

# PERSPECTIVES FOR CARBON STORAGE IN ONSHORE NON-CONVENTIONAL OIL RESERVOIRS AND OFFSHORE SEDIMENTARY BASINS IN SOUTHEAST BRAZIL

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Institute of Energy and Environment  
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Research Centre  
for Gas Innovation

cleaner energy for a sustainable future

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# Research Team

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- Edmilson M. dos Santos (IEE)
- Célio Berman (IEE)
- Carlos H. Grohmann (IEE)
- Claudio Riccomini (IEE)
- Fábio Taioli (IEE)
- Lucy Gomes Sant'Ana (IEE/EACH)
- Ligia Vizeu Barroso (FFLCH/Geografia)

# Research Students Team

## **PhD students**

1. Haline Rocha (Evaluation of CO<sub>2</sub> Storage Capacity - Isotherm etc)
2. Vitor Emanuel (Numerical simulation of CO<sub>2</sub> Storage - turbidites Santos Basin)

## **MSc Students**

1. Stephanie San Martin (Relation mineralogy of shale and CO<sub>2</sub> adsorption capacity, Paraná Basin)
2. Nathalia Weber (Numerical Simulation of CO<sub>2</sub> storage in shale Paraná Basin)
3. Mariana Ciotta (Evaluation of turbidites and other rocks for CO<sub>2</sub> storage, Santos Basin)
4. Fastudo Mabecua (Shale gas potential evaluation for Parana Basin)
5. Raiana Schirmer Soares (Environment Risks of CO<sub>2</sub> storage in geological reservoirs)
6. Fabio Palma de Lima (clay mineralogy in shales)
7. João Maria Santana (Structural Geology and CO<sub>2</sub> storage, Paraná Basin)

## **Undergraduate Student**

1. Jessica dias de Souza (Mineralogy of shale and TOC)
2. Isis Brighetti (Environment Risks of CO<sub>2</sub> storage in geological reservoirs)
3. Bruno Alves Pereira (Environment Risks of CO<sub>2</sub> storage in geological reservoirs)

## Main goal

- The project aims to evaluate the geological feasibility of implementing technology for carbon storage in non-conventional onshore oil reservoirs and those associated with offshore sedimentary basins in the southeastern region of Brazil.

**PROJECT  
TARGET**

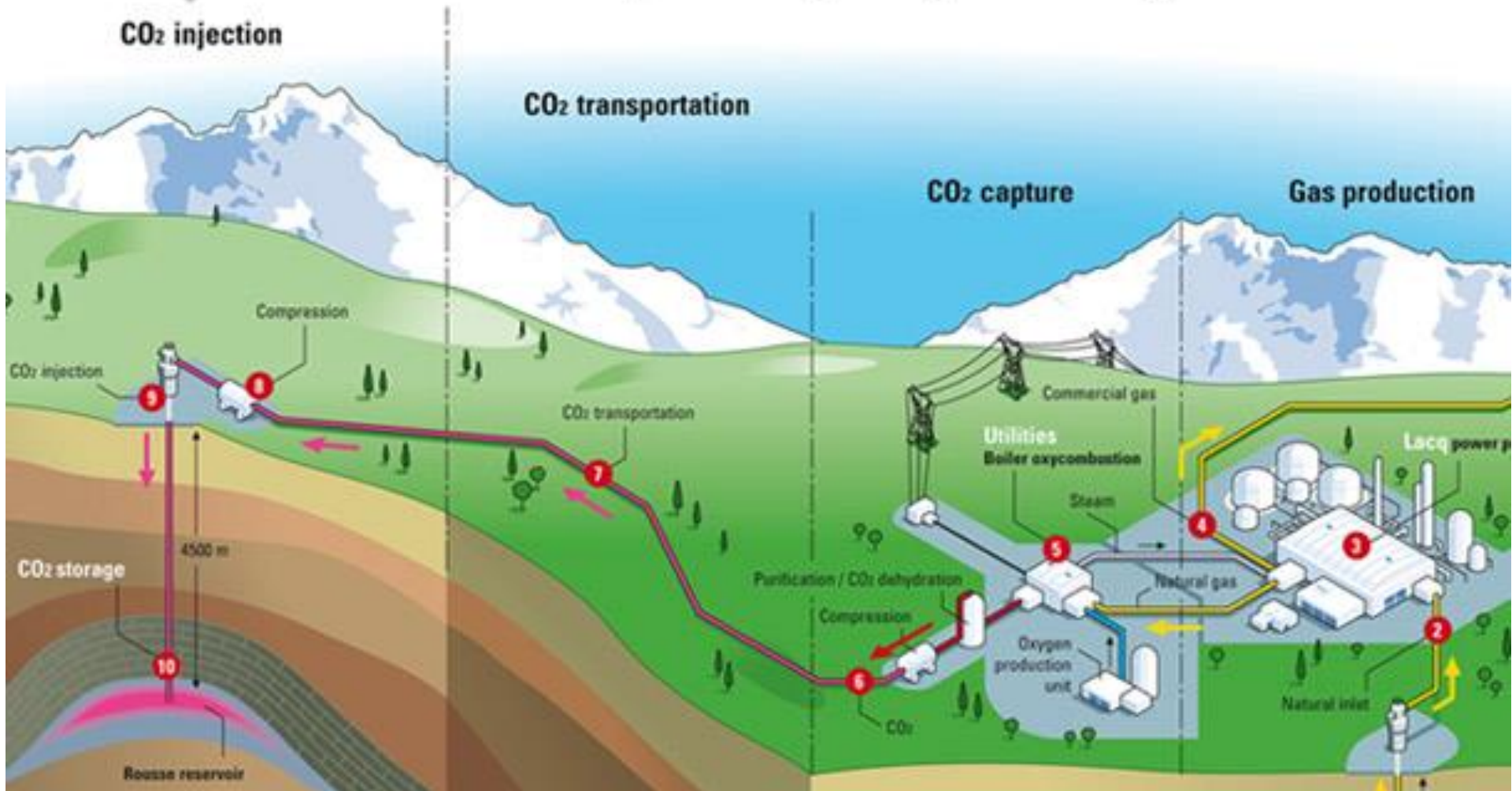
# Carbon capture & geological storage

CO<sub>2</sub> injection

CO<sub>2</sub> transportation

CO<sub>2</sub> capture

Gas production



# Brazilian sedimentary basins



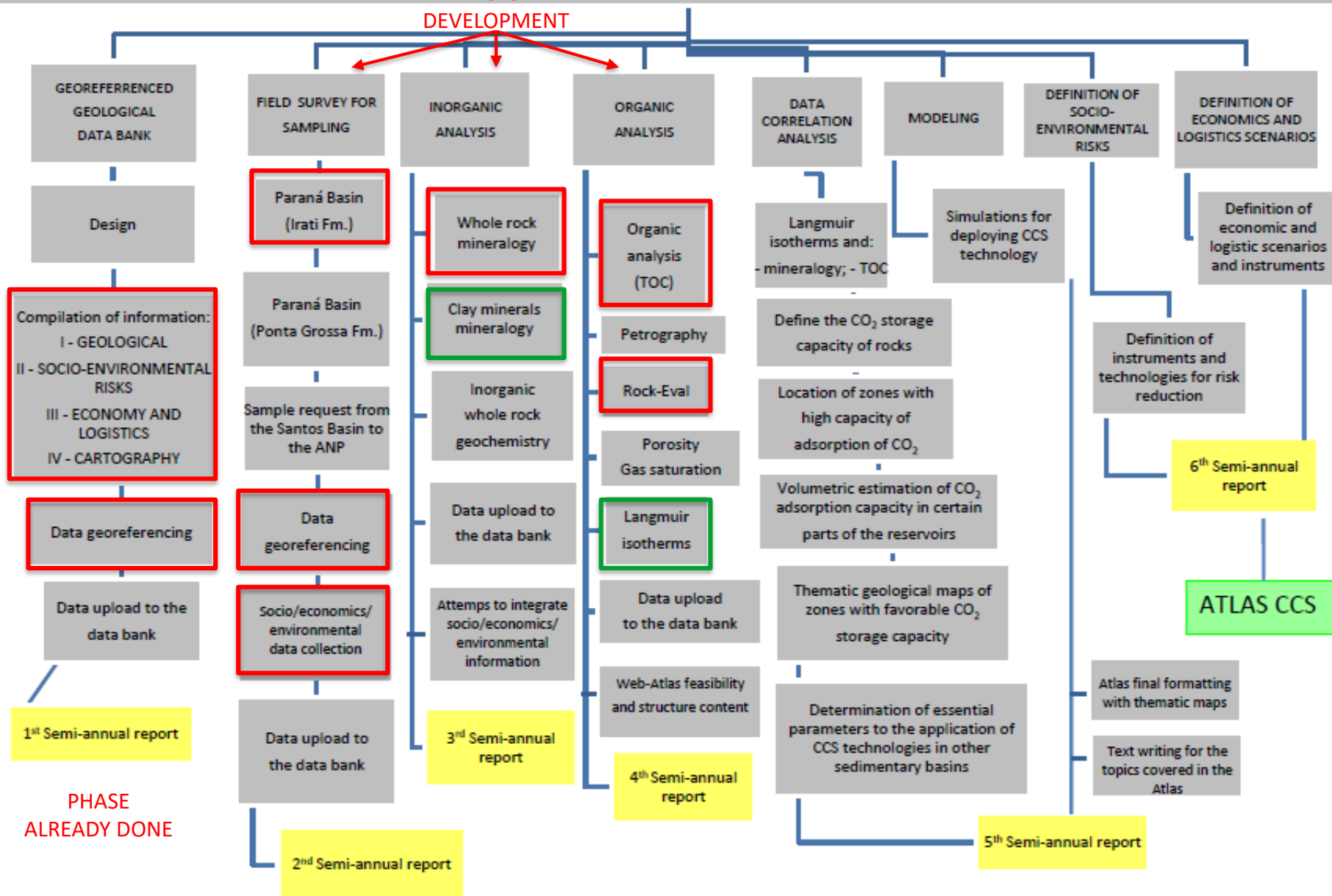


# Objectives

- To test the hypothesis that shales rich in organic matter from the Paraná Basin and turbidites from the Santos Basin can adsorb significant amounts of CO<sub>2</sub>, compatible with the quantities released in productive activities, and constitute important reservoirs of carbon in the region.
- Characterization of socioenvironmental impact risks resulting from the use of areas identified for CCS.
- Definition of economic and logistic scenarios of the use of selected areas for CCS projects.
- To provide a Carbon Storage Atlas with under an integrated view (from sources of emissions to storage sites of carbon) to show information related to the existing infrastructure.
- CCS Atlas's text boxes will provide additional information regarding the state-of-art of economics and logistics assessment in CCS research and pilot deployment, as well as, the expected evolutions in “learning curves” and “potential of cost reductions” – especially in operation of multimodal integrated networks.

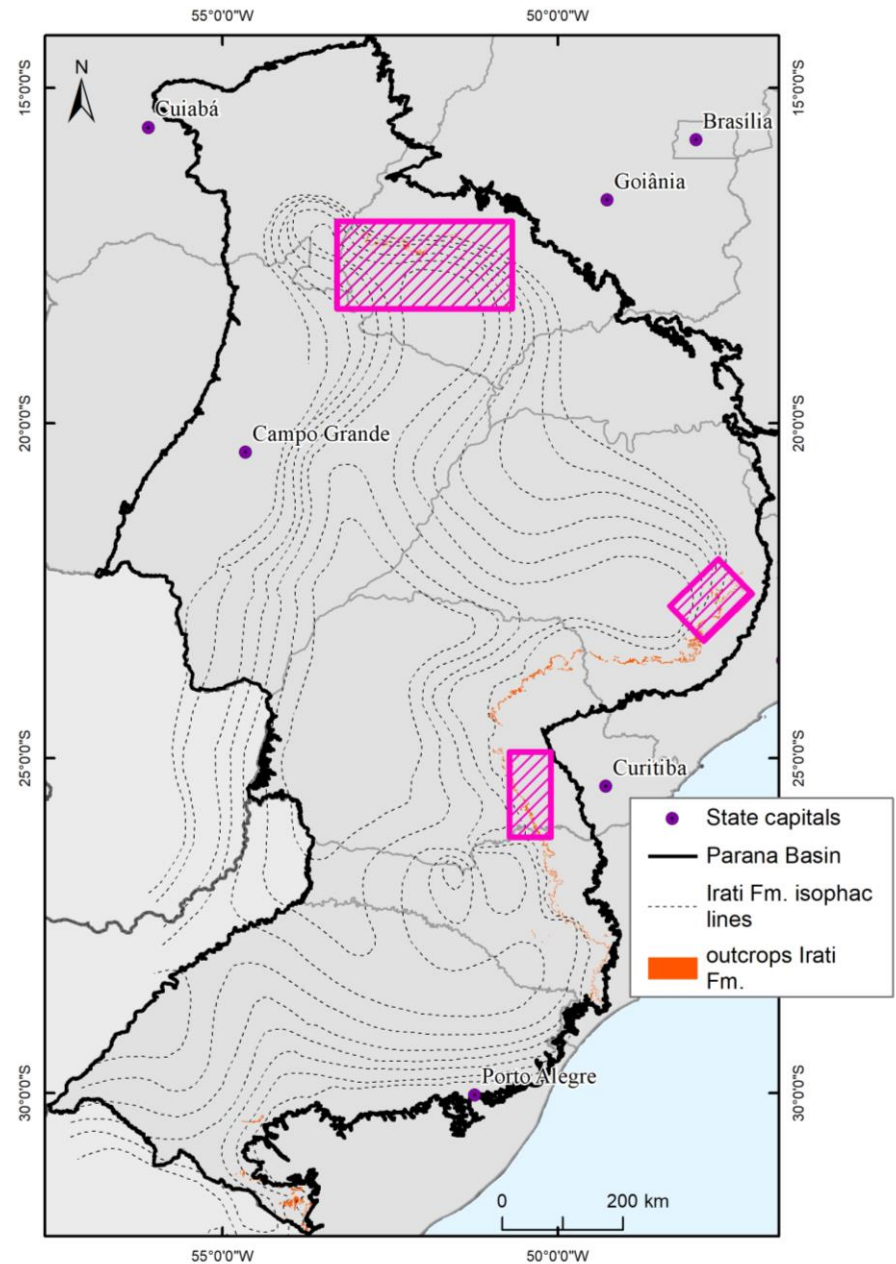
# Perspectives for carbon storage in onshore non-conventional oil reservoirs and offshore sedimentary basins in Southeast Brazil

## PHASES IN DEVELOPMENT





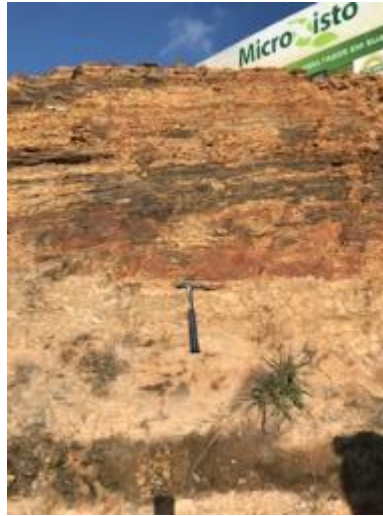
# Paraná Basin Sampling areas



# Paraná Basin



Frente de Pedreira



Corte de Estrada



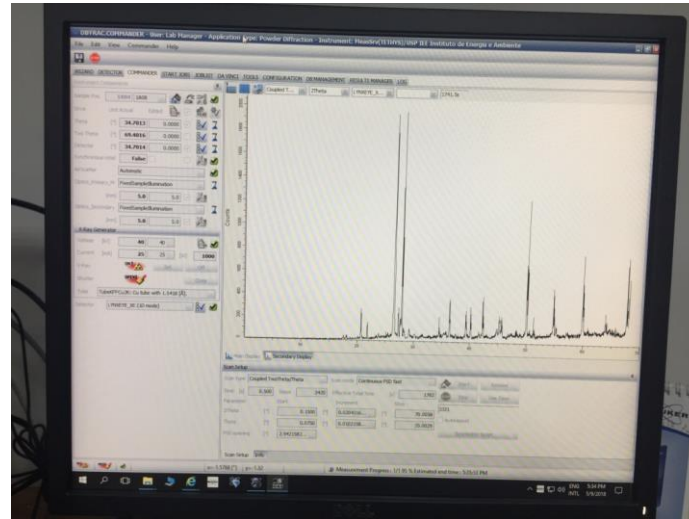
Testemunho de Sondagem



Irati Fm. , São Mateus do Sul (PR)

## main usp analytical facilities available for the project

X-ray diffractometer  
Bruker, D8 Advance



Mineralogy and clay minerals identification

Institute of Energy and Environment  
Division of Oil and Natural Gas  
Laboratorial Infraestructure

# main usp analytical facilities available for the project



Scanning Electron Microscope



Electronic Microprobe

Institute of Geoscience  
USP

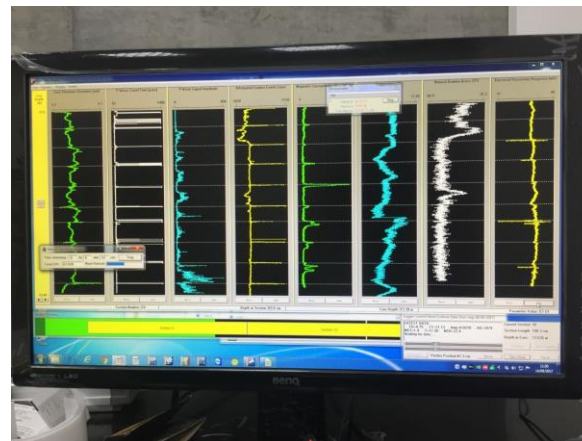
## Multi-Sensor Core Logger Geotek



P Wave  
Attenuated Gamma  
Magnetic Susceptibility  
Electrical Resistivity Response



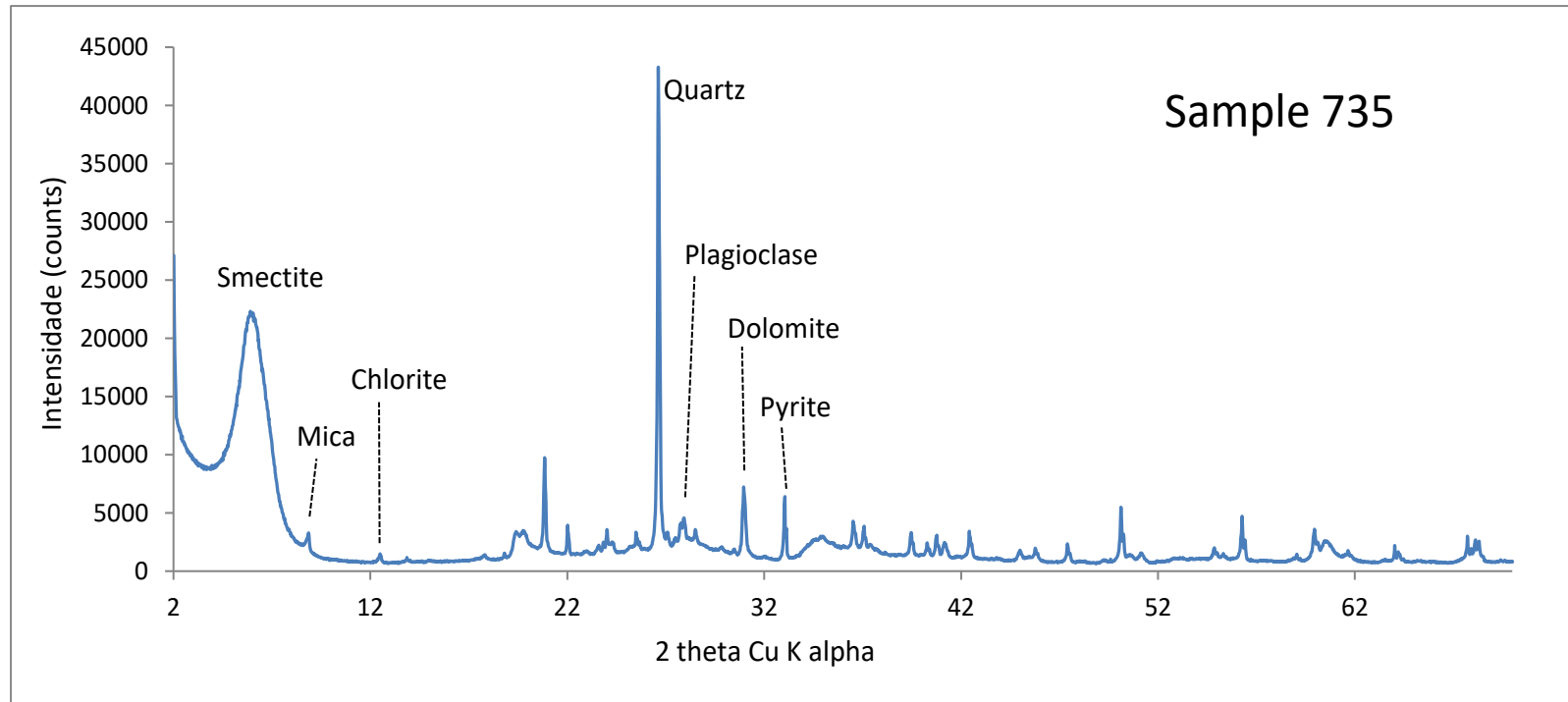
Institute of Energy and Environment  
Division of Oil and Natural Gas  
Laboratorial Infrastructure



Porosity  
Water saturation  
TOC and others



# Whole-rock mineralogy of shale of the Irati Fm. from the Paraná Basin

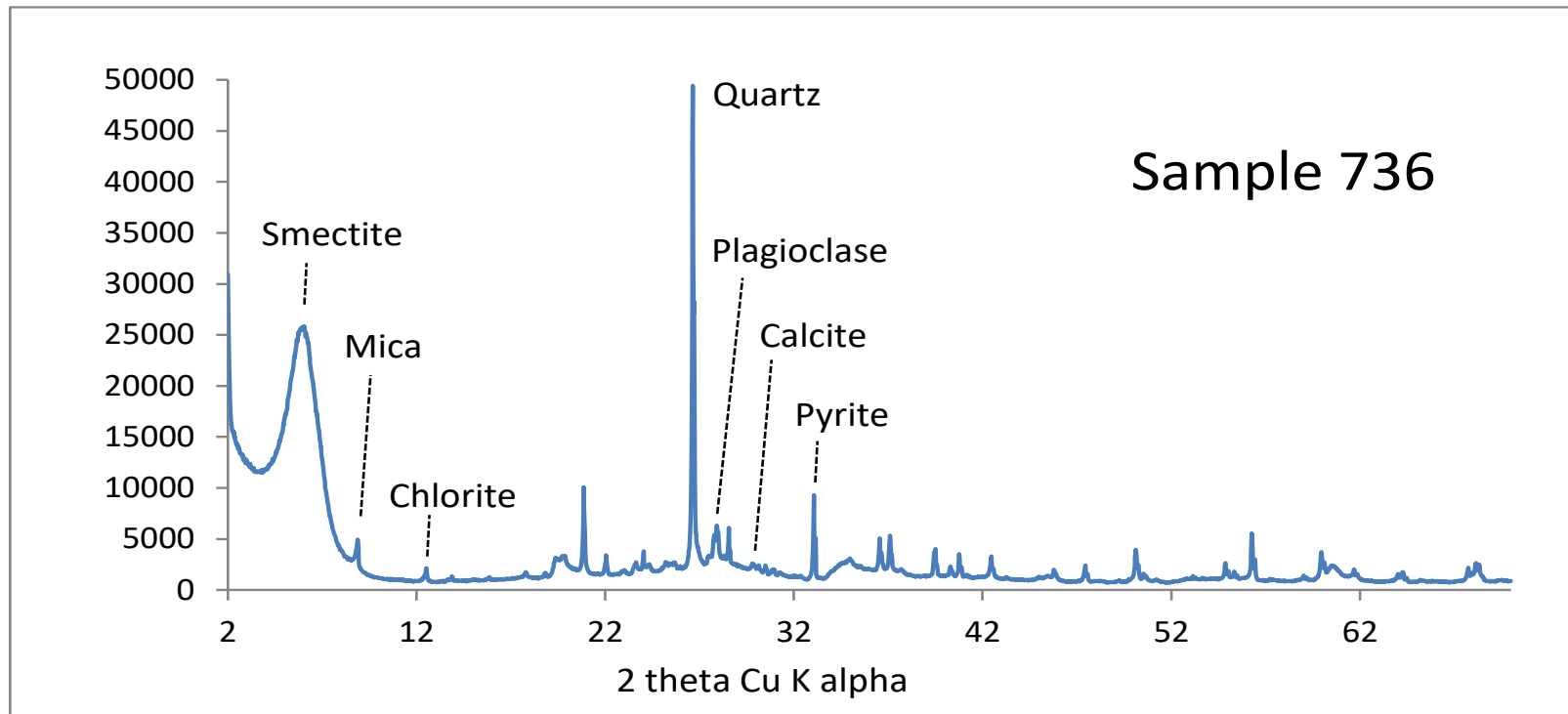


X Ray diffractometry

Souza – undergraduated memory  
San Martin MSc thesis



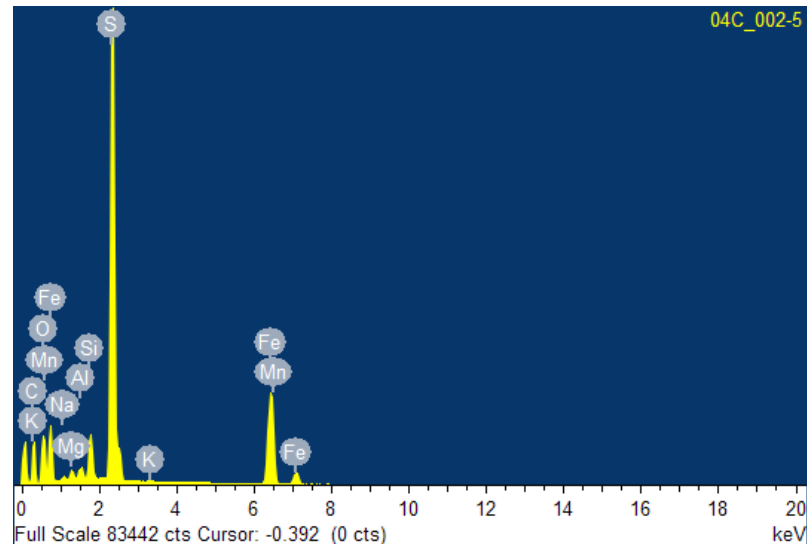
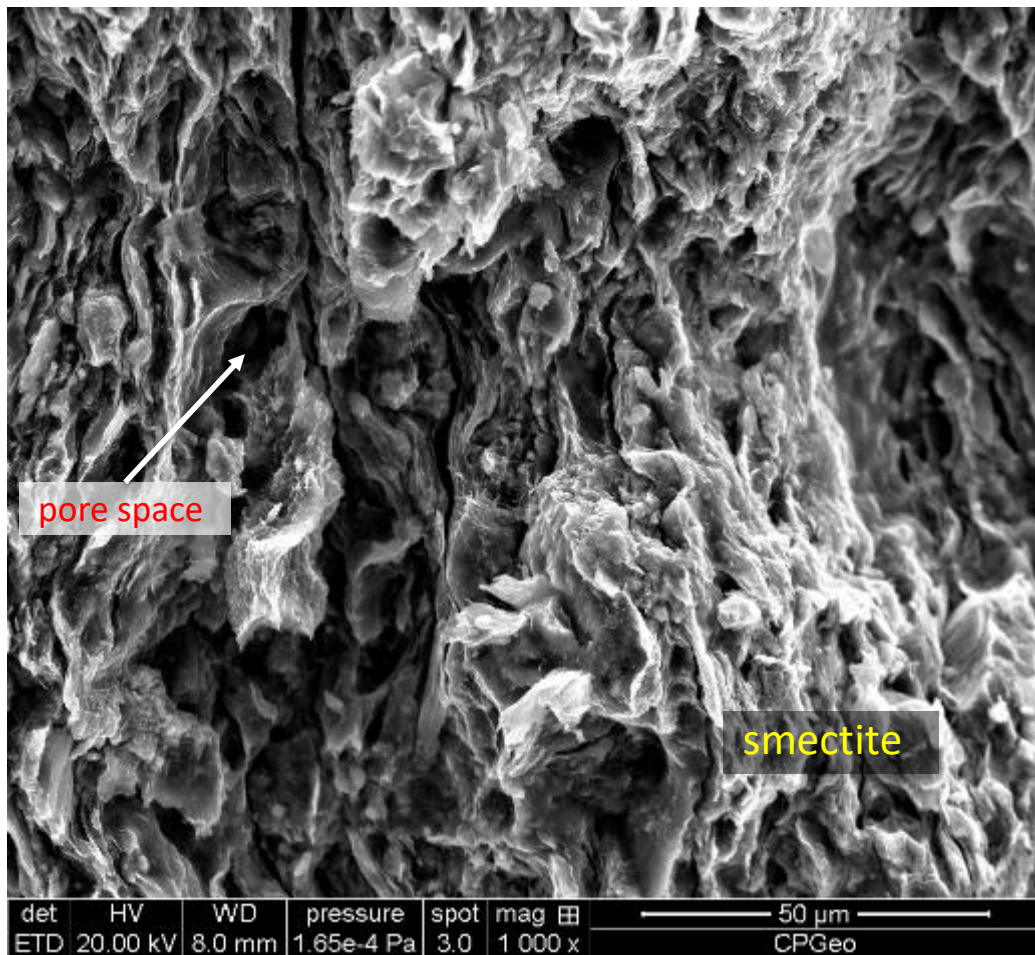
# Whole-rock mineralogy of shale of the Irati Fm. from the Paraná Basin



X Ray diffractometry

Souza – undergraduated memory  
San Martin MSc thesis

# IMAGENS E ANÁLISES (EDS) EM MICROSCÓPIO ELETRÔNICO DE VARREDURA DE MINERAIS DE ARGILAS



Souza – undergraduated memory  
San Martin MSc thesis

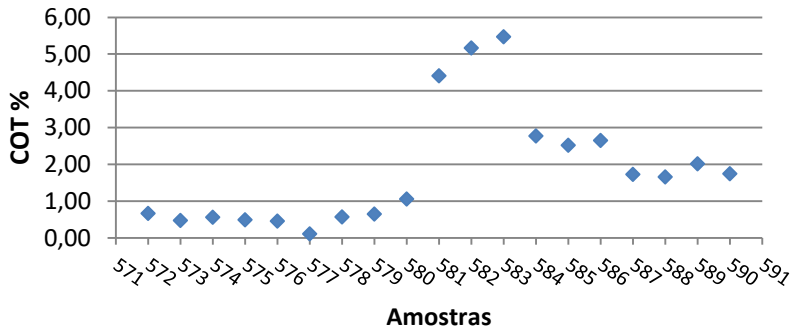
# ÍNDICES GEOQUÍMICOS ORGÂNICOS

**TOC** is obtained by heating the rock to generate the combustion of organic matter and the formation of CO<sub>2</sub>. The released CO<sub>2</sub> is proportional to the amount of C. (Pyrolysis)

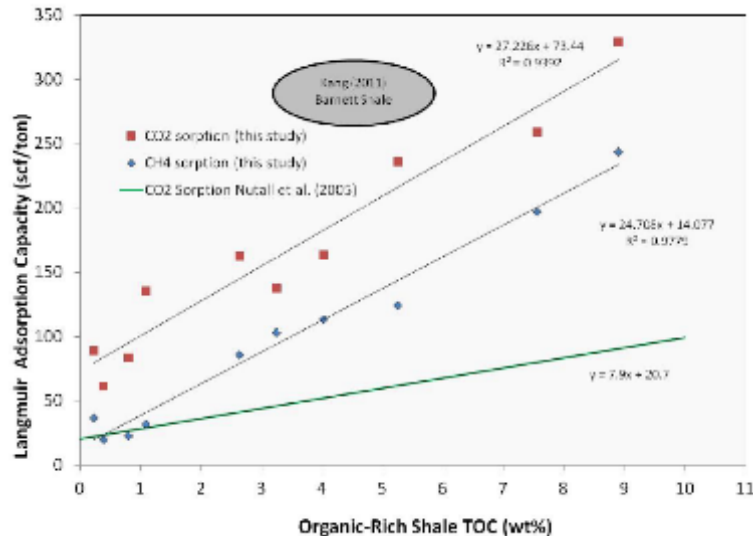
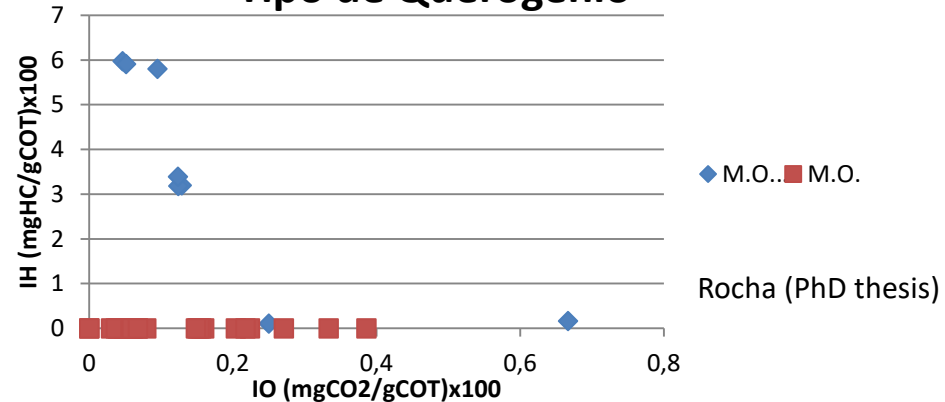
**Rock eval** is the trade name for a set of equipment used to measure the organic content of rocks, as well as, other properties of organic products that help identify the kerogen type.

# Preliminary sample distribution of the results of TOC and Rock-Eval analysis of GO and MT samples

Teor de Carbono Orgânico Total %

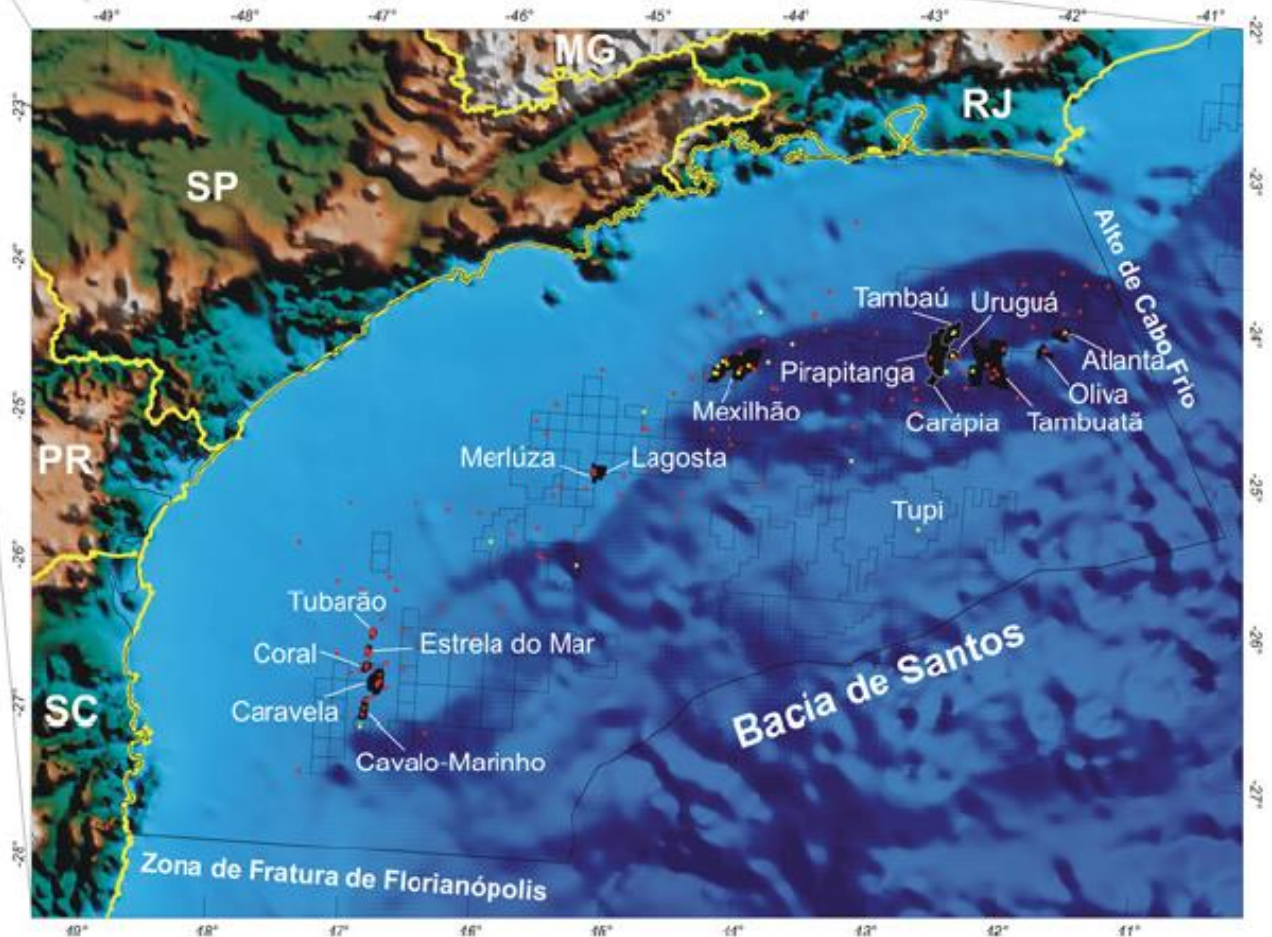
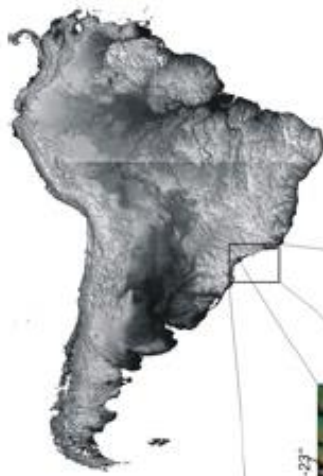


Tipo de Querogênio



Dilmore (2014)

# Santos Basin



Chang et al. 2008







# Academic revision

## *(Economics and Logistics Aspects)*

- The so-called ROADMAPS on CCS (trying to extract economics and logistics revisions presented by authors)
- Models of LNG multimodal integrated transport in Brazil (unpublished) (to base models of CO2 transport)
- International experiences with CCS Atlases (usually not including economics and logistics)
- The Brazilian first Atlas of CO2 CS (published in 2015) by CEPAC-PUCRGS (which attempts to take an integrated approach ... Methodological and data accuracy deserve some criticism, including economic and logistical issues)
- Race, J.M., Seevam, P. N., Downie, M. J. (2007). Challenges for offshore transport of anthropogenic carbon dioxide.
- HENDRIKS, GRAUS and BERGEN (2004)(\*) – Comprehensive economic/logistical study of CCS projects  
TRL review (reference for our basis scenario ... Processes of Updating and Adapting to the Brazilian economics to be proceeded by Proj 36's Team)

## *(Economics and Logistics)*

- Continuous literature revision on CCS economics and logistics (Updating our Reference Scenario)
  - Location and estimates of CO2 emissions;
  - Transport challenges for CCS;
  - Viable CO2 transport modals – beyond pipelines and shipping;
  - Costs of CO2 transport and storage in international cases;
  - Injection of CO2 in reservoirs for an improvement of the extraction of hydrocarbons (oil and gas).
- Critical analysis on literature review and domestic estimations (taking into consideration the local economics and logistics picture)
- Case studies (logistical and economics estimating of potential integrated CASES STUDES ... Described on the PUC - Atlas)
- Boxes of texts (General perceptions of CCS economics and logistics to Atlas readers)

# Environmental and social suitability map for CCS

## Data sources:

### Environmental data:

- **Isopach lines:** from Northfleet et al. (1969)
- **Surface water:** georeferenced data (lakes, rivers and reservoirs) from IBGE (2017), original scale 1:250,000 ([geoftp.ibge.gov.br/cartas\\_e\\_mapas/bases\\_cartograficas\\_continuas/bc250/versao2017/Shapefile/](https://geoftp.ibge.gov.br/cartas_e_mapas/bases_cartograficas_continuas/bc250/versao2017/Shapefile/))
- **Natural reserves:** conservation units (2015) from Ministério do Meio Ambiente do Brasil ([mapas.mma.gov.br/i3geo/datadownload.htm](https://mapas.mma.gov.br/i3geo/datadownload.htm))
- **Groundwater productivity:** hydrogeology from SGB – CPRM (2014) ([www.cprm.gov.br/publique/Hidrologia/Mapas-e-Publicacoes/Mapa-Hidrogeologico-do-Brasil-ao-Milionesimo-756.html](http://www.cprm.gov.br/publique/Hidrologia/Mapas-e-Publicacoes/Mapa-Hidrogeologico-do-Brasil-ao-Milionesimo-756.html))
- **Potentially critical areas for the use of groundwater:** Instituto Geológico do Estado de São Paulo (2010) ([igeologico.sp.gov.br/wp-content/uploads/noticias/igeologico/ps\\_down\\_outros.aspm.htm](http://igeologico.sp.gov.br/wp-content/uploads/noticias/igeologico/ps_down_outros.aspm.htm))

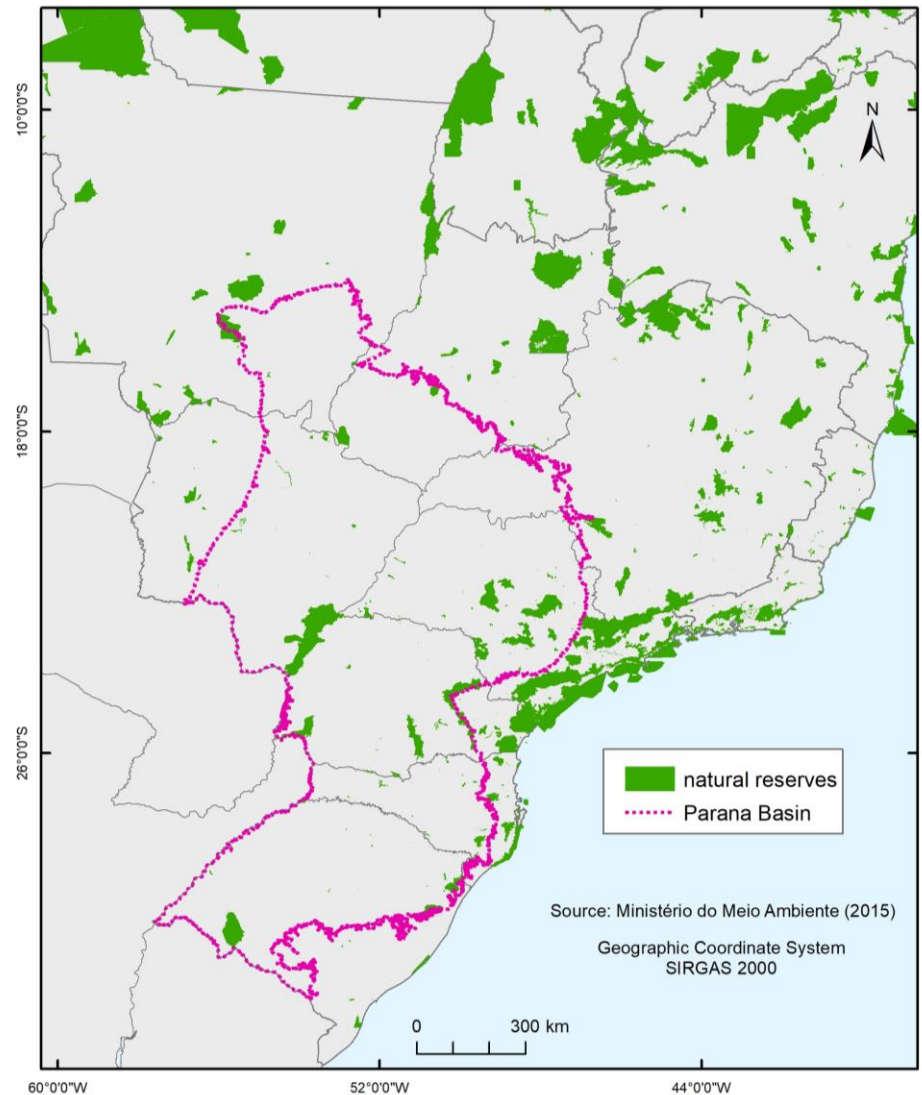
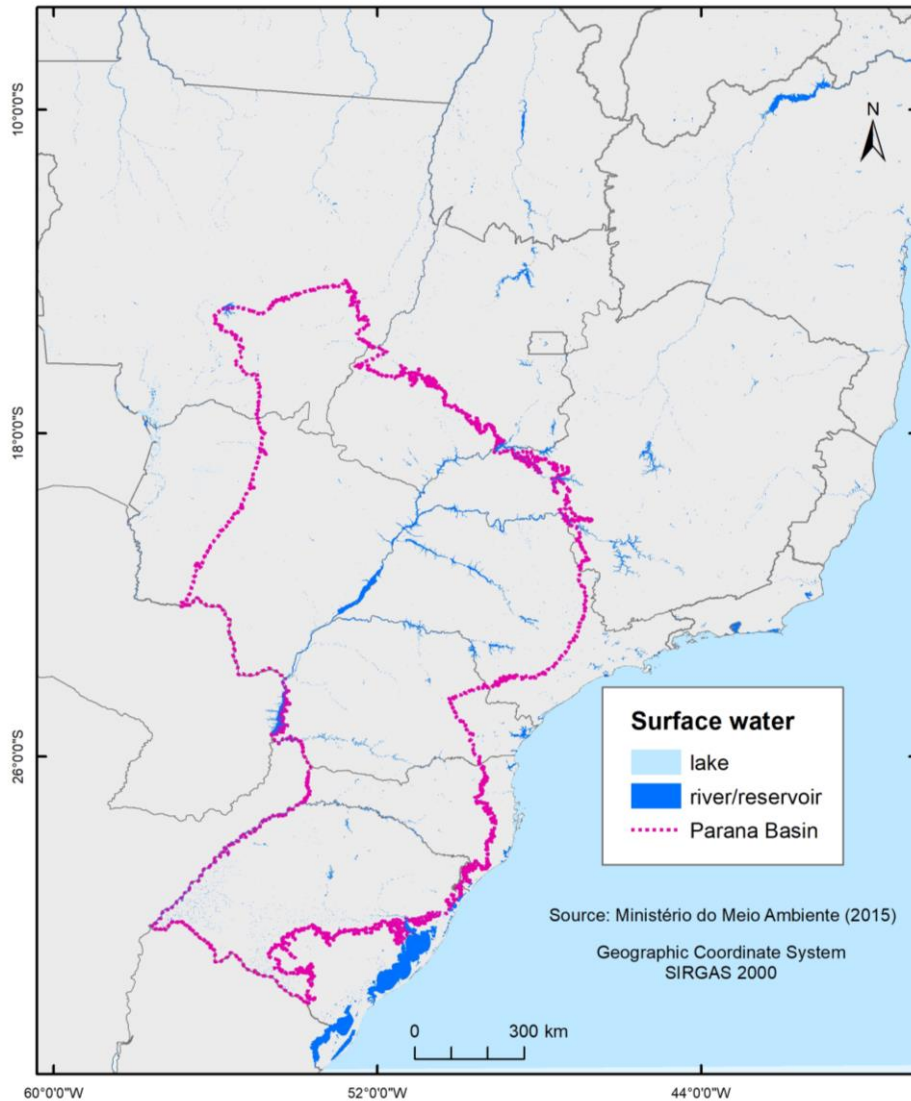
### Demographic and Socioeconomic data:

- **Population density:** Demographic Census (2010) and municipality area from IBGE (2011) (<https://www.ibge.gov.br/geociencias-novoportal/organizacao-do-territorio/estrutura-territorial/15761-areas-dos-municipios.html?=&t=downloads>)
- **GDP per capita:** gross domestic product (at purchasing power parity) per capita by municipality (2015) from IBGE (<https://www.ibge.gov.br/estatisticas-novoportal/economicas/contas-nacionais/9088-produto-interno-bruto-dos-municipios.html?=&t=downloads>)
- **Indigenous land:** from IBGE (2017), original scale 1:250,000 ([geoftp.ibge.gov.br/cartas\\_e\\_mapas/bases\\_cartograficas\\_continuas/bc250/versao2017/Shapefile/](https://geoftp.ibge.gov.br/cartas_e_mapas/bases_cartograficas_continuas/bc250/versao2017/Shapefile/))

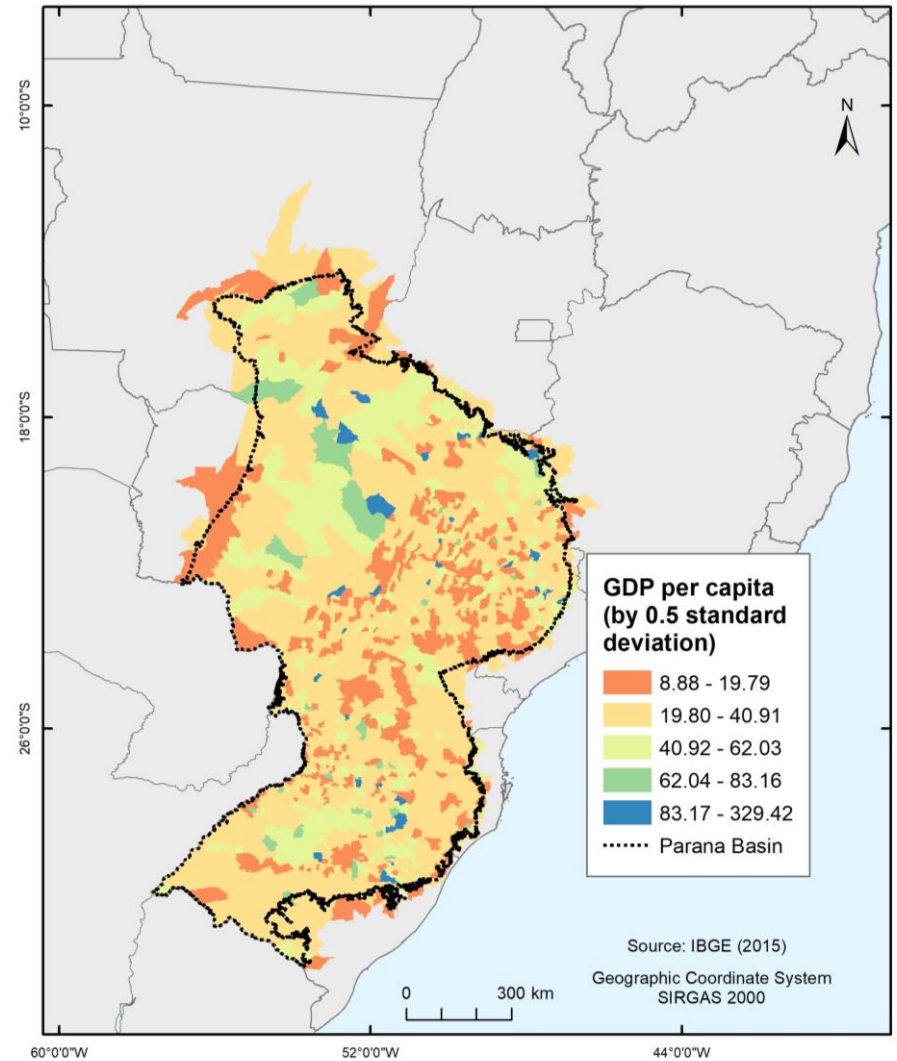
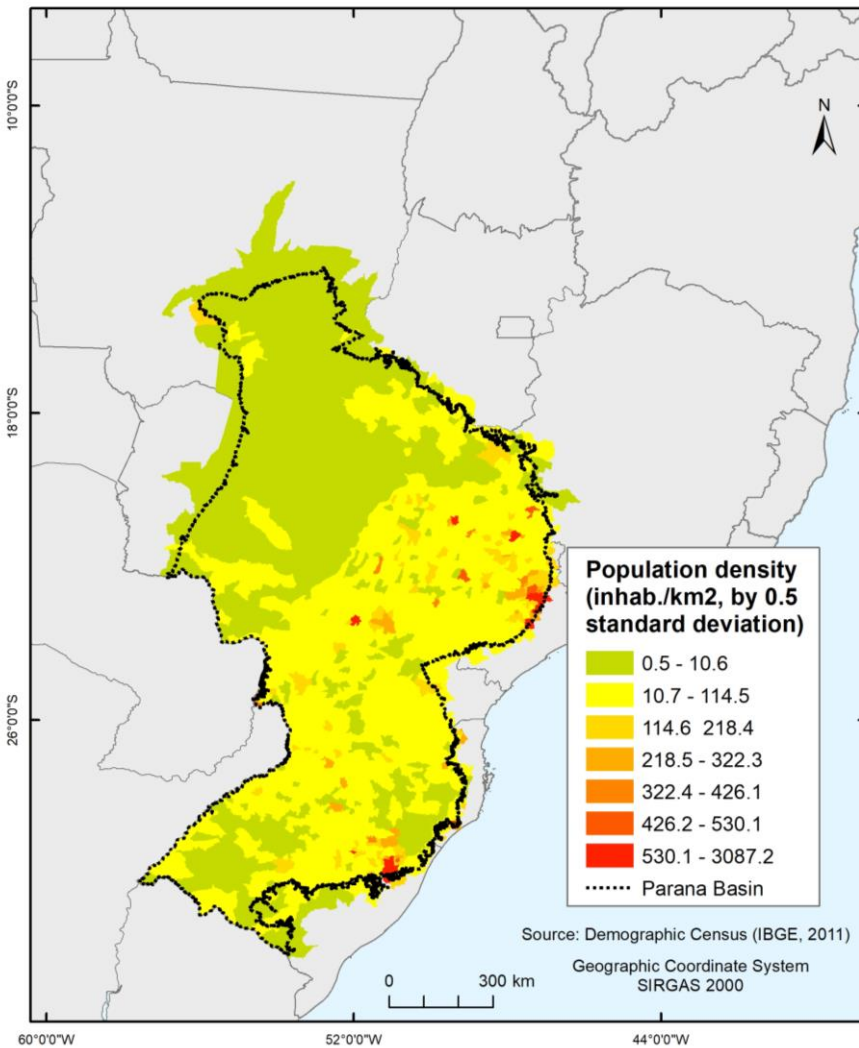
### Infrastructure:

- **Pipelines:** from Ministério do Meio Ambiente do Brasil PNLT (2008) ([mapas.mma.gov.br/i3geo/datadownload.htm](https://mapas.mma.gov.br/i3geo/datadownload.htm))

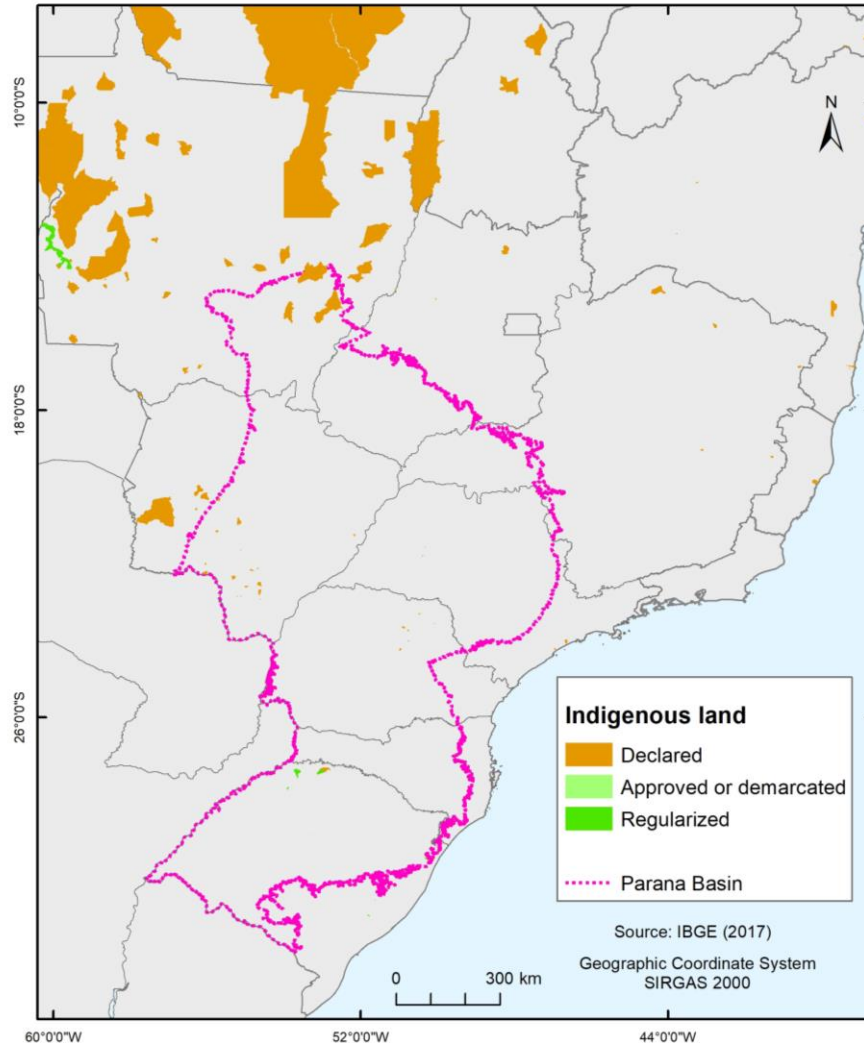
# Environmental suitability map for CCS



# Socioeconomic suitability map for CCS

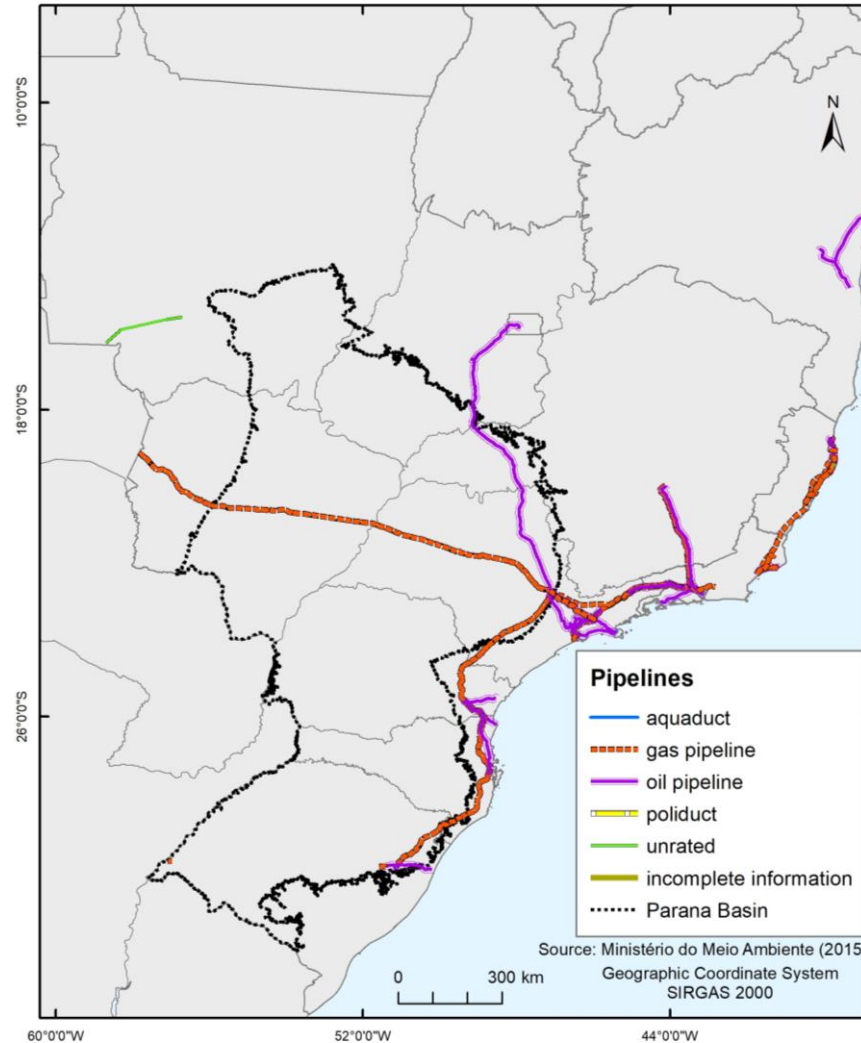


# Socioeconomic suitability map for CCS





# Infrastructure



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