GEOLOGIC AND HYDROGEOLGIC ASPECTS OF THE THERMAL AQUIFER SYSTEM IN ARGENTINEAN EASTERN CHACOPARANENSE BASIN

Silva Busso Adrián Angel [1]

Abstract - The following work is a summary of the pricipal geologic aspects and hydrogeologic of the Thermal Aquifers contained by the Botucatú Formations and Serra Geral in the oriental region of the Watershed Chacoparanense Argentina and their correlation with the geologic units and similar hiyrogeologic in the western region of the Oriental Republic of Uruguay.

In the Oriental Republic of Uruguay studies have been carried out previously partial tending to the quantification of the Hydrotermal Resourse and their possibilities, (TAHAL, 1986, HIDROSUD, 1988, Montanio and Carrion, 1990; Catteno, 1992; Montyear Xavier and Collazo Caraballo, 1998).

During the last years a geologic and hydrogeologic study has been carried out in the institutional mark of the INA with the support of the UNESCO that gave place to the realization of a doctoral thesis in the University of Buenos Aires, (Silva Busso, 1999). Starting from this last one the author has summarized the general aspects in this work including the hydrogeologic map of the Thermal Aquifer System and recommendations for its future exploration and exploitation and an estimated evaluation of the resource. The objective of this study is the correlation and geologic and hydrogeologic interpretation, in a regional context, as a consequence of the childbirth in the Argentinean sector

Key words - Hydrogeology, Hydrothermal, South America

INTRODUCTION AND AREA OF STUDY

The study area understands the Oriental region of the Mesopotamia Argentina and Western of the Oriental Republic of Uruguay understood approximately among those

[1] PNTAS, Instituto del Agua y Ambiente Argentina. Autopista Ezeiza-Cañuelas, tramo J. Newbery km 1,620, Ezeiza, Argentina (1824). Tel/Fax: 05711-44800295. E-mail: pntsas@ina.gov.ar

29°30´ and 33°30´ South latitude and the 57° and 60° longitude West just as it can be observed in the figure N°1. Possibly it has been considered geologic and hydrogeologic information of the district understood between the blooming of the Botucatú and Piramboiá Formation (Rivera and Tacuarembó) in Uruguay, the Río Paraná, the blooming of the Formation Serras Geral in Argentina and the Delta of the Paraná, (see Figure 1).

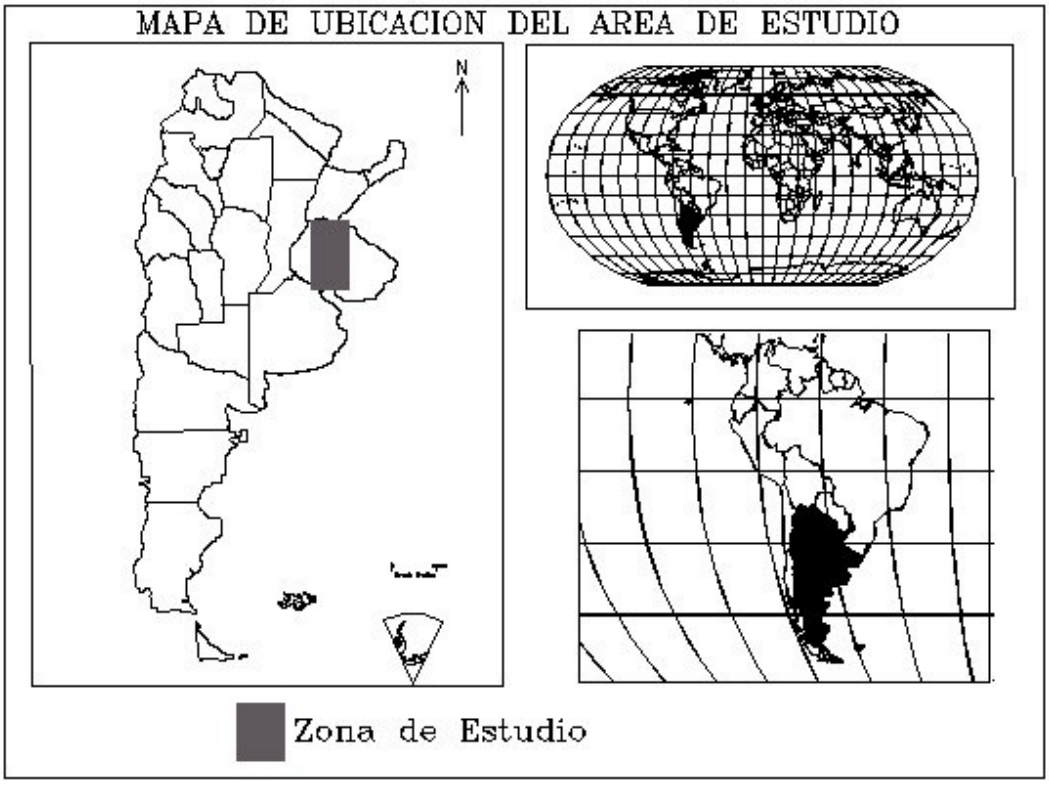

Figure N°1. Map Location of the study Area

The Formations containing and/or related with the Thermal Aquifer System of the Watershed Chacoparanense Oriental is the denominated Formations Piramboiá and Botucatú (Gonzaga of Fields, 1889; Bigarella and Salamuni, 1961, 1964; Salamuni and Bigarella, 1967)or Formations Tacurembó and Rivera (Falconer, 1931, 1937; Ferrando and Anderis, 1986) in Uruguay and Formation Serras Geral (White, 1908), in Uruguay denominated Formation Arapey (Bossi, 1966), and in Argentina Formation Serras Geral (Hausen, 1919) thoroughly studied in blooming and that have continuity in the Argentinean underground.

The Thermal Aquifer System has been defined in function of its lytologic, hydraulic and hydrochemicals characteristics relating it with their recharge areas in the Uruguay and differentiating it hydrogeologicaly of the aquifers that in units the same formations are

found in the Brazilian underground. The possible general reaches of the original study (Silva Busso,1999) summarized in this work that are enumerated in the following points:

- It compiles and it analyzes a group of geologic and hydrogeologic information that in a way it would get lost, or dispersed in partial studies.
- It contributes to the knowledge and correlation of the units of the underground of the Watershed Chacoparanense and it proposes a geologic mark and appropriate hydroestratigraphic for the hydrogeologic interpretation.
- It can be considered as orientative of future explorations and possibilities of exploitation of the underground resources of the Thermal Aquifer System.
- A Conceptual Hydrogeologic Model product of the information proposes more modernized perfectible in future investigations.
- It contributes to the local Knowledge of one of the most important Aquifer Systems in the region. Characterizing it inside a more regional group represented by those same geologic units in Brazil and in Paraguay.

ESTRATIGRAPHIC AND HYDROESTRATIGRAPHY OF THE THERMAL AQUIFER SYSTEM

The regional extension of the Thermal Aquifer System is related with the geology of the underground, it is supposed the existence of a system of blocks related to old faults observing a deepness of the basin in the perforation Nogoya-1,(YPF, 1962). Toward the west, beyond the Río Gualeguay the lateral variations of the geology in depth offers few possibilities to contain the aquifers of the Thermal Aquifer System. It can be considered like a general interpretation that the area of study inside the basin presents a profundness in Southwest address toward Nogoyá -1 constituting a subwatershed. In that region of the basin the structures of blocks in consequent depth of the event tecto-efusive that originated the vulcanites of the Formation Serras Geral have expression, at least, in the mesozoic infrabasaltic levels and it has very possible conditioned sedimentation processes of great part of the deposits suprabasaltic until the most recent.

In this interpretation it was adopted as probable the following approaches like base for the geometry of the contained aquifers in the Formations Serras Geral and Botucatú, being considered this structural model as possible for the Thermal Aquifer System of the Watershed Oriental Chacoparanense Argentina.

The defined geologic units based on the blooming and perforations of the Oriental republic of the Uruguay possesses continuity lytologic and estratigraphic in the perforations carried out toward the west on the Argentinean sector, at least for the region of the Mesopotamia, (Silva Busso, 1997 and 1999). In the study area in Entre Rios this approach can be necessary at least until the basin of the Río Gualeguay in the center and south of the county and until the towns of San Salvador -Chajarí - Guaviraví (Corrientes) in the north. This area can be considered in depth and it stops mesozoic ages like domain of the Formations Serra Geral, Botucatú and Piramboiá taking and recommending the nomenclature used in Brazil, to be these the first ones in defining the strata types of these units in the Watershed Chacoparanense (Argentinean Committee of Estratigraphy, 1992) .

The geologic units defined in the perforations of Nogoyá and Gualeguaychú to the south and to the east of the study area in the county of Entre Rios possess an similar estratigraphic position, with litologic variations that allow an appropriate identification of the units and it is convenient to consider them as co-relatable with the units defined in Uruguay and Brazil.. The reception Gualeguaychú-1 possesses levels that represent, litologic and estratigraphicaly to both units and in the peculiar case of the perforation given Nogoyá ENR-1x the absence of terms comparable to the eolianites was considered these levels co-relationable with the Formation Piramboiá, (Silva Busso, 1999).

The perforations of the north region and this of the Watershed denominated Chacoparanense White tree SEAB-1x, Pirané FP-1x, Charata ChCH-1x, The Brenias I and II ChLB-1x/2x, Those Oriental Brenias, The Caburé SEEC-1x and Field Rooster SECG-1x, they don't allow an appropriate identification of the units because of the litologic variations, their distance to the areas where the strata type and the height and estratigraphic relationship were identified with the units infra and suprarecumbent. It is suggested to preserve Grupo Alhuampa's denomination for the sedimentary group of possible correlation with the mesozoic clastic units of the basin in the perforations where the absence of the complex tecto-efusive doesn't allow an appropriate correlation, (Padula and Mingramm, 1968).

In the County of Entre Rios certain degree of translation of the structures extensionable of the complex tecto-efusive that originates the vulcanites of the one denominated Formation Serras Geral. These structures of depth that can have influence on the most recent geologic levels and in occasions arriving to the Quaternary one (Tujchneider and Filí, 1988), determining possibly certain control on the geomorphologic characteristic of the region. To be the study area an area where the fluvial processes are of more importance in the modelation

of the landscape, these can be considered a superficial expression of the structural limits in depth, (Silva Busso, 1999).

Based on the above-mentioned, this region would be affected for at least three systems of limits (possible flaws); one direction transcurrent NO-SE, one normal of meditate NE - SO and one normal of direction N-S. This structural control controls the estratigraphy and it is the base for an appropriate interpretation of the mesozoic geology of depth in the region and in the study area.

In function of the geologic history of the region and the superimposed tectonic phenomenons it is possible to suppose that it could also act as a structural control of the different depositional processes. Coinciding with the interpretation proposed by diverse authors (Pezzi and Mozetic, 1989; Reboucas, 1994; Frank Araujo and Potter, 1995; Gomez Rifas and Masquelin Arcelus, 1996). The structure proposed in that study constitutes the estratigraphic and structural limits, geometry of the geologic units, load areas and their discharges, streams of flow, relationship of pressures and hydrochemistry of the Thermal Aquifer System in the study area, with probable influence on the contained aquifers in the suprabasaltic units.

The estratigraphy and structural geology of the basin in Brazil are comparable with those of the study area in Argentina and originated Uruguay of a group of processes tecto -efusive and tecto-sedimentary in common that happened during the mesozoic. The aquifers of the Formations Serras Geral and Botucatú are controlled by the structures mentioned. The hydrogeologic characteristics of each Aquifer System defined in Brazil and Argentina-Uruguay is related with the disposition of the depocentres and high existent that control locally each one of them. This particularizes the contained aquifers in the northeast of the basin in Brazil, of the aquifers of the Thermal System in Argentina-Uruguay.

The factors mentioned to understand the System Aquifer Thermal content in one particular and independent hydrogeologic subwatershed of other thermal aquifers in the region are summarized in the following ones:

- The geologic and hydrogeologic map of the region show in the study area the blooming of the Formation Serras Geral on the oriental band of the river Uruguay, on the State of Rio Grande do Sul and the north of the Republic of the Uruguay and in Argentina in the county of Misiones (to the north) central region of the county of Corrientes to the (Northeast). Other blooming in the study area is restricted and related to the Río Uruguay, as in Salto Grande and Entre Rios. The whole blooming region can be described as a strip of clear

orientation NNE-SSO. In the South of Corrientes and the County of Entre Rios the formation Serras Geral has only been found in depth with one descending altimetry with direction NE-SO and AND-OR controlled by the structures of depth until approximately the 34° of latitude coining against the crystalline basement of the basin or high of the ¨Rio de la Plata", (Fernandez Garrasino and Vrba, 1999). Toward the north, the Arch of Rio Grande approximately until the town latitude of Itacurubí in Rio Grande do Sul, Brazil or the well Guaviraví-1 in the homonymous town in the County of Corrientes, Argentina the thickness of the Formation Serras Geral it is deepened limiting the basin hydrogeologic considerably. Toward the northwest the high of Pay Ubre in Corrientes rationed with the high of Asunción allows the blooming of these units (Chebli, Tófalo and Turazzini, 1989). To the west of the Río Paraná, Formation Serras Geral disappears until it is no longer recognized in the estratigraphy from the wells to the west of the central region of the County of Santa Fé. Toward the South their extension is bigger and it is recognized in the perforation of Firamt-1 in Santa Fé, Ordoñez and Camilo Aldao in Córdoba appearing in Río Cuarto's proximities to Sierras Pampeanas's south. These two last correspond to the extension of the Formation Serras Geral and not of the System Aquifer Thermal that is already restricted to the study area defined, of equal forms that the aquifers to the north of the Arch of Rio Grande toward Brazil and Paraguay, (Araujo, França and Potter, 1995)

- The Formation Botucatú and Piramboiá or Formation Rivera and Tacuarembó in Uruguay that constitute the geologic units that contain the best levels producing of the one Thermal Aquifer system appears exclusively in Uruguayan and Brazilian territory. They prepare forming a parallel cord to the blooming of the Serras Geral formation toward the east of the same one, with orientation N-S. In the study area they have been defined in depth starting from the carried out perforations and interpreted. According to these exposed Formations also in depth they extend in N-S direction, verified the receptions of the western riverbank of the Río Uruguay among Villa Elisa-1 and Guaviraví-1 those that present a litology co-relationable with the receptions and blooming to the east of the Río Uruguay. The lateral variations of these Formations would constitute the limit of these producing levels for their contents. Toward the south of the county of Entre Rios, the increase altimetric of the Basement verified in those perforations of Concepción the Uruguay-1,

Gualeguaychú-1, Gualeguay-4 and the reduction of thickness of the Formation Serras Geral they constitute a basin border for Mesozoic ages that control the power of the Formaciones Botucatú and Piramboiá reducing their thickness and coining in North-south direction. Possibly the structure of blocks supposed for the region it allowed that facieses of finer litology are preserved in the geologic registration, like in Gualeguaychú-1 and Nogoyá-1. In Colón-1 the situation is more complex due to proximity of the volcanic chimney defined in May 1 by several authors, causing a piling up of laundries represented in an increase of the thickness of the Formation Serras Geral in its influence area that diminishes gradually toward the ENE. Reason to explain the absence of the Formation Botucatú/Piramboiá in the geologic registration of Columbus -1 where the producing levels correspond to the Aquifer Solari that is interbasaltic. Toward the Southwest of Entre Rios the well Nogoyá ERN-1x constitutes the most representative in the lateral variations of the clastic levels mesozoic in the study area represented in that case by the Formation Piramboiá, (file loamy-sandy) and absence in the registration of the Formation Botucatú (fundamentally sands with inserted slime-clay). According to Fernandez Garrasino, (1996) Formation Misiones' denomination is assigned to the clastic levels co-relationable with the Formaciones Botucatú/Piramboiá or Formations Rivera/Tacuarembó at these levels the perforations to the west of the study area vary litologically of these in that levels the fraction clastic Slime-clay prevails for on the fraction sand characteristic fine-stocking of the eolic levels of the Formation Botucatú

- The Basement doesn't appear in the study area, more to the south it appears in Isla Martín García, Juncal and San Gabriel, but in the area to the north of the Islands of the Ibicuy has been played to different depths in the receptions Gualeguay-4, Concepción the Uruguay-1, Gualeguaychú-1 in the Entreriano sector and in Guaviyú and Arapey in the Uruguayan sector. The altimetry of the contacts increases in depth in NO-SE direction coinciding with the direction in which the Mesozoic is deepened. The control of the sedimentation for the Basement at least for the age levels previous to the inferior Cretacic (Cycles II and III), (Chebli, Tófalo and Turazzini, 1989) pointing out the high one from Martín García to the south of the area of study and the High of Pay Ubre. The control estratigraphic is translated in a control

hidrogeologic of the aquifer to the south, Southwest and to the northwest of the study area probably interrupting the direction of flow (Silva Busso, 1999).

The extension of the aquifers of the Thermal Aquifer System not necessarily should to coincide with the regional extension of the units formational that contain them. The aquifer concept involves, other of the litology and its structures, the physical parameters that characterize them, as piezometric heights of the recharge area, discharge area, hydrochemistry of its waters, phases of balance water-mineralogy, direction of the net of underground flow, isotopy of its waters, among others that allow to limit its extension and to study it like an unit aquifer characteristic.. In the case of the Thermal Aquifer System sinks also the condition that one finishes Thermal Aquifer System is not closed or limited only for a certain group of Formations, but for those that also involve aquifer able to fulfill the condition of Schoeller, (1962) where T(acuífero)>T (it mediates) + 4°C (Hipertermas or thermal). In the study area it is represented by the Aquifer Solari and Botucatú (possibly some aquifer level inserted in Piramboiá), without excluding aquifer levels that, in future investigations, could be considered included in the Thermal Aquifer System.

It comes off of this concept that the Guarani Aquifer System to be defined in blooming (Montyear Xavier and Collazo Caraballo, 1998) doesn't complete the condition expressed thermometric, therefore to avoid confusion in this respect, although they understand each other that its possesses aquifer in common (Botucatú-Rivera and Tacuarembó-Piramboiá) that characterize the area of recharges in depth don't understand the same " System " for what intends to avoid their correlation with the levels in depth until future studies, detailed, allow to make it. The estratigraphy presented file the regional extension of the formational units and their lateral variations toward the west of the Watershed Chacoparanense and it presents a structural model that conditions the extension and geometry of the aquifers. The mentioned depocentres and the depth of the units in study area in direction NE-SO has control on the address of underground flow. It should be considered that in the study area presents a depocentres that is deepened NE-SO separated from those depocentres defined in Brazil by the Arch of Rio Grande that elevates the altimetry of the Basement and the Formations suprarecumbent. Plus detailedly, the geometry of those aquifers can be considered characterized based on the following considerations:

- The geometry of the productive units, that is to say of the levels of gritty ground - fine of good selection that characterize the Formaciones Botucatú

and the Mbo. Solari, should be considered from a subordinate hierarchy to the estratigraphy and the structures that the Sections Hydrogeologic Infrabasaltic and Interbasaltic control.

- Based on this approach the correlation of the horizon resistives of the polls electric vertical with the estratigraphy in the county of Entre Rios, it is possible locally and with the support of the near perforations to the same ones that allow to interpret capable parametric polls in particular for each area avoiding to extrapolate them at big distances. Reinterpreting the existent information they propose three areas with possible correlations among horizons resistive and characteristic estratigraphy for each one of them separately. The same ones Federación/Concordia, Colón/Concepción of the Uruguay and Villa Elisa will denominate / Nogoyá. These in turn can be considered as representative of the areas north and center and south-Southwest of the study area. The same ones allow to characterize those Cut proposed Hydroestratigraphic and in some cases when the contrast allows, as the aquifers of the Formation Paraná, aquifer units are identified included in the same ones.

The levels geologic continents of the Thermal Aquifer System don't have blooming in the area of study of the Sector Argentinean Mesopotámico. The distribution of the blooming in Uruguay and the considerations allow to define the basin in depth. The Formation Serras Geral appears approximately from the Río Uruguay and extends toward the east until approximately the parallel one 56° toward the south to the Rio Negro, to the North extend on Brazil (Rio Grande do Sul). The Formation Botucatú in the region prepares like a fringe south north of 10 at 100km of wide entity the parallel 56° and 55° approximately. The topographical bench marks increase gradually toward the east in such a way that the blooming of the Formation Serras Geral they are usually among the 50-100 m.s.n.m, while the blooming of the Formation Botucatú are usually above the 100m.s.n.m being able to arrive to the 200 m.s.n.m. (Rivera) .Toward Rio Negro and toward Rio Grande do Sul (Brazil) the bench marks descend progressively and they don't end up overcoming the 100 m.s.n.m.

GEOMETRY, AREAS OF RECHARGE PROPOSALS AND CHARACTERISTIC HYDROGEOLOGIC AND GENERAL HYDRAULICSES OF THE THERMAL AQUIFER SYSTEM .

The Formation Serras Geral overimpose to the sequence of gritty of the Formation Botucatú, and toward the west the first one acts as level confinante of second o'clock.
In fact the aquifer in depth and according to diverse authors has hydraulic characteristics of an aquifer confined in Uruguay and also in Argentina and of free aquifer in blooming, (Montyear and Pessi, 1985). Even this way, some factors that should exist to be considered when defining that is with more detailed recharge areas:

- The clastic levels inserted in the vulcanites possesses characteristic of aquifer levels (Aquifer Solari) with indexes and similar hydraulic parameters to the Aquifer Botucatú infrarecumbent makes us suppose a continuous recharge of these units or to the one less similar to the aquifer infrarecumbents.
- The intense fracturación of the Formation Serras Geral with at least three games of fractures or diaclases of different direction, the structures previous distentive, the discontinuities among laundries (for supertax or columnar disjunction) and the discontinuities between the vulcanites and the clastic levels, can, at least in blooming and to depths shallow, to form a net of underground flow or fractured aquifer (Aquifer Arapey) with certain degree of hydraulic connection with the underlying aquifer levels
- The piezometry of the Thermal Aquifer System presents a maximum height reached in the near perforations to 100 m.s.n.m., supposing a balance condition hydrodynamic stable this would be the maximum bench mark of the recharge area. The bench mark of 100 m.s.n.m. in the Rep. Ort. of the Uruguay corresponds mostly to blooming areas of the Formation Serras Geral as long as the Formation Botucatú usually appears to bench marks superiors to the 150 m.s.n.m. This difference altimetric corresponds to an almost so extensive area in the land as the surface of the blooming of the Formation Botucatú.
- On the whole the analysis of the information hydrochemistry with respect to the possible origin of the Fluorine and Arsenic allows to suppose that at least it leaves the area of blooming of the Formation Serras Geral can participate of the recharge of the Thermal Aquifer System.
- In accordance with the antecedents the Isotopía of C14 and C13 of the waters of those Uruguayan perforations (Delepere, 1992) allows to infer waters with different ages in the receptions (between Arapey and Guaviyú)

that would make suppose different distances of circulation of the flow in depth. It should be added to the isotopy the result of the employment of the SiO2 as geothermometer where we arrive to similar conclusions.

As general conclusion it is considered that the aquifer units of the Aquifer System Thermal have similar magnitudes in their hydraulic properties, reason that reinforces the concept of considering to this an Aquifer System, (Silva Busso, 1999) This is compatible with the concept proposed hidroestratigraphic and they should be considered to the Aquifer System Thermal embracing the aquifer clastic of Sección Interbasaltic and the Section Infrabasaltic, (Santa Cruz and Silva Busso, 1999).

The Thermal Aquifer System presents the following characteristic hydrogeologic and general hydraulicses, taken of Silva Busso, (1999).

Aquifer	Depth of top (m.b.b.p.)	Depth of Botton (m.b.b.p)	Thickness (m) .	Temperature (°C)
Solari	300 – 425	640 – 765	10 – 65	32 – 39
Botucatú	540 – 972	810 – 1185	70 – 313	42 – 47

Square N°1 Regional variations foreseen for the Aquifers of the Thermal System based on the existent wells, (Silva Busso, 1999).

Aquifer	Pressure head Kg/cm2	Discharge Pressure Kg/cm2	Static level m.s.n.m.	Dynamic level.	Artesian discharge m3/h
Solari	0 – 1,86	0 – 0,89	1,3 – 38,21	-25,7 – 28,19	0 – 144
Botucatú	1,21 – 6,4	0,53 – 4,62	44,79 – 104,11	21,65 – 85,72	50 – 300

Square N°2. Regional hydraulic variations for the Aquifers of the Thermal System based on the existent wells, (Silva Busso, 1999).

The Thermal Aquifer System in the study area is subjected to a geothermal gradient, among 0,0208 - 0,024 °C/m and it is considered a dear real speed of horizontal flow among 1,43.10-5–1,79.10-5 cm/seg several orders of magnitude smaller than its maximum speed of Darcy (estimated in 7,38.10-2 cm/seg). It is considered a storage coefficient of the order of 1.10-4 having in mind the occurrence of the Aquifer System, (Silva Busso, 1999).

Aquifer	Total Porosity %	Porosity Effective%	Factor of retention%	Factor of Formation	Hydraulic gradient
Solari	17 – 24	10,8 – 19,2	4,7 – 6,2	17,3 – 21,6	7.10^{-4}
Botucatú	17 – 20	11,22 – 19,3	4,34	27,3 – 28,0	9.10^{-4}

Square N°3. Regional variations of the containing Formations of the Aquifers of the Thermal System based on the existent wells, (Silva Busso, 1999).

Aquifer	Permeability (Darcy) m/día	Intrinsic Permeability (cm2)	Specific yield m3/h.m	Transmissivity m2/dia
Solari	8,06 - 16,94	$9,34.10^{-5}$	5,3 – 14,27	376,38
Botucatú	6,21 - 13,74	$7,23.10^{-5}$	5,18 – 14,79	367,10 – 555,19

Square N°4. Regional variations of the hydraulic parameters of the Aquifers of the Thermal System based on the existent wells, (Silva Busso 1999).

HYDROCHEMISTRY CHARACTERISTICS OF THE THERMAL AQUIFER SYSTEM

The feature more significant product of this study, on the hydrochemistry of the System Aquifer Thermal is the identification of two Areas clearly defined Hydrochemistrys. It could be considered like a third area to the recharge area assisting to the classification hydrochemistry of the free aquifer contained by the Formation Botucatú in the areas of blooming carried out by other authors

AREA HYDROCHEMISTRY OF RECHARGE:

In the blooming area the waters contained by the Formaciones Botucatú (Rivera) and Piramboiá (Tacuarembó) they are classified as calcic cloruradas and calcic bicarbonatadas, the concentration of Calcium overcomes that of Sodium, in accordance with other authors, consequent with the cementation of the units in blooming, (Montyear Xavier and Collazo Caraballo,1998).

In the area of Salto, in the Oriental Republic of the Uruguay, the aquifer Arapey presents secondary porosity for breakening, diaclasment and even to vacuolar level there is interconnection. This allowed to define glide addresses related to the surface structures with directions northwest-southeast and north-south. The wells of the region possess depths different to different intervals among 10-20 m.b.b.p., 20-30 m.b.b.p., 30-40 m.b.b.p. and 60 m.b.b.p. This aquifer unit in the region of Salto, it was classified as calcic bicarbonated, with values of TDS between 200-410 mg/dm3 and conductivities among 342-759 µS/cm, pH between 7,0 -7,6 and temperatures in mouth of well of 19-23 °C (MGAP, MTOP, BIRF, 1995)

AREA HYDROCHEMISTRY I:

It is characterized by sweet waters (TDS <1500mg/dm3), Soft to Medium hard, of high alkalinity, type Sodium Bicarbonated to Chloride-Sulfated Sodium. In general drinkable restricted by the concentration of F that can exceed the norm. The aptitude for watering is limited with indexes of LEVEL (Relationship of Adsorption of Sodium) between 3 -44 and an average of 12, an adjusted LEVEL among 6 - 46 and an average of 17.

It presents waters oversaturated in carbonates (Calcita and Aragonita) and with degrees of variable saturation for the diverse crystalline varieties of SiO2 (Calcedonia and Quartz).The cationes relationships and anions relate them with the recharge area toward the west of the study area where these units appear.

The representative samples of those more shallow aquifers as the Aquifer Arapey probably related with in the one recharge area, the Acuífero Salto in Uruguay, already in bordering areas (and even Ituzaingó in the study area), they spread toward a relationship of rich majority species in HCO3 - and Ca2+ similar to those that will have been able to suppose in the blooming areas and it recharges of the geologic continents formations of the Thermal Aquifer System in depth, (Silva Busso, 1999).

AREA HYDROCHEMISTRY II:

It is characterized by brackish waters to salted (TDS <15000mg/dm3), Hard, of high alkalinity, type Sodium Clorurorada. It exceeds in several parameters the potability limits. Totally unable for watering with indexes of LEVEL (Relationship of Adsorption of Sodium) among 37 -69 and an average of 60, an adjusted LEVEL among 72 - 194 and an average of 150. It presents waters oversaturated in carbonates (Calcita and Aragonita) and variable insaturated for the diverse crystalline varieties of SiO2 (Calcedonia and Quartz). The cationes relationships and anions allow to suppose them like mixture waters with certain connection degree with the waters coming from the recharge area and certain participation into the composition of waters connatas or to possess (or to have possessed) hydraulic lateral and/or vertical connection.

Through discontinuities (structural limits) they could be connected with the aquifers of the Sección Suprabasaltica, in particular the Aquifer of the Formación Paraná of marine origin whose appearance in geologic registration of depth begins almost to the same latitude in which is the limit between the Zone Hydrochemistry I and II. Have in mind that the gradient hidroquímico between Colón-1 and Villa Elisa-1 is approximately of 420 mg/dm3 of Total

Salts for Kilometer, while enters Colón-1 and Arapey it is of 2 mg/dm3 for kilometer, (Silva Busso, 1999).

HYDROCHEMICAL CHARACTERISTICS OF THE BOTUCATÚ AND SOLARI ACQUIFERS:

The hydrochemistry difference of the waters of these aquifers is related with the diferenciation in the values of concentration of Fluorine and Arsenic of the Aquifer Solari. They are usually superior to the values of concentration of the Aquifer Botucatú that is characterized by the Iron and Manganese. The relationship among this minority species can be used as approach to differentiate the proveniencia or magnitude of the contribution of one or another aquifer in the perforations.

The concentration of SiO2 possesses different saturation conditions in both aquifers. This diference can be explained starting from that the waters of the Aquifer Solari don't overcome the temperature in depth calculated starting from the geothermal gradient. They differ of the waters of the Aquifer Botucatú because these they have oversaturation conditions with silica varieties that determine bigger temperatures between these and the waters, without overcoming the awaited depth for the geothermal gradient.

EVALUATION OF THE RESERVATIONS AND RECHARGES. HYDROGEOLOGIC CONCEPTUAL MODEL.

The one denominated in this study Thermal Aquifer System of the basin Oriental Chacoparanense Argentina constitutes an extensive one aquifer regional deep, confined (artesiano), with recharge areas that distan at least at 200km of the occurrence region in Argentina.

It is observed a profoundization of the aquifer units and the levels bordering with direction NE-SO from the blooming areas and it recharges until the western region of the Mesopotamia Argentina and accompanied by a gradual reduction of thickness and changes litologic that cause the deteriorate of their hydraulic characteristics. The Thermal Aquifer System would be controlled by structures in depth that also have control on the hydraulics and hydrochemistry of the same one. This Thermal Aquifer System would have its occurrence in depth in the region oriental center of the county of Entre Rios and the district northoccidental of the R.O of the Uruguay. The bordering pressures are related with the area of more profoundization the same as the temperature. This last one depends exclusively on the geothermal gradient calculated among 0.208-0,024°C/m. The piezometry would allow to infer the theoretical limit of the bordering, leaving an intermediatete area that the traditionally

supposed recharge area can increase for these aquifers. The address of flow locates to the Argentinean sector of the Thermal Aquifer System in to the area of " discharges" or ¨ dilute below" of the same one.

Inside the study area, in the Uruguayan area of blooming of the Formación Botucatú (Tacuarembó) there are data of an estimate of the dear recharges starting from the precipitations with values understood among 0.044–0.088 Km3/year (Rome, 1983)

It is intended here for the calculation of the total reservations of the study area to consider to the Thermal Aquifer System in their group. To be an evaluation of the thermal resource it implies that inside this reservation evaluation the restrictive of the temperature of the water contained in the aquifer exists that, to depend on the geothermal gradient, it is related with the depth. Therefore the waters should reach a bigger depth at 300m. to reach to the thermalism condition.

To this approach a second restrictive aspect related with the piezometry of the Thermal Aquifer System should be added that can be considered that the 100 m.s.n.m doesn't exceed and that it limits the recharge bench mark where the aquifer is not entirely confined and certain participation of the vertical recharge can exist.

An intermediatete area exists, this way considered that it would be understand the blooming of the Formation Geral it Saws among the bench marks of 100-150 m.s.n.m. To bench marks inferior altimetric and of agreement the structural maps of the Thermal Aquifer System the increment begins in the profoundization of the containing units of the aquifer that allow to increase the temperature of its waters.

To bench marks superior altimetric it usually appears the Formación Botucatú understood by diverse authors like the recharge area. For the I calculate of the total Reservations it will be considered a half productive thickness on the whole for the Thermal Aquifer System of 250 meters and a coefficient of storage of 1.10-4 in the bordering areas.

The Total Reservations of the Thermal Aquifer System considering the Zones Hydrogeologic (Silva Busso, 1999) based on the map Hydrogeologic (it figures N°2) for the study area they are:

Areas	Total reserve in Km3
Area intermediatete(1) (Zone Hydrochemistry I)	0,302
Area of bordering Zone Hydrochemistry I	1,28
Area of bordering Area Hydrochemistry II	0,87
Total	2,462

The total reservations calculated for the Thermal Aquifer System in the study area would understand a total volume of 2,462 Km3 if it is considered the intermediatete Area as having confined and of 2,1600 Km3 without considering it. This intermediatete area would correspond at the 12, 3% of the Total Reservations.

The reservations of to the Zone Hydrochemistry I corresponds to sweet waters (of less than 1g/dm3de total salts) with a Total Reservation of 1,587Km3 considering included the intermediatete area, corresponds to 64.46% of the Total Reservation of the Thermal Aquifer System. The intermediatete area represents 23,54% of the Zone Hydrochemistry I.

The Area Hydrochemistry II corresponds to brackish-salted waters (more than 10g/dm3 of total salts) still of importance to be a thermal resource has a Total Reservation of 0,875Km3 and it corresponds to 35.53% of the total reservation of the Thermal Aquifer System.

The Argentinean Sector of the Thermal Aquifer System possesses the following Total Reservations in the different Zones Hydrochemicals:

Areas	You reserve Total in Km3
Area of bordering Zone Hydrochemistry I	0,375
Area of bordering Area Hydrochemistry II	0,875
Total	1,25

In the Argentinean Sector of the Thermal Aquifer System the Zone Hydrochemistry I corresponds to sweet waters (of less than 1g/dm3de total salts) with a Total Reservation of 0,375Km3 and it corresponds to 30% of the Total Reservation of the Thermal Aquifer System in this sector. The Area Hydrochemistry II corresponds to brackish-salted waters (more than 10g/dm3 of total salts) it has a Total Reservation of 1,25Km3 and it corresponds to 70% of the total reservation of the Thermal Aquifer System.

The Uruguayan Sector of the Thermal Aquifer System possesses the following Total Reservations in the different Zones Hydrochemicals:

Areas	You reserve Total in Km3
Area intermediate(1) (Zone Hydrochemistry I)	0,3025
Area of bordering Zone Hydrochemistry I	0,910
Total	1,2125

In the Uruguayan Sector of the Thermal Aquifer System it is in the Zone Hydrochemistry I that corresponds to sweet waters (of less than 1g/dm3de total salts) with a Total Reservation of 1,5875Km3. Of this analysis comes off that the total reservations of sweet water are considered in 1,9625Km3 where the Uruguayan Sector of the Thermal Aquifer System contains 80.89% and the Argentinean Sector 19.11% of the same one. The recharge of the system happens in the Uruguayan Sector, in the blooming areas and possibly with certain degree of participation of the intermediatete area. this can be evaluated starting from the precipitations stockings and infiltrations calculated starting from the meteorological data of the stations in Uruguay.

In the alone Argentinean Underground 15% of the total reservations corresponds to the Zone Hydrochemistry I (you dilute with less than 2000µS/cm). The Area Hydrochemistry II understands 36% and it is in the Argentinean Sector (dilute with less than 10000µS/cm).

The most important fraction in the total reservations considering the sumatoria of the Zone Hydrochemistry I and the intermediatete one is in Uruguayan sector and they understand 49% of the same ones, all them with waters of good chemical quality.

It was considered a half precipitation for the area of blooming of the Formaciones Piramboiá and Botucatú of 1300 mm/year with a near calculated infiltration to 3,5% of the precipitations. In the intermediatete area it will take the near annual half precipitation 1100mm/year and an infiltration of 1%. Based on these values an estimate of the Annual Recharge was obtained by precipitations considering the precipitations stockings and the blooming area.

Areas	Surface km2	Infiltration p/p%	Precipitations Annual stockings	Total annual recharge in Km3
Area of Recharge F.Botucatú and Piramboiá	3850	3,5	1300 mm	0.1751
Intermediate area (1) F. Sierras Geral	12100	1	1100 mm	0.1331

The intermediate area the estimated Recharge annual total is of 0.3082Km3 that it has more than enough the total reservation of the Thermal Aquifer System estimated in 2,4625Km3 it represents 12.51%. It is evident that the recharge volume yearly is sufficiently high thing to saturate the Thermal Aquifer System and the water surplus you drena for the superficial scorrenty, coinciding with the interpretation given by other authors.

On the other hand the current exploitation in ten o'clock (10) receptions of the study area in the República Argentina are of 0,01778Km3/year,con a half flow of each one of them of 0.001778Km3/year (near at 200m3/h). This figure represents 5,76% of to the Annual Recharge, being that hypothetically they would be needed around 130 perforations like the existent ones to commit the Annual Recharge.

Regionally the thermal resource of the region should still be considered in an exploration stage whose density of perforations constitutes a limited exploitation of the resource starting from which will be carried out the studies and to take the necessary cautions for a correct sustainable exploitation and the preservation of the environment. It is presented the map next Hydrogeologic for the area of study considered toamda of Silva Busso, (1999)

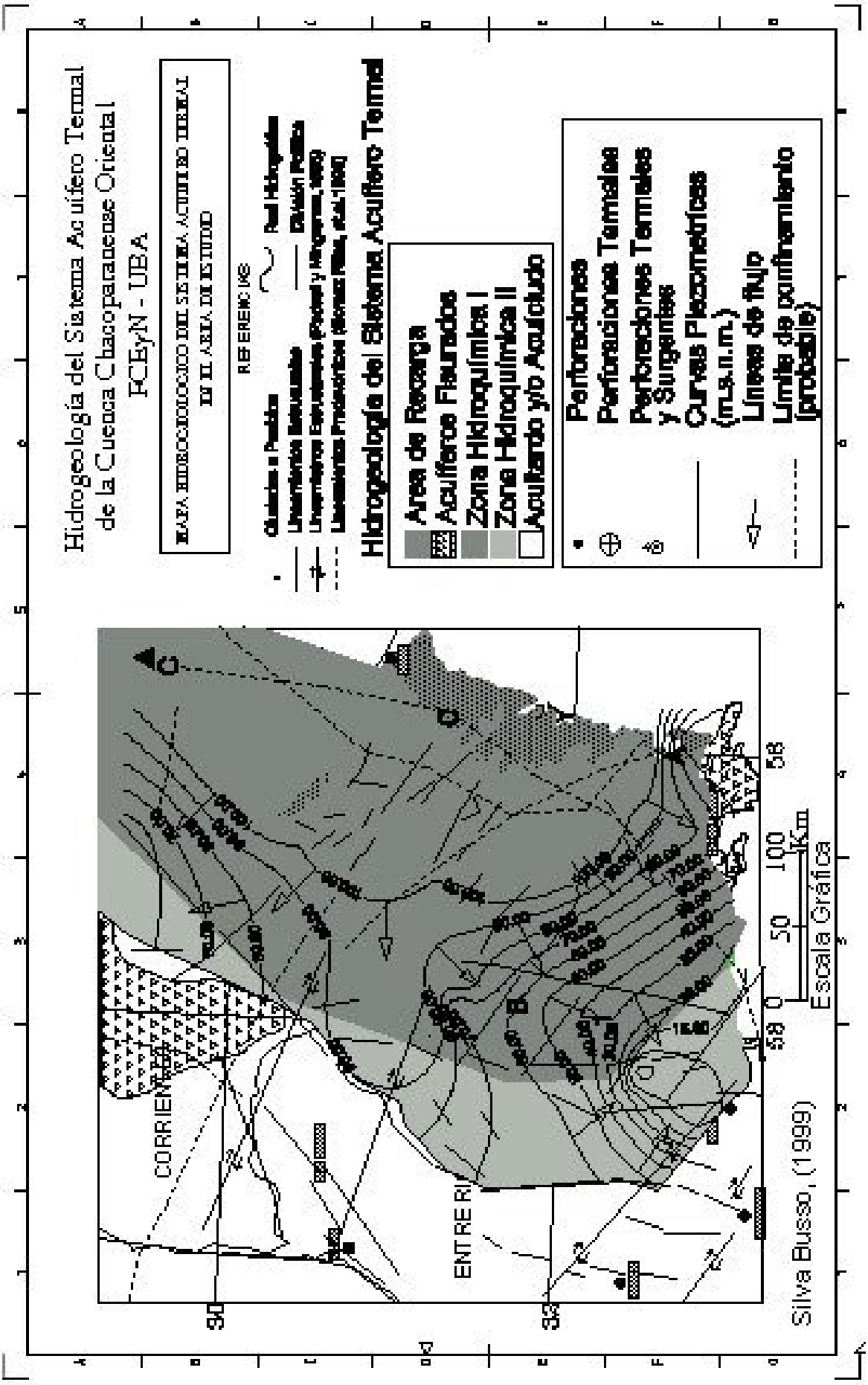

Figure N°2. Map Hydrogeologic of the study area, (Silva Busso, 1999)

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