Groundwater ages and hydrochemical evolution along a flow path in the Northeastern sector of Guarani Aquifer System (GAS) derived from structural geology, isotope, noble gas and hydrochemical data.

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Guarani Aquifer System (GAS)

- GAS covers about 1,100,000 km² in Brazil, Argentine, Paraguay and Uruguay

- GEF Project “Guarani Aquifer Program for groundwater resource sustainability and environmental protection”
## Geological Setting - Results of GAS Project

<table>
<thead>
<tr>
<th>Sedimentary Basin</th>
<th>Country</th>
<th>Uruguay</th>
<th>Argentina</th>
<th>Paraguay</th>
<th>Brazil</th>
</tr>
</thead>
<tbody>
<tr>
<td>POST-GAS Ki</td>
<td></td>
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<tr>
<td>Sedimentary Basin</td>
<td></td>
<td>Arapéy</td>
<td>Serra Geral or Posadas/Solari (Mariano Boedo in Occidental region)</td>
<td>Alto Paraná</td>
<td>Serra Geral</td>
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<tr>
<td>GAS J-Ki</td>
<td></td>
<td>(Sup. Member) Tacuarembó (Inf. Member) Itacumbú?</td>
<td>Missiones or Tacuarembó</td>
<td>Missiones</td>
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<td>Sedimentary Basin</td>
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<tr>
<td>PRE-GAS P</td>
<td></td>
<td>Buena Vista Yaguari</td>
<td>Buena Vista</td>
<td>Tacuary Independencia Group</td>
<td>Sanga do Cabral</td>
</tr>
</tbody>
</table>

1. Jurassic Inner Basin Unconformity
2. Permo-Eotriassic Regional Unconformity
Geological Setting - Results of GAS Project

Serra Geral

Botucatu / Pirambóia

Corumbataí

Araraquara, SP

Contacto con paleorelieve

Unconformity
Geological Setting - Results of GAS Project

- Outcrops along eastern and western boundaries

- Thickness vary from 50 to more than 600m – average 250m

- Geometry is controlled by major geological structures
Hydrogeological Setting - Results of GAS Project

- Recharge along most outcrop areas
- Main flow path from NNW-S
- Artesian zone in the center of the aquifer
- Higher hydraulic gradients – near boundaries
- Low hydraulic gradients – center
Isotope and Groundwater Ages - Results of GAS Project

- Recharge areas – δ\(^{18}\)O match the present day precipitation values

- Confined areas – δ\(^{18}\)O more negative values than the present day precipitation (up to -3‰ with respect to the present δ\(^{18}\)O)
Isotope and Groundwater Ages - Results of GAS Project

- Recharge areas – Recent groundwaters (110 to 80 pMC)

- Confined zones – Old groundwater (less than 10 pMC)

- Rapid decline in C-14 activities.
Isotope and Groundwater Ages - Results of GAS Project

Source: Aravena (2008) - Final Report Guarani Aquifer Project
Isotope and Groundwater Ages - Results of GAS Project

GAS Northern Compartment

Source: Aravena (2008) - Final Report Guarani Aquifer Project
IAEA/UNESP Project

- Uncertainties about old groundwater ages in GAS confined portion
- Important key for the correct resource management
- Assessment of past recharge conditions – stable isotopes and noble gas
- Dating old groundwater using Kr$^{81}$
Preliminary Results – Study Area
Preliminary Results – Geological Section

Legend

- Bauru Group
- Basalts (Serra Geral Fm.)
- GAS Sediments (Botucatu and Pirambóia Fms)
- Pre-GAS Sediments
- Basement

Potentiometric Level

Wells

GAS-BR-16  GAS-BR-08  GAS-BR-04  GAS-BR-07  GAS-BR-16  GAS-BR-14  GAS-BR-01  GAS-BR-12

750 m  750 m

400 km  200 km
Preliminary Results – Methods

Sampling groundwater for chemical analysis, stable isotopes, C-14, $^{81}$Kr and Noble Gases
Preliminary Results – Water Chemistry

Piper Diagram

Guarani Aquifer System

Total Dissolved Solids
(Parts Per Million)

- GAS-BR-01
- GAS-BR-02
- GAS-BR-04
- GAS-BR-08
- GAS-BR-09
- GAS-BR-10
- GAS-BR-12
- GAS-BR-13
- GAS-BR-16
- GAS-BR-18
Preliminary Results – Water Chemistry

![Graph showing anions concentration (mg/L) vs. estimated distance from recharge area (km). The graph includes points for Alkalinity, Chloride, and Sulfate.]
Preliminary Results – Stable Isotopes

\[ \delta^{2}H = 6.55\delta^{18}O - 2.96 \]
Preliminary Results – Stable Isotopes
Preliminary Results – Stable Isotopes

Graph showing the relationship between δ13C (% VPDB) and Alkalinity (mg/L HCO₃).
Preliminary Results – Stable Isotopes

![Graph showing C-14 (pmC) vs. Estimated distance from recharge area (Km)]
Preliminary Results – Stable Isotopes

![Graph showing stable isotopes data](image-url)
SUMMARY

- Groundwaters evolve from Ca-Mg-HCO$_3$ waters in recharge areas to Na-HCO$_3$ and then to Na-Cl-SO$_4$ waters in confined zones.

- Geochemical processes observed are mineral dissolution and ion exchange.

- Recent groundwater in outcrop areas: C-14 activity up to 80pmC and $\delta^{18}$O comparable to present day rain (-6.0 to -6.5‰).

- Rapid decline in C-14 activities followed by isotopic content decrease downdip along the studied transect.
SUMMARY

- Groundwaters with low C-14 activities present more negative $\delta^{18}O$ contents, up to 3‰ V-SMOW lower than present day.

- $\delta^{18}O$ contents suggest three distinct weather conditions during the recharge for GAS, however these need to be confronted to noble gas results.

- $^{81}$Kr dating will permit further improvement on the knowledge of groundwater evolution of GAS.
THANK YOU