gypsum, varicolored shales, salt, red mudstones, and sandstones. This sequence is separated by an unconformity from the gas-bearing Neuquén Group, a thick continental sequence.

40. Reservoirs and Traps: Commercial accumulations are found in strata all the way from Permo-Triassic (top of the Choiyoi Group--Fig. 2) to Late Cretaceous (Neuquén Group), in a great variety of reservoir lithologies. In the low-porosity Choiyoi Group, the oil is reservoired in abundant fractures. Quartzose sandstones (with some conglomerates) are the most common reservoir rocks in Jurassic strata; oolitic limestones, calcarenites and highly calcareous sandstones are more common in Late Jurassic and Cretaceous rocks.

41. The majority of the oil accumulations in the Neuquén Embayment are in combination traps (updip pinchouts of porosity in sandstones or limestones). The few structural traps in the Embayment developed from the reactivation of basement faults, creating horst blocks, asymmetric anticlines, and gentle folds. Some structures have been accentuated by differential compaction over basement features of high relief.

San Jorge Basin

42. Located in Central Patagonia, the San Jorge Basin underlies a large part of the tableland of the provinces of Chubut and Santa Cruz, and continues offshore into the Gulf of San Jorge, which gave the basin its name. The center of petroleum activity in this basin is the port of Comodoro Rivadavia—birthplace of the Argentine oil industry—located within the producing trend known as the "North Flank." The parallel South Flank producing trend likewise extends inland from the coast. No production has yet been established in the offshore part of the basin, nor in its northern and western extremities. About half of the basin's total area of 170,000 km^2 is considered prospective.

43. Tectonics: The San Jorge Basin is a classic intracratonic trough, elongated east-west and separated from the Neuquen Basin to the northwest by the North Patagonian massif; it is separated from the Austral (Magallanes) Basin to the south by the Deseado Massif. The northeasterly-trending Rio Chico Lineation divides the basin into two tectonic environments--to the northwest, a folded sector, and to the southeast, a block-faulted sector where most of the oil occurs in normal-fault traps. The western fold area has not contributed much oil, perhaps because the subsurface anticlines were strongly eroded in the past; only a few small flank accumulations have been found.

44. Stratigraphy: On an economic basement of Paleozoic (?) metamorphic rocks intruded by granites, deposition began in Early Cretaceous; the prolonged, slow, and almost uninterrupted subsidence was characterized by euxinic shales (Las Heras Group). Laterally, fanglomerates and deltaic clastics were deposited. The deposition was evidently affected by a direct shallow-marine connection with the Austral Basin, possibly via narrow channels through the Deseado Massif. This sedimentary cycle is separated from the overlying Chubut Group by an angular unconformity and by a pyroclastic event.

45. The sand-shale sequences of the Chubut Group, with some intercalated lava flows, are entirely continental except for Late Cretaceous marine

intercalations in the eastern (offshore) part of the basin. The majority of the reservoirs are fluvial sandstones with marked lateral variations in porosity; the undip pinchouts act as traps, in addition to the faulting mentioned above.

46. Following the post-Chubut unconformity, marine deposition began in the early Tertiary. The transgressive basal unit is the Glauconite Sandstone member of the Salamanca formation, which is the youngest oil-producing unit in the basin (the overlying Rio Chico formation produces gas). The total sedimentary fill reaches a thickness of at least 8,000m.

47. Productivity: Daily production totals around 107,000 barrels (17,000 m3/d) from the North Flank fields and around 91,000 barrels (14,500 m3/d) from the South Flank, for a basin total of almost 200,000 BOPD (31,500 m3/d). The per-well average is 56 BOPD (9 m3/d) on the North Flank and 40 BOPD(6.5 m3/d) on the South Flank.

Austral (Magallanes) Basin

48. The southernmost basin (as implied by its name) in Argentina, the Austral Basin occupies the whole onshore and offshore area south of the Deseado massif, from the Andean-Fuegian fold belt on the west and south to the Rio Chico, or Dungenes, High (a SSE extension of the Deseado Massif) on the east. Of the total surface area of 180,000 km2, about two-thirds is considered prospective. The present producing area stretches in a trend about 50 km wide along the coast, from southwest of Santa Cruz in the north to the Rio Grande in the south--a distance of more than 400 km.

49. Tectonics: The basin is an asymmetric trough elongated NNW-SSE, with a steep (folded and thrusted) western flank and a broad, gently dipping east flank; thus the basin axis, where sediment thickness exceeds 9,000m, is much closer to the Andean-Fuegian fold belt. The productive trend mentioned above lies within the broad platform of the eastern flank, parallelling the basin axis.

50. Stratigraphy: Basin subsidence and deposition began upon a very irregular floor of Jurassic volcanics and sediments. The high relief of this underlying surface is responsible for a mode of petroleum occurrence that is unique in Argentina: most of the oil is found in the Lower Cretaceous Springhill formation, an irregularly distributed clastic fill (mainly continental sandstone and carbonaceous shales) that is absent over basement highs and reaches maximum development in the intervening lows. The traps are thus formed by pinchout against the highs, with most of the oil occurring on the flanks and even in the low areas. Some petroleum has also accumulated in the Jurassic Tuffaceous Series, directly underlying the Springhill. The source of the oil was the mid-Cretaceous Palermo Aike formation, a thick marine shale that directly overlies the Springhill.

51. Productivity: Daily production reaches 6,300 BOPD (1,000 m3) in the Santa Cruz (northern) sector of the basin, and 25,000 BOPD (3,950 m3) in the Tierra del Fuego sector, for a total of around 31,000 BOPD (4,950 m3). For these two sectors the per-well averages are about 80 BOPD (13 m3/d) and 150 BOPD (24 m3/d) respectively.

Malvinas (Austral Marine) Basin

52. The most prospective of the major basins that does not yet have commercial production is the Malvinas Basin, also known by three other names: South Malvinas Basin, West Malvinas Basin, and Austral Marine Basin. The largest of Argentina's offshore basins, it is a triangular intracratonic trough between the Rio Chico-Dungenes High on the west; the Falklands Platform on the northeast; and on the south, the major thrust zone that forms the northern limit of the Burdwood Basin. The total area thus enclosed is about 150,000 km2, with sediment thickness reaching 10,000m in the deep southern part of the basin.

53. Prospective strata include the basal Cretaceous Springhill (see Austral Basin, above); younger Cretaceous marine units; and poorly consolidated Tertiary clastic units of high porosity. In addition to the two Esso discoveries discussed in a following section of this brief, Shell has also recorded encouraging tests in a recent wildcat in this basin.

Northeast (Chaco-Parana) Basin

54. The largest sedimentary basin in Argentina is the Northeast Basin (Fig. 1), which forms roughly one-third of the immense Paraná Basin of Brazil, Paraguay and Uruguay. The exact area of the Argentine sector depends on how the basin limits are defined, but it can be taken as about 520,000 km2, or more than twice the area of any other basin in the country.

55. The northwesterly limit of the basin is usually taken to be the Rincón-Caburé High, which may be a prolongation of the Asunción Arch that borders the Paraná Basin on the northwest in Paraguay. The southerly limit is the Martín García Anticline.

56. The maximum thickness of strata probably exceeds 5,000m, as it does in Brazil, but the true figure is unknown because of the lack of (1) outcrops, (2) geophysical data, and (3) exploratory drilling. These last two factors are due in turn to the thick cover of Juro-Cretaceous basalt flows, covering more than 1 million sq. km. in Brazil, Argentina, Paraguay and Uruguay, and considered the largest lava field in the world.

57. The maximum thickness of basalt exceeds 1,100m in Argentina; in the Brazilian sector of the basin, one well reported 1,531m of basalt. This great thickness impedes the seismic exploration that normally precedes drilling; hence, most of the stratigraphic information is from outcrops, or is extrapolated from wells in Brazil.

58. Crystalline basement (dated in nearby uplifts) is Proterozoic; on top of this is up to 1,900m of Cambro-Ordovician clastics. The overlying Siluro-Devonian sequence includes marine shales and continental and marine sandstones, with a maximum thickness estimated at 3,300m. The Carboniferous-Permian, up to 2,200m thick, has the same mix of continental and marine clastic rocks.

59. Paleozoic deposition may have taken place in an intracratonic basin of continental proportions, including present-day separate basins to the south (Macachín, Salado, Colorado, etc.) and others to the north, in Brazil. Later, during the rifting associated with the opening of the South Atlantic, this

giant basin was broken up into a number of distinct Meso-Cenozoic depositional sites.

60. In Argentina the Cretaceous strata overlying the basalt flows are continental clastics. The Paleocene to Lower Miocene strata are also continental clastics, but the mid-Miocene to Upper Pliocene includes marine shales and fossiliferous sandstones, deposited when a shallow sea covered the entire region from south of the present Salado Basin up to Paraguay, and west almost to the present San Luis Basin.

61. As indicated above, the petroleum potential of the northeast (Chaco-Paraná) Basin remains largely unevaluated. It is important to note that Petrobras discovered gas at Rio Chapeco in the Brazilian sector. Although commercial oil has not yet been found anywhere in this huge basin, its Argentine sector remains a major target for modern exploration methods.

Geology of Minor Onshore Basins

62. The seven onshore basins discussed in this section have surface areas of 5,000-16,000 sq. km. and sedimentary sections of only 1,000-6,000 meters. Although their petroleum possibilities are not comparable to those of the basins discussed above, most of them are untested and their real hydrocarbon potential is still unknown. The seven minor basins are listed in Table I and their locations are shown in Fig. 1.

63. - The Ischigualasto-Villa Unión Basin, in southeastern La Rioja Province, is an intermontane synclinal basin of Mesozoic age. Its estimated surface area is 5,000 sq. km. On a substrate of early Permian, sedimentary fill may reach a total thickness of 5,000m; it consists largely of volcaniclastic and continental sediments (redbeds), mainly Triassic, with some Cretaceous strata. No source rocks have been identified, and no drilling for petroleum has taken place.

64. - Little is known about the Las Salinas Basin, located near the southwest corner of Santiago del Estero Province; it is not mentioned in the authoritative publication Geologia Regional Argentina. Most of the present basin surface is a large intermittent lake that gives the basin its name; the surface area is roughly 8,000 sq. km. The inferred structure is that of a half-graben, faulted on the east side. The thickness of basin fill, consisting of continental clastics of Meso-Cenozoic age topped by late Cenozoic playa deposits, has not been determined. The petroleum potential is unknown.

65. - The San Luis Basin is located mainly in the province of that name, extending into southern La Rioja Province. With an area of approximately 16,000 sq. km., it is the most extensive of the minor onshore basins. The San Luis Basin is an intermontane trough with prominent compressive features; a high-angle reverse fault, the San Luis Fault, borders the basin on the east side, separating it from the Sierra Grande. The Gigante Fault bounding the basin on the west side is also thought to be a reverse fault. Its Triassic to Cretaceous sedimentary section, about 4,000m thick, is mainly continental and volcaniclastic sediments. YPF has drilled several unproductive wildcats in this basin.

66. - The Mercedes Basin, with an area of roughly 8,000 sq. km., is located in southwestern Córdoba Province. A north-south positive feature, the La Pampa High, separates this basin from the Levalle Basin to the east. The Paleozoic in this region is thought to have formed in a single large basin; the small intracratonic basins like the Mercedes are Meso-Cenozoic in age. The basin fill consists of some 2,300m of continental clastics. The petroleum potential has not been evaluated.

67. - The Levalle Basin lies mainly in northern La Pampa Province. It is a small, narrow intracratonic basin oriented north-south, on trend with the Macachín Basin (Fig. 1). It is about 12,000 sq. km. in area, but has a total Meso-Cenozoic section estimated at only 1,200m, the thinnest of any of the minor basins for which estimates are available. Its hydrocarbon possibilities are unknown.

68. - The Macachín Basin is located in southwestern Buenos Aires Province, with its southern tip close to the coastal city of Bahía Blanca. Like the nearby Levalle Basin, it is a linear intracratonic feature with an area of about 12,000 sq. km. The total sedimentary section is estimated at 3,000m. Beneath the nearly flat-lying, undisturbed Meso-Cenozoic section, the Paleozoic shows up on seismic records as strongly folded; faults parallelling the fold axes are also present. The sequence of folded rocks is bounded above and below by angular unconformities; by correlation with outcrops in the nearby Sierra Austral, this sequence is considered Siluro-Devonian to Permian in age. The folding could provide petroleum traps, but the subsurface picture is poorly known from only a few wells. The only definite marine strata are shales of the Oligo-Miocene Macachín formation.

69. - The Ñirihuau Basin is a small, relatively deep Tertiary basin in Rio Negro and Chubut Provinces. Although its area is only about 7,000 sq. km., the sedimentary section is estimated at 6,000m (the thickest of any of the minor onshore basins). Tectonically it is classed as an inter-arc fold basin. The Eocene to Miocene sequence of continental clastics and volcaniclastics was deposited on a Lower Jurassic substrate. The hydrocarbon potential of the Ñirihuau Basin has not been evaluated.

Potentially Productive Coastal/Offshore Basins

70. With the exception of the Colorado Basin, the basins discussed below are smaller than the Malvinas Basin (described previously); but the main reason for separating them from the "Major Basins" is that they have yet to show the hydrocarbon potential of the Malvinas Basin.

Colorado Basin

71. With a total area of some 20,000 sq. km., the Colorado Basin is the largest of the sedimentary basins on the Argentine continental shelf (a small portion of the basin extends onshore). It is separated from the Salado Basin to the north by the Tandilia-La Ventana High, on which basement rocks are partially covered by a thin Tertiary section. Its separation from the Valdes and Rawson basins to the south has not been defined geologically.

72. The Colorado is a taphrogenic basin, but its axis, unlike those of most of the Atlantic coastal basins (especially in Brazil), is essentially

perpendicular to the edge of the craton. This orientation is thought to be due to the effect of old transform faults that affected the craton at the beginning of the separation of South America from Africa. However, the Colorado Basin does contain transverse highs (roughly parallel to the coast), evidently reflecting the same tectonic forces that formed the Brazilian coastal basins.

73. The Colorado Basin is essentially a Cretaceous feature. It is floored by Serra Geral basalts, from the same volcanic episode that covered the Paleozoic in the Paraná Basin. The basalts under the Colorado Basin are assigned a latest Jurassic to earliest Cretaceous age. In a few areas there are seismic indications of folded strata beneath the basalt, presumably of Paleozoic age.

74. The Mesozoic history of the Colorado Basin can be summarized in four phases:

1)	Pre-rift	deposition of Jurassic fluvian and lacustrine sediments capped by Serra Geral basalts
2)	Rift	earliest Cretaceous fluvial and marine sediments interstratified with volcanic deposits
3)	Post-rift	deposition of Lower Cretaceous marine sediments, continental redbeds, and basalts
4)	Drift	deposition of Upper Cretaceous marine shales, shaly siltstones, and possible carbonates, topped by Paleogene clastic rocks.

75. This basin has apparently been consistently more negative than the Salado Basin, since marine incursions show up earlier in the Colorado Basin, and extend further westward.

76. The hydrocarbon potential has been only partially evaluated. Although 14 wells have been drilled to date, no source rocks have been located and no shows have been recorded. The remaining prospects lie largely to the east, in deeper water.

Salado Basin

77. The Salado Basin straddles the coastline south of the city of Buenos Aires. Its axis is roughly perpendicular to the coast, like that of the Colorado Basin. This orientation, along with its Cretaceous age and the presence of transverse intrabasin highs, indicates that the two basins were created by the same forces.

78. The Salado Basin is separated from the Northeast (Chaco-Paraná) Basin by the Martín García High; an eastward prolongation of the Uruguay High evidently separates it from the small Santa Lucía Basin of SE Uruguay. The coastal high of Tandilia-La Ventana separates it from the Colorado Basin to the south.

79. The sedimentary section of 6,000m is Cretaceous and Tertiary in age; the depositional history is similar to that described for the Colorado Basin. Much of the Cretaceous sequence is continental, while the Tertiary is paralic to marine.

80. The prospectiveness for hydrocarbons is considered relatively low. There are no seeps in the onshore sector, and no shows have been reported in the four wildcats drilled.

Valdes Basin

81. The smallest of the coastal basins of Argentina, the Valdes Basin has an area of some 18,000 sq. km., almost entirely offshore (Fig. 1). One onshore well (at the tip of the Valdes Peninsula) and marine seismic surveys provide most of the information on the basin.

82. The Valdes Basin is a downfaulted intracratonic block. Seismic records show horst-and-graben structure oriented north-south (i.e., typical orientation for Atlantic coastal basins of South America). The maximum sedimentary thickness is only about 3,000m.

83. The basin substrate consists of lightly metamorphosed sediments of possible Devonian age, or in some localities, Jurassic volcanics. Jurassic shales have also been reported. The basin is filled largely with Cretaceous redbeds and Tertiary marine shales. Minor Tertiary carbonates are also reported to be present.

84. The Valdes Basin has low to moderate petroleum potential. Jurassic shales would be possible source rocks.

Rawson Basin

85. The least-known of the sedimentary basins off Argentina's east coast, the Rawson Basin lies in deep water (more than 200m) east of the Valdes Basin. Seismic interpretation suggests that the sedimentary section is predominantly marine, with possible traps created by growth faulting and by stratigraphic pinchouts. As no wells have been drilled, nothing is known of reservoir possibilities or source-rock potential.

PRODUCTION AND RESERVES

NATIONAL HIGHLIGHTS

86. Since oil production began in Argentina in 1907, the percentage of national demand supplied internally has fluctuated from 100% down to as low as 43% (in 1958); by 1975 it was back to over 90%. Gas production supplied nearly 100% of the country's needs from 1950 through 1971, then began to lag behind the increased consumption; by 1975 it was supplying 84% of total demand. Current oil production is around 487,000 BOPD (77,500 m3/d) and gas production is about 1.24 Bcf/d (35.2 million m3/d).

87. Converting gas reserves to oil equivalent, in 1976 oil accounted for 65% of the total hydrocarbon reserves and gas, 35%. In 1980 these proportions were reversed: gas increased to 63%, vs. 37% for oil. The change was due

largely to the discovery of gas-condensate fields, principally in the Neuquén Basin, which registered a 600% increase in gas reserves in four years.

88. As Table V shows, the most important basins in terms of current oil production are the San Jorge, the Neuquén, and the Cuyo, which together account for over 90% of present production. The first two of these basins also account for 80% of the present reserves (proved and probable); the Cuyo Basin is an old producing area, and its current oil reserves make up less than 10% of the total. Additional information on oil production and reserves is given below in the discussion of individual basins.

HEAVY OIL

89. Argentina has a number of heavy oil areas, which have yet to be fully explored and defined. The most important at the present time is in the northern part of the Neuquén Basin, near its eastern limit, where the Llancanelo field is located. In 1981 Union Oil and two Argentine partners signed a contract with YPF to operate this heavy oil area, which includes a known deposit of 12o API oil. It was discovered by YPF in the Rayoso sandstone at a depth of 800 to 1,000m. As operator for the group, Union will make use of its experience with heavy-oil reservoirs in California in a pilot project for thermal recovery from the Llancanelo field.

NATURAL GAS

90. Argentina has five main gas-producing areas that, along with the minor fields, accounted for a daily rate of 1.24 Bcf (35.2 million m^3) in 1980. In order of importance the major gas basins are the Austral, the Neuquen, and the Northwestern (tripartite) basins, which together accounted for over 95% of the daily production just mentioned. These basins also have the bulk of the proved and probable reserves (likewise 95%), but in the case of reserves the Neuquén Basin is the most important, with 73% of the proved and probable gas.

WELL STATISTICS

91. Table V shows the latest figures available for wells drilled in Argentina, with a grand total of 24,456 wells of all types (naturally excluding wells drilled for groundwater). It is noteworthy that currently active oil producers account for a quarter of all the wells drilled, whereas active producers of dry gas only, make up less than 1% of the total wells. This reflects the importance of associated gas in Argentina's total gas production.

92. The number of abandoned wildcats (2,944), while accounting for 12% of all wells, is relatively low compared to the number of successful exploration wells (696), which gives Argentina a very favorable wildcat success "ratio" of nearly 20%. On the other hand, dry development/stepout wells account for 17% of all wells drilled, and no less than 7,008 wells were awaiting abandonment (over 28% of the total).

SECONDARY RECOVERY AND PRESSURE MAINTENANCE

93. Current figures from YPF engineers show that less than 1% of proved oil reserves (only 21 million barrels, or 3.4 million m^3) are currently credited to secondary recovery (figures for probable reserves from secondary recovery were not available). This low figure is perhaps reflected in the well statistics (Table V), which show that 5.5% of the currently active wells were injecting water, and only 2.5% were being used for pressure maintenance. Thus, despite the 70-year history of Argentina's petroleum operations, there is still plenty of scope for increased production through secondary recovery.

BASIN HIGHLIGHTS AND PROSPECTS

94. The following discussion supplements the economic aspects reviewed under "Major Basins" in the preceding section entitled "Geologic Framework."

Cuyo Basin

95. One of the oldest producing regions of Argentina is the Cuyo Basin (Fig. 1), with original producible oil estimated at 1.12 billion barrels (178 million m^3), of which more than two-thirds has already been produced from nearly 900 wells. As this basin has little potential for large discoveries in the future, most of the additions to present reserves will have to come through secondary recovery operations. The Cuyo Basin is thought to have negligible potential for new discoveries of gas.

Northwest Basins

96. Geologically the most complex of the Argentine producing regions, the tripartite Northwest Basin is comparatively more important for its gas production (one-quarter of the national total from six different fields) and for condensate, than for its oil (only 2% of total current production). This basin is characterized by the deepest reservoirs in the country, with average drilling depths in the range of 3,500m to 6,000m. Because of the depth and structural complexities, the potential of the Northwest Basins, while important, is not so attractive as that of the basins discussed below.

Neuquen Basin

97. In terms of present production of both oil and gas, as well as future potential, the Neuquen Basin is definitely the most important onshore basin in Argentina. In oil, its present rate of 135,700 BOPD (21,574 m^3/d) accounts for 28% of present national production; it also has 43% of the country's proved and probable reserves. With respect to gas it is even more important, yielding nearly a third of current production from a large number of fields, with 70% of the proven reserves and 80% of the probable reserves. Since only about half the basin area has been explored and developed, it still has major potential for future discoveries.

San Jorge Basin

98. Unlike the three basins discussed above, the San Jorge Basin lies partly offshore. The shelf portion of the basin has yet to be drilled,

although oil activity in this basin has long centered around the Comodoro Rivadavia district, adjacent to the coast. Thanks to the long history of activity at Comodoro Rivadavia, the basin has around 40% of all the wells drilled in the country (over 10,000 wells). Of these, around 3,000 are still active producers.

99. Producing areas in the basin are very clearly delimited in two separate east-west trends, called the "North Flank" (in Chubut Province) and the "South Flank" (in Santa Cruz Province). The South Flank has somewhat over half the active wells, current production, and primary reserves.

Austral Basin

100. The last of the major productive basins of Argentina, like the San Jorge Basin, has an unexplored offshore portion. This large basin is located in Tierra del Fuego, with extensive onshore areas that are untested. It has over 20 oilfields, but a relatively small number of producing wells. Current oil production of 32,100 BOPD (5,100 m3/d) makes up only 6.5% of the national total, whereas the gas production of 494 MMcf/d (14 million m3/d) is the largest of any basin, accounting for 40% of the total. In terms of future potential, the Austral Basin is likewise comparatively more important for gas than for oil.

HISTORICAL REVIEW

101. Oil was first discovered in Argentina in 1907 by government engineers drilling for water in the Comodoro Rivadavia area, on the Patagonian coast. This kicked off the country's first oil boom, soon joined by private companies (mostly Argentine, but including Royal Dutch Shell). In 1918 activity spread to the Neuquén Basin with a discovery by the Mining and Geological Bureau, and two years later, Esso began exploring in the Neuquén area.

102. Starting in 1929, YPF was granted full control of exploratory activities in the country, restricting private oil companies to the contract areas already granted. By 1958 YPF production had outstripped that of the private sector, but reserves were dwindling rapidly and the country was no longer self-sufficient. The Frondizi Government therefore decided to provide incentives to private risk capital under four different arrangements:

(a) Drilling contracts in areas of proven production;

(b) Exploration contracts in "stepout" areas in the vicinity of producing fields (Cities Service, Amoco, Tenneco and others entered Argentina under this setup);

(c) Exploration contracts in poorly-known sectors of basins with proven production (in this arrangement, Esso and Shell obtained blocks in Neuquén; Union and the Loeb Bank were granted areas in the San Jorge Basin); and,

(d) Exploration contracts in rank wildcat areas (Conoco-Marathon and Shell obtained rights in the Northeast and Colorado Basins, respectively).

103. Within five years the increased activity that resulted from these new contracts was reflected in higher producing rates and increased reserves; nevertheless, the Ilia Government annulled some of the existing contracts and started to negotiate compensation with the companies concerned. In 1966 the treatment of foreign companies abruptly changed again; the Onganía Government continued negotiations with the companies still awaiting settlement of annulled contracts, but also promulgated a new hydrocarbon law in 1967, aimed at encouraging foreign investment.

104. Response to the new law was favorable; new contracts were signed in 1968 with a number of international companies and consortia that included Phillips, AGIP, Tenneco, Esso, Hunt, Sinclair, Sun, Amerada, Marathon, Union, and Conoco. Drilling on these contract areas began in 1969; at the same time additional companies signed up under the new law, including Cities Service, Signal, Cabot, Shell and Amoco.

105. As a result, in 1970 no less than 30 wildcats were completed, including 17 offshore. Underlining the exploration risks, only two of these wells tested oil in significant amounts, but both were deemed subcommercial at 1970 crude prices. For the next several years, acreage relinquishments outnumbered new contracts, reflecting continued lack of success in wildcatting (e.g., 27 dry holes in 1971, including 10 offshore). By 1973, all the offshore blocks had been returned to the government, and some onshore areas were relinquished as well. Cities Service continued to operate in the Mendoza area and Amoco in the San Jorge Basin, both under service contracts with YPF.

RECENT AND CURRENT ACTIVITY

106. The decline in exploration described above continued until 1976; then the government again moved to encourage exploration by private firms--a move that was made much easier by the sharp rises in world oil prices. Both geophysical exploration and wildcat drilling have thus increased since 1976. In consequence, the decline in reserves was turned around by 1978, when crude reserves increased by some 270 million barrels (34 million m^3). This was the largest gain in reserves during the 1970s.

107. Among exploration activities, the increased level of seismic surveying is especially notable. In 1978 YPF began using seismic contractors for the first time, and in 1979 increased the volume of seismic work to about 15,000 line-km onshore and 11,000 line-km offshore,. YPF's onshore surveying is concentrated in the Neuquén and Northwest basins; the offshore work covers areas that are to be awarded under risk contracts. Companies that were operating prior to 1976 (e.g., Cities Service and Amoco), as well as companies with new contracts, have stepped up both onshore and offshore seismic surveying.

108. As a result, in 1980 onshore seismic lines totalled 21,000 km (17,000 by YPF and 4,000 by private contractors), while offshore work totalled 10,000 km. Wildcat drilling onshore has declined from its 1974 peak, largely because YPF's exploration budget has been cut back. On the other hand, wildcatting by private companies has generally increased since 1976; by the end of 1978 one marine unit (semi-submersible) and 34 other rigs were active. At the same time, YPF was drilling with 40 rigs.

109. In 1979 YPF began drilling a number of deep (6,000m+) wildcats in the Northwest Basin. Offshore drilling by private companies also increased somewhat in 1980, as previously defined seismic prospects were tested. A total of 104 exploratory wells was drilled in 1980, 82 of them by YPF and 22 by contracting companies. This compares with 581 development wells drilled (386 by YPF and 195 by private operators).

110. Among promising recent finds, two offshore wildcats by Esso near the center of the Malvinas Basin (Fig. 1) deserve special mention. In April 1981, Esso announced that the CMA-12-CA-X1 had tested at rates up to 3,100 BOPD (493 m^3/d) from relatively shallow depths. Very recently, it was reported that a second wildcat, the CMA-13-SA-X2, had tested 600 BOPD (96 m^3/d) and 21 MMcf/d (598,000 m^3/d) of gas from 2,600m depth.

FUTURE ACTIVITIES

111. The government's goal for the 1980s is to discover and develop at least 2.3 billion barrels (366 million m^3) in additional crude reserves, thus maintaining the ratio of reserves to anticipated production at 15 years' supply. In 1979, it was estimated that this effort would require a total investment of some US$26 billion ($16 billion from the public sector and $10 billion from the private sector). To this end the government has given top priority to encouraging further participation by the private sector; it is recognized that the private capital and technical expertise of both international and domestic oil companies will continue to be important complements to YPF's own operations.

Table I. CLASSES OF ARGENTINE SEDIMENTARY BASINS

CLASS	No. of Basins in Class	NAMES OF BASINS*	TEXT REFERENCES
Major Basins with Commercial Production	7	Devonian, Carboniferous, NeoCretaceous } Northwest Cuyo Nuequén San Jorge Austral	Table II; pp. 3, 5-9, 16-17
Major Basins— No Commercial Production	2	Malvinas Northeast	Page 10; Table III
Minor Onshore Basins	7	Ischigualasto-Villa Union San Luís Mercedes Levalle Macachín Ñirihuau	Pages 11-12
Other Basins (largely offshore) —No Production	4	Salado Colorado Valdés Rawson	Table III; pp. 12-14

*for geographic locations, see Fig. 1

TABLE II. MAJOR PRODUCTIVE BASINS OF ARGENTINA: SUMMARY

NAME	TYPE	GEOLOGIC AGE	SURFACE AREA (km^2)		ESTIMATED MAXIMUM SEDIMENTARY SECTION, TYPICAL LITHOLOGY	PRODUCTIVE POTENTIAL: SOURCE ROCKS	RESERVOIR ROCKS	TRAP TYPES	OUTLOOK
NORTHWEST (SALTA - JUJUY)	geosynclinal	Devonian	220,000	160,000	6,500m marine shales, quartz sandstones	gray to dark gray bituminous shales	fractured quartzitic sandstones	linear (N-S) asymmetric folds	deep prospects for oil, condensate, and gas, especially in the Devonian
	intracratonic	Carboniferous		15,000	1,800m continental clastics		porous sandstones	updip truncations by normal faults	
	intracratonic platform	Neocretaceous (Coniacian-Danian)		110,000	2,800m continental, littoral and open-marine	gray oölitic ls.; dark gray to black shales	calcareous sandstones; limestones	normal faults; diapiric folds (rare)	
CUYO	taphrogenic	Triassic, Cenozoic (hiatus during Cret.)	80,000		7,000m Triassic alluvial clastics; late Triassic-Cretaceous basalt	Cacheuta formation (black shales)	quartz sandstones, tuffaceous or shaly	Tertiary anticlines in the western part of the basin	future discoveries probably limited to small fields, perhaps with heavy oil
NEUQUEN	miogeosynclinal	Mesozoic (Jur.-Cret.) [volcanic and magmatic events in Cenozoic]	140,000		7,000m two Jurassic marine cycles (incl. evaporites); two Cretaceous cycles, mainly clastics	Las Molles black shales; fossiliferous Barda Negra limestone	sandstones and conglomerates in lower part of section; calc. sandstones, sandy limestones, and dolomites in middle and upper part	uplifts over reactivated basement faults; draping over erosional relief features; updip pinchouts (flanks of folds, homoclines)	about 50% of area has been explored; still has important potential for oil, and largest proven gas reserves in country
SAN JORGE	intracratonic trough	late Jurassic-early Cret. [Tertiary cover]	134,000		8,000m Cretaceous continental clastics; marine Tertiary	thick sequences of dark gray to black organic-rich shales and oolitic ls.	tuffaceous sandstones (relatively poor reservoirs)	western sector: folding related to basement faults. Central: symmetrical folds. Eastern sector: down-to-basin and antithetic faults	fair prospects for future exploration; offshore sector has potential (but primarily for gas??)
AUSTRAL	miogeosynclinal	Cretaceous-Tertiary	180,000		9,000m lwr Cret. continental clastics (Springhill fm); marine shales; Jurassic tuffs	gray-dark gray shales overlying Springhill; glauconitic shales in top of Springhill	Springhill quartz sandstones (oil); younger sandstones (gas)	pinchouts against pre-Springhill topography, combined with dip or faulting	still prospective, though gas may be more likely than oil. Gas reserves are second to those of Neuquén

TABLE III. POTENTIALLY PRODUCTIVE SEDIMENTARY BASINS OF ARGENTINA[1]

ZONE	NAME	SURFACE AREA (km^2) EST. PROSPECTIVE	SURFACE AREA (km^2) TOTAL	TECTONIC TYPE	MAXIMUM SEDIMENT THICKNESS meters	AGE of main depositional sequences	WILD-CATS DRILLED	NOTES ON PROSPECTIVENESS
OFFSHORE	Malvinas (Austral Marine)	90,000	150,000	miogeosynclinal	10,000	Cretaceous-Tertiary	6	Fair oil tests (Esso) and good gas gas tests (Shell and Esso). This basin has major potential for commercial production.
	Rawson	10,000	100,000+	intracratonic graben(?)	?	Cretaceous-Tertiary	0	Water depths in excess of 200m. Section predominantly marine, with potential stratigraphic traps and trapping by growth faults.
ESSENTIALLY OFFSHORE	Colorado	70,000	200,000	intracratonic graben	7,500	Cretaceous-Tertiary	14	Continental Cretaceous and Paleogene clastics. No source rocks located to date; no shows. Remaining prospects are to the east, in deeper water.
	Valdés	?	18,000 (offshore)	downfaulted intracratonic block	3,000	Jurassic, Cretaceous, Tertiary	0?	Cretaceous clastics; Tertiary fine-grained clastics + minor carbonates. Jurassic shales are possible source rocks. Low to moderate prospectivity.
ONSHORE-OFFSHORE	Salado	12,000	77,000 (offshore)	intracratonic graben	6,000	Cretaceous-Tertiary	4	Continental Cretaceous; marine to paralic Tertiary. This basin has low prospectivity: no seeps, no shows reported.
ONSHORE	Northeast (Chaco-Paraná)	?	520,000[2]	intracratonic downwarp	3,000-5,000	Silurian to Permian; Cretaceous-Tertiary		Negligible hydrocarbon exploration on account of the thick basalt cover. Potential unknown, but could be significant on account of large size of the basin.

[1] Omitted from this table are seven small, unexplored onshore basins listed in Table I and shown in Fig. 1.

[2] Areal extent within Argentina only

TABLE IV. ARGENTINE PRODUCTION AND RESERVES, BY BASIN

BASIN	NUMBER OF OILWELLS	CRUDE TYPE	OIL				GAS			
			PRODUCTION		*RESERVES AT END OF 1980*		*PRODUCTION*		*RESERVES AS OF 6-81*	
			DAILY PROD. IN 6-81 m^3/d	CUMULATIVE PRODUCTION 10^6 m^3	PROVED 10^6 m^3	PROBABLE 10^6 m^3	DAILY AVG (1980) 10^6 m^3	CUMULATIVE THRU 1980 10^9 m^3	PROVED 10^9 m^3	PROBABLE 10^9 m^3
NORTHWEST	47	light (50° API) with high GOR & condensate ratios	1506	27.4	13.4	23.7	9.2	40.2	60	20.4
CUYO	870	around 31° API, highly paraffinic; some heavy (8-12° API)	17,942	122.3	47	8.7	0.2	3.2	1	--
NEUQUEN	1,747	average 34° API	21,574	114.1	153	94.0	10.6	58.7	457	196.5
SAN JORGE	4,184	mostly med. to high API gravity w/ normal to high GOR	31,418	232.1	161.4	49.8	1.2	59.3	39	2.3
AUSTRAL	257	as for San Jorge Basin	5,104	19.9	16.8	6.2	14	30.0	98	24.5
TOTAL ARGENTINA	7,105	--	77,544	515.8	391.6	182.4	35.2	191.4	655	243.7

Table V

ARGENTINA

Well Statistics—1977*

Group		OIL	GAS	TOTAL NO. OF WELLS
I	Active producers	6,303	226	6,529
	Shut-in or shut down**	1,236	556	1,792
	Subtotals	7,539	782	8,321
II	Pressure maintenance			180
	Active water injectors			399
	Inactive secondary recovery			781
	Subtotal			1,360
III	Awaiting abandonment			7,008
	Dry development or stepout wells			4,127
	Subtotal			11,135
	TOTAL DEVELOPMENT WELLS			20,816
IV	Successful wildcats opened to production			696
	Unsuccessful wildcats			2,944
	TOTAL EXPLORATORY WELLS			3,640
	GRAND TOTAL OF WELLS DRILLED THROUGH 1977			24,456

*latest comprehensive figures available

**shut down for mechanical reasons

Figure 2: GENERALIZED STRATIGRAPHIC NOMENCLATURE

ERA	SYSTEM	NORTHWEST BASINS: SANTA BARBARA	NORTHWEST BASINS: SUBANDEAN RANGES AND CHACO SALTEÑO	CUYO BASIN	NEUQUEN BASIN	SAN JORGE BASIN	AUSTRAL BASIN: SANTA CRUZ SUR	AUSTRAL BASIN: TIERRA DEL FUEGO	CHACO-PARANÁ BASIN
CENOZOIC	TERTIARY	JESÚS MARÍA ANTA RÍO SECO LUMBRERA MAÍZ GORDO MEALLA OLMEDO YACORAITE LECHO PIRGUA	CHACO CANDADO OR TRANQUITAS EL MADREJÓN	PAPAGAYOS		SANTA CRUZ PATAGONIA SARMIENTO RIO CHICO SALAMANCA	SANTA CRUZ MAGALLANES GROUP	"SERIE ARENOSA" "MARGOSA SUP" "GLAUCONÍTICO A" "MARGOSA MEDIA E INF" "SENONIANO"	CHACO MARIANO BOEDO
MESOZOIC	CRETAC.				NEUQUÉN GROUP RAYOSO HUITRÍN AGRIO CENTENARIO MULICHINCO CHACHAO QUINTUCO LOMA MONTOSA VACA MUERTA Q. del SAPO TORDILLO Sas BLANCAS	CHUBUT GROUP POZO D. 129	PALERMO AIKE SPRINGHILL FM.	CABEZA DE LEON ARROYO ALFA NUEVA ARGENTINA PAMPA RINCÓN SPRINGHILL FM.	TACUAREMBO SERRA GERAL
MESOZOIC	JURASSIC				AUQUILCO BARDA NEGRA LOTENA LOS MOLLES PUNTA ROSADA	POZO Co. GUADAL es-1 LONCO TRAPIAL GROUP VARIED FORMATIONAL NOMENCLATURE	TUFFACEOUS OR LAVA COMPLEX	LEMAIRE	
MESOZOIC	TRIASSIC		CUEVO GROUP: VITIACUA … CANGAPI	PUNTA D. L. BARDAS BARRANCAS RÍO BLANCO CACHEUTA POTRERILLOS LAS CABRAS RÍO MENDOZA	PLANICIE MORADA	?			
PALEOZOIC	PERMIAN			CHOIYOI	CHOIYOI	?			NO FORMAL NOMENCLATURE
PALEOZOIC	CARBONIF.		SAN TELMO LAS PEÑAS TARIJA ITACUAMI TUPAMBI		(GRANITES)				
PALEOZOIC	DEVONIAN	ARROYO COLORADO	IQUIRI ? LOS MONOS– SANTA ROSA TONONO RÍO PESCADO MICHICOLA PORONGAL	VILLAVICENCIO	INTRUSIONS	?	RIO LACTEO BAHIA DE LA LANCHA	?	RINCÓN CABURÉ COPO
PALEOZOIC	SILURIAN	CACHIPUNCO ZAPLA	BARITU ? LIPEON–ZAPLA KIRUSILLAS						ZAPLA
PALEOZOIC	ORDOVICIAN	SANTA VICTORIA GROUP	SANTA VICTORIA GROUP	SAN JUAN					ÁRBOL BLANCO PIRANÉ LAS BREÑAS
PALEOZOIC	CAMBRIAN	?	MESON GROUP						
PRECAMBRIAN			CAÑANI						

ABSENT · OIL · OIL & GAS · GAS · GAS & CONDENSATE

World Bank 24042

Figure 3
NORTHWEST BASIN
Regional Cross Sections

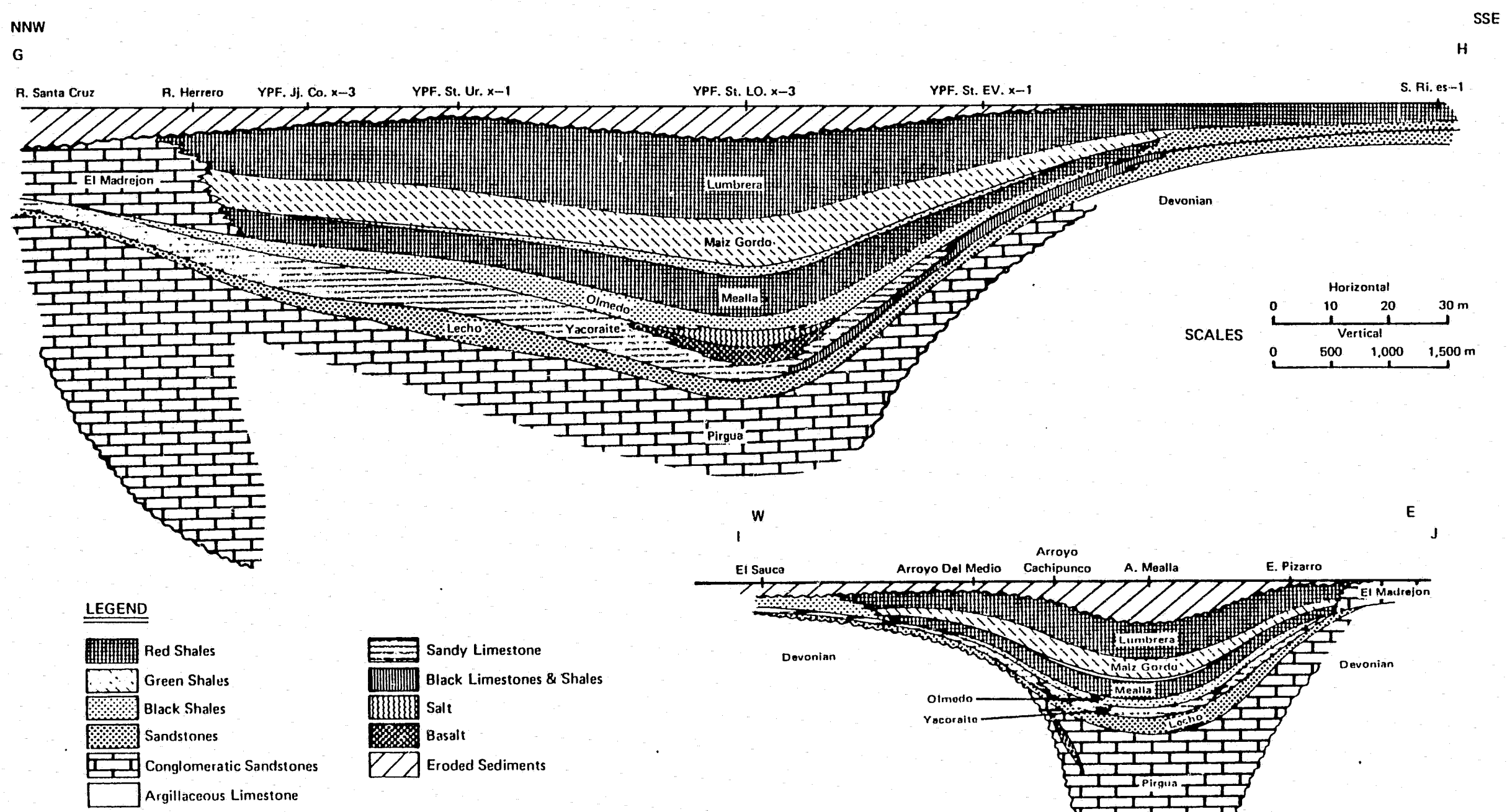


Figura 4
CUYO BASIN
Regional Cross Section

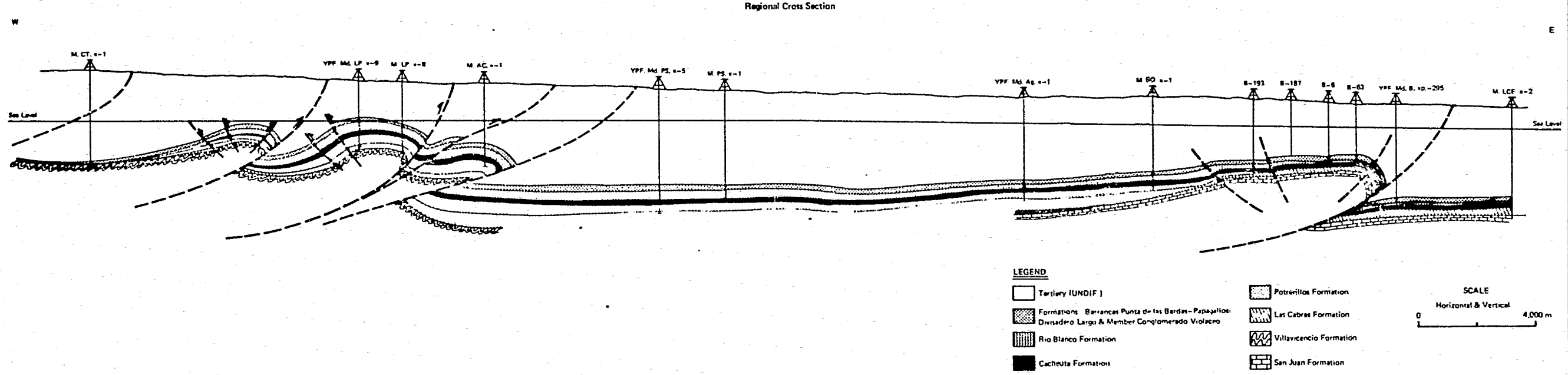


Figure 5
NEUQUEN BASIN
Regional Cross Section Rio Salado-Pampa del Álamo

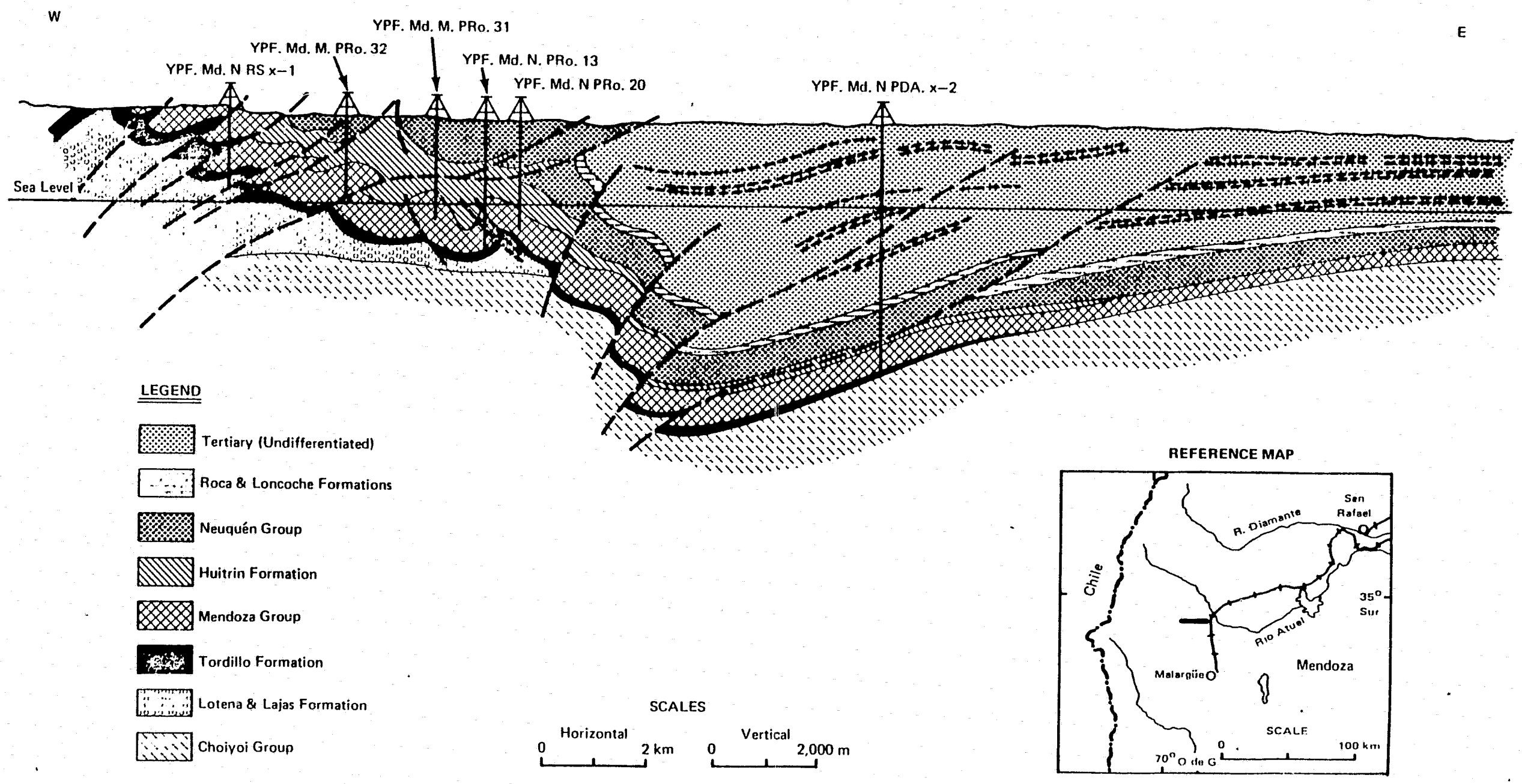


Figure 6
SAN JORGE BASIN
Schematic Cross Section through the Basin at around Parallel 45° 30′

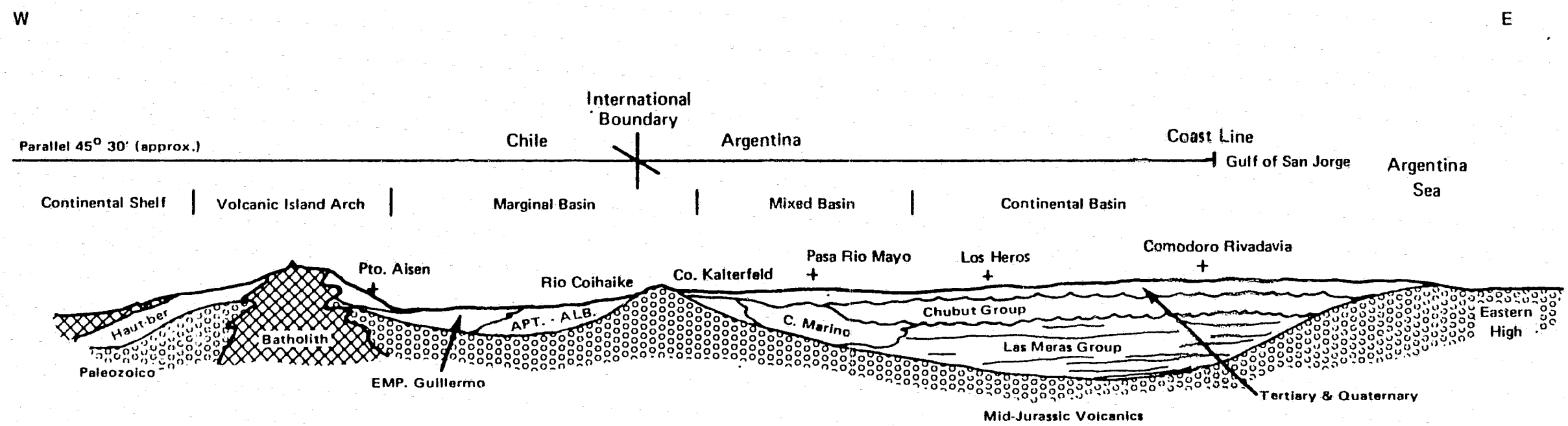
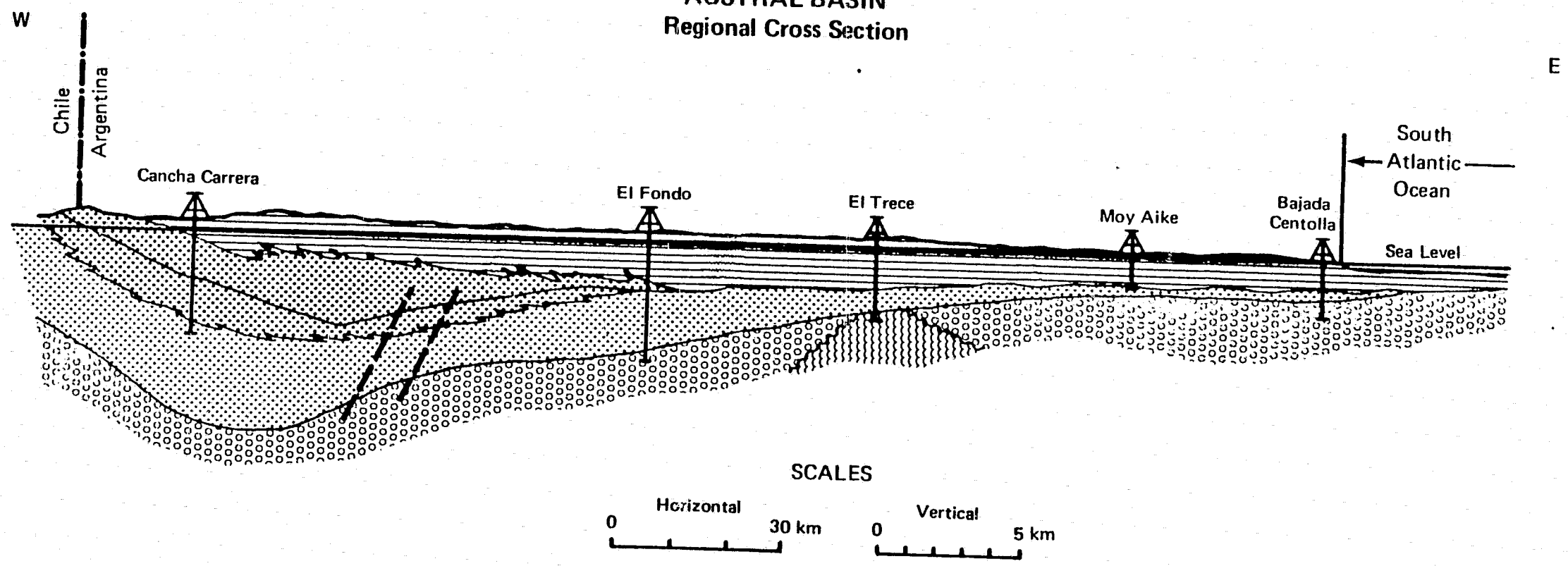


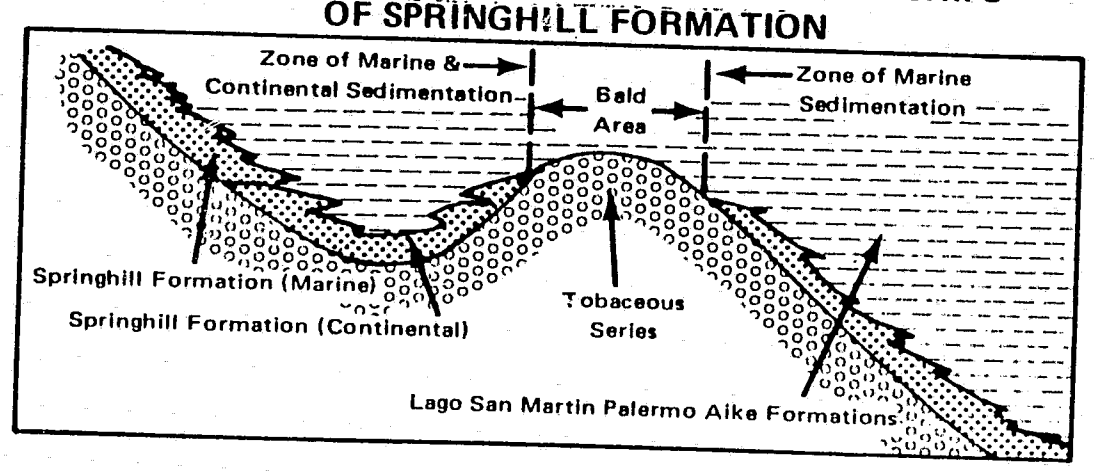
Figure 7
AUSTRAL BASIN
Regional Cross Section



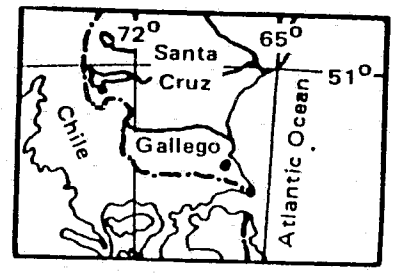
LEGEND

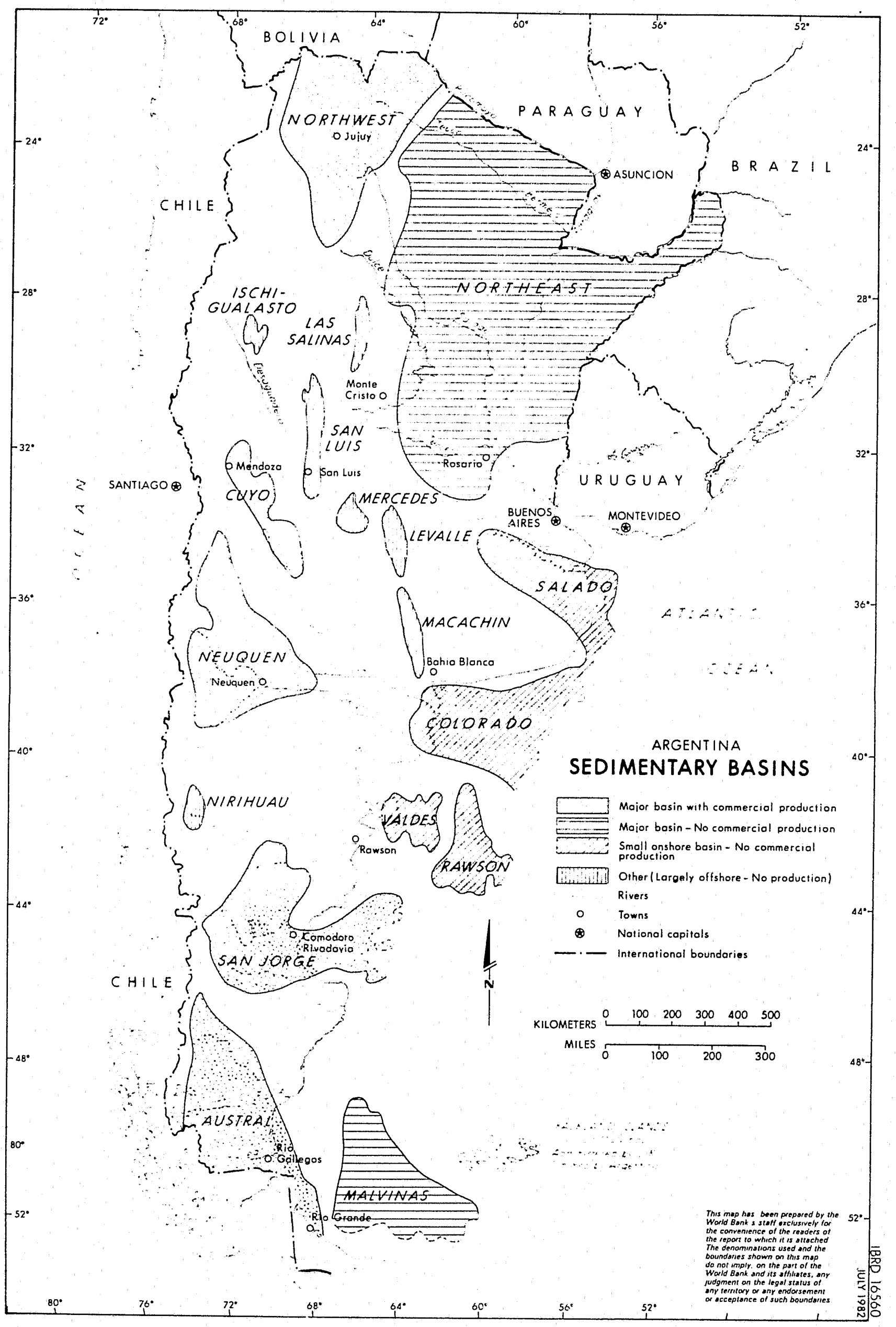
- Tertiary
- Cretaceous
- Porphyries & Pyroclastics of the Bahia Laura Group (Mid-Jurassic)
- Schists & Phyllites (Lower Paleozoic)
- Predominantly Sandy Facies
- Fault
- Well

DETAIL SHOWING DEPOSITIONAL RELATIONSHIPS OF SPRINGHILL FORMATION



REFERENCE MAP




ARGENTINA
SEDIMENTARY BASINS
Major basin with commercial production
Major basin – No commercial production
Small onshore basin – No commercial production
Other (Largely offshore – No production)
Rivers
Towns
National capitals
International boundaries
KILOMETERS 0 100 200 300 400 500
MILES 0 100 200 300
BOLIVIA
PARAGUAY
BRAZIL
CHILE
URUGUAY
ASUNCION
SANTIAGO
BUENOS AIRES
MONTEVIDEO
NORTHWEST
Jujuy
NORTHEAST
ISCHI-GUALASTO
LAS SALINAS
Monte Cristo
SAN LUIS
Mendoza
San Luis
Rosario
CUYO
MERCEDES
LEVALLE
SALADO
MACACHIN
Bahia Blanca
NEUQUEN
Neuquen
COLORADO
NIRIHUAU
VALDES
Rawson
RAWSON
Comodoro Rivadavia
SAN JORGE
AUSTRAL
Rio Gallegos
MALVINAS
Rio Grande
ATLANTIC OCEAN
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