VIII GeoSciEd 2018 – 8th Quadrennial Conference of the International Geoscience Education Organisation (IGEO)
– Geosciences for Everyone –
VIII Simpósio Nacional de Ensino e História de Ciências da Terra / EnsinoGEO-2018
– Geociências para Todos –
Campinas – Sao Paulo – Brazil, July 2018

Three-dimensional physical models of sedimentary basins as a resource for teaching-learning of Geology

Celso Dal Ré Carneiro, Kauan Martins dos Santos, Thiago Rivaben Lopes, Filipe Constantino dos Santos, Jorge Vicente Lopes da Silva, Ana Lucia Nogueira de Camargo Harris

University of Campinas

Graduate Program of Teaching and History of Earth Sciences (THES), Institute of Geosciences, Unicamp

Institutions

1. Geosciences Institute, University of Campinas
   - Graduate Program of Teaching and History of Earth Sciences
   - Undergraduate Course of Geology
2. Renato Archer Information Technology Center (ITC)
3. Faculty of Civil Engineering and Architecture, University of Campinas

Objectives

New didactic resources, starting from **physical models of sedimentary basins**, to improve geological 3D visualization, with the support of the Renato Archer Information Technology Center

- Three-dimensional modeling connects several fields of knowledge, both basic and applied
- Manipulation of 3-D objects benefits students' acquisition of spatial vision
  - 3-D models may be good educational tools
- Portuguese publications on the subject, at least for Geosciences, are lacking

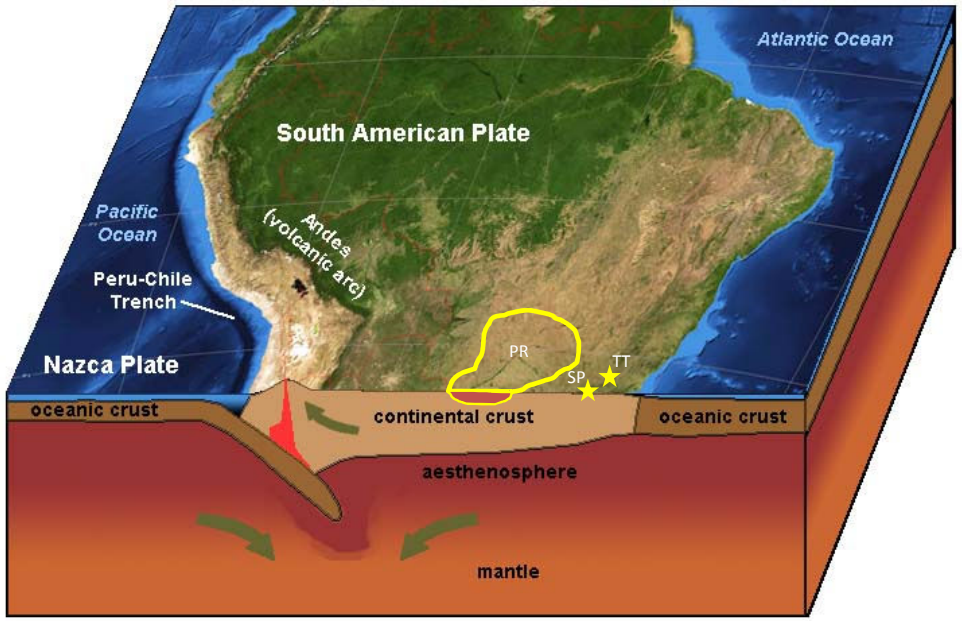
The studied basins

Research aims to create examples of 3-D models of sedimentary basins:

PR: Paraná Basin (Silurian-Upper Cretaceous)

SP: Taubaté basin (Neogene)

TT: São Paulo basin (Neogene)



http://geologycafe.com/images/south_america_subduction.jpg

Methods and Materials

- There are many techniques for producing physical models in state-of-the-art 3D-compatible printers
- Printers will generate didactic and exposure material of: (a) the whole basin (**TT**, **SP**) or (b) regional stratigraphic levels (**PR**), as the Guarani Aquifer System (**GAS**)
  - Digital and physical 3D models of selected rocky bodies and sedimentary basins rely on geo-interpreted representations
    - **Deep contour maps**, charts, images, photographs and geological-structural profiles

A few examples, among others:

Rhino 5 for Windows®
URL: https://www.rhino3d.com/

Sketchfab
URL: https://sketchfab.com

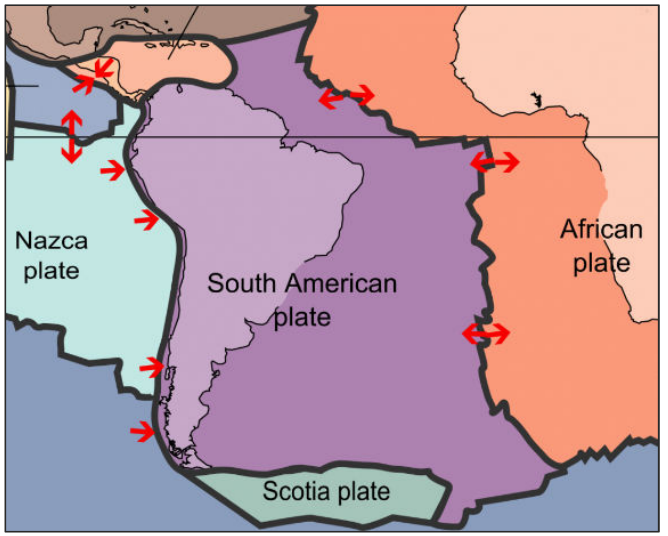
Visible Geology
URL: http://app.visiblegeology.com/

Agisoft PhotoScan
URL: http://www.agisoft.com/

If millions of people make 3D models or digitize the real world in 3D, why would they share that in 2D? YouTube made it for video creators, or SoundCloud for musicians, we want to do for 3D creators (Sketchfab 2016)

Project Purposes

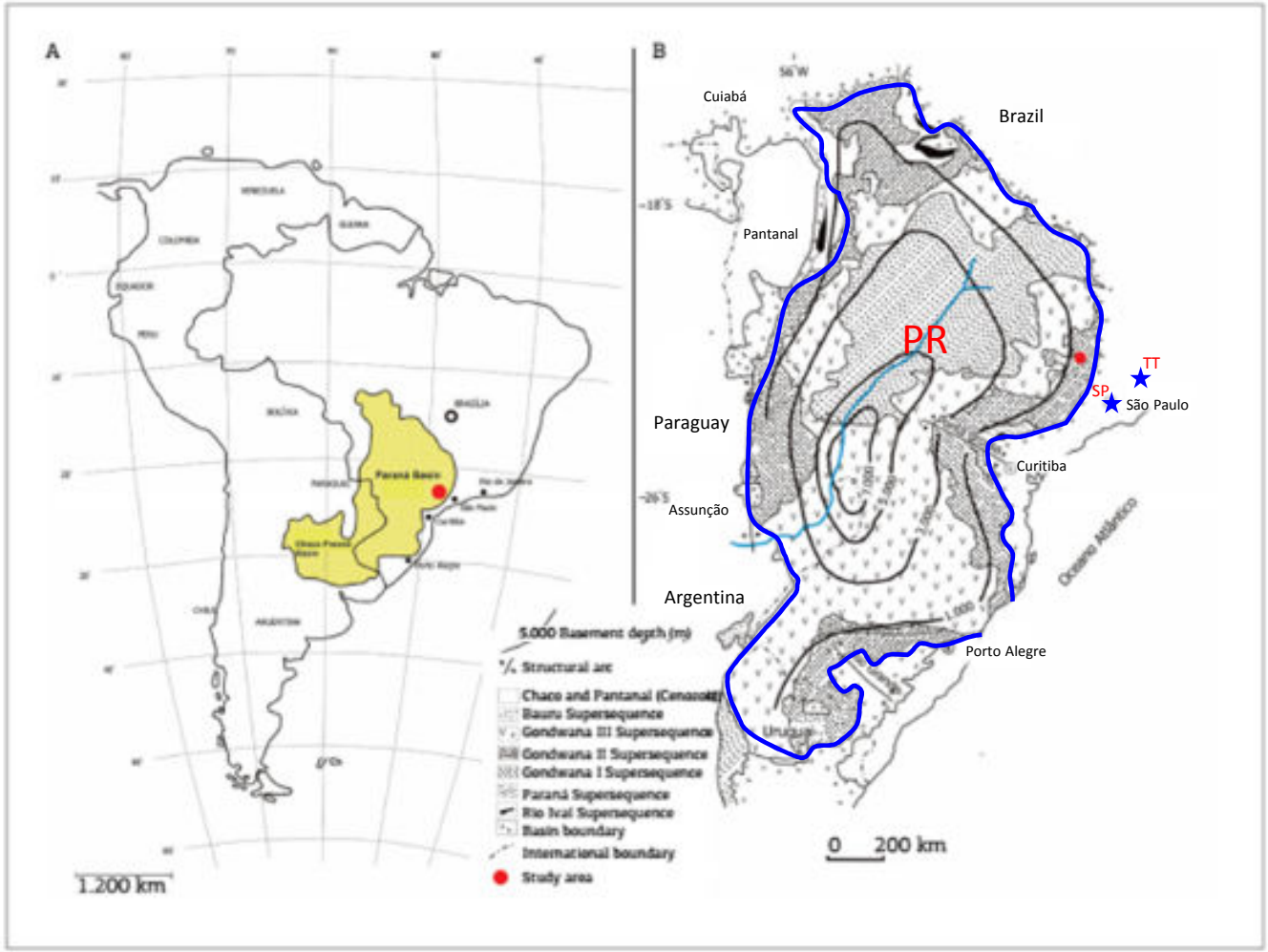
- Physical model focus on Geoscience teaching
  - Didactic guide for practical classes will include:
    - General and specific information about each individual selected basin, structure and evolution
- The resources will support **training workshops** for in-service teachers



http://brazilcultureandhistory.com/bchp-001-geology-geography/

Model #1

PARANÁ BASIN



http://www.scielo.br/img/revistas/bjgeo/v47n2/2317-4692-bjgeo-2317-4889201720160117-gf2.png

The first 3-D physical model of the Parana Basin

Physical model produced using a 3-D printer (3h15’)
12cm X 8cm, automatic pencil for scale

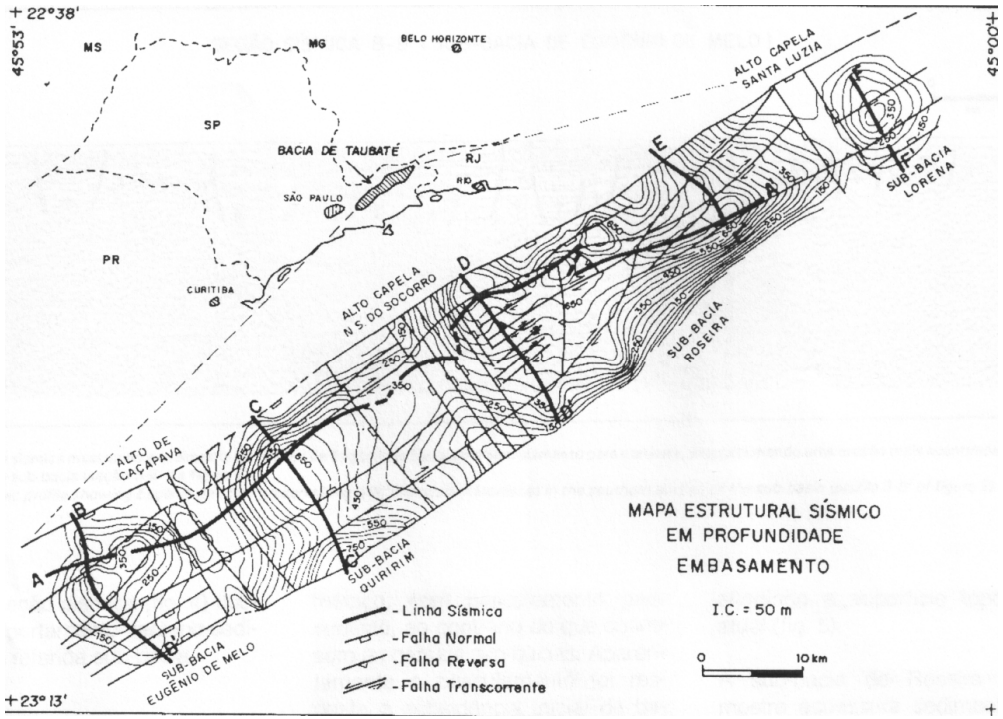
3-D model by **Ana Lucia Nogueira de Camargo Harris**

Earth Science Spatial Thinking (ESST)

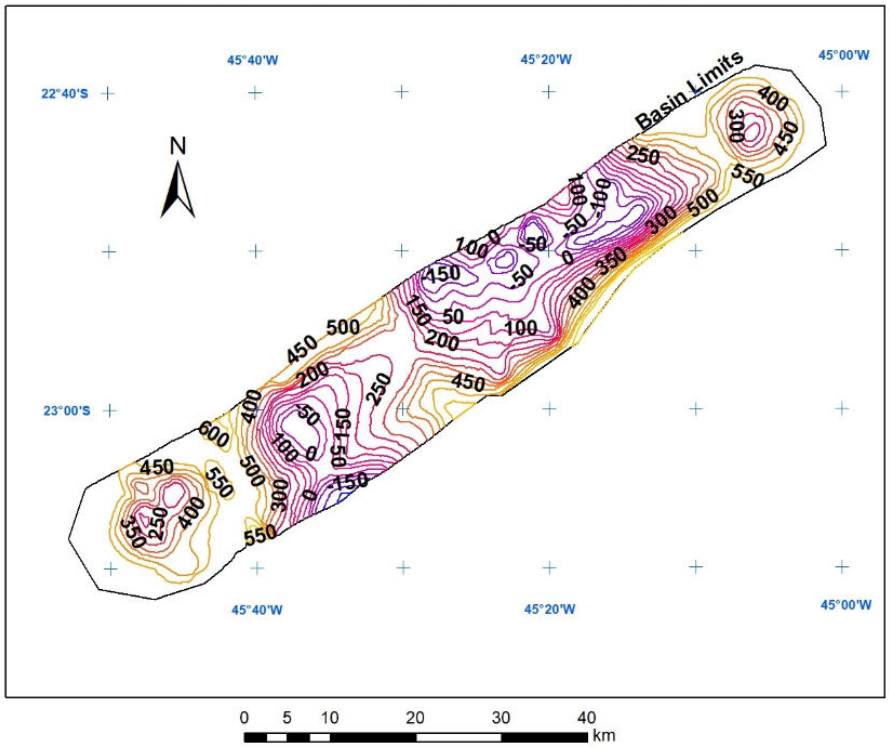
The ability to visualize geological structures within solid rock masses is critical for geologists and other professionals. It depends on the learner to develop, or to construct, a visual penetrative ability

ESST involves "envisioning, manipulating, or drawing meaning from the position, shape, orientation, trajectory, or configuration of objects or phenomena, or groups of objects or phenomena" (Kastens et al. 2014)

From a 2-D representation into a 3-D model

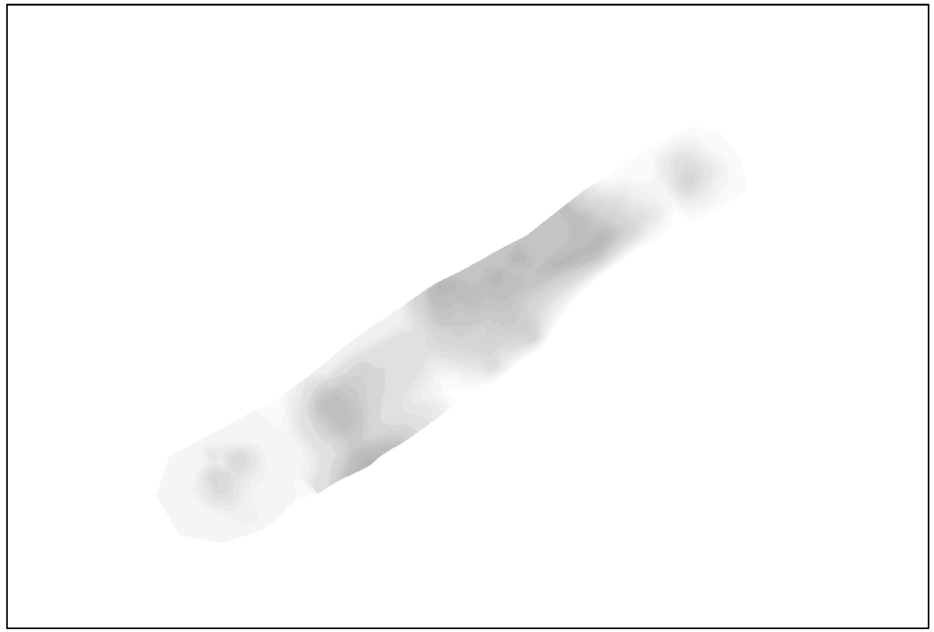


Marques A. 1990. B. Geoci. PETROBRAS, 4:253-262

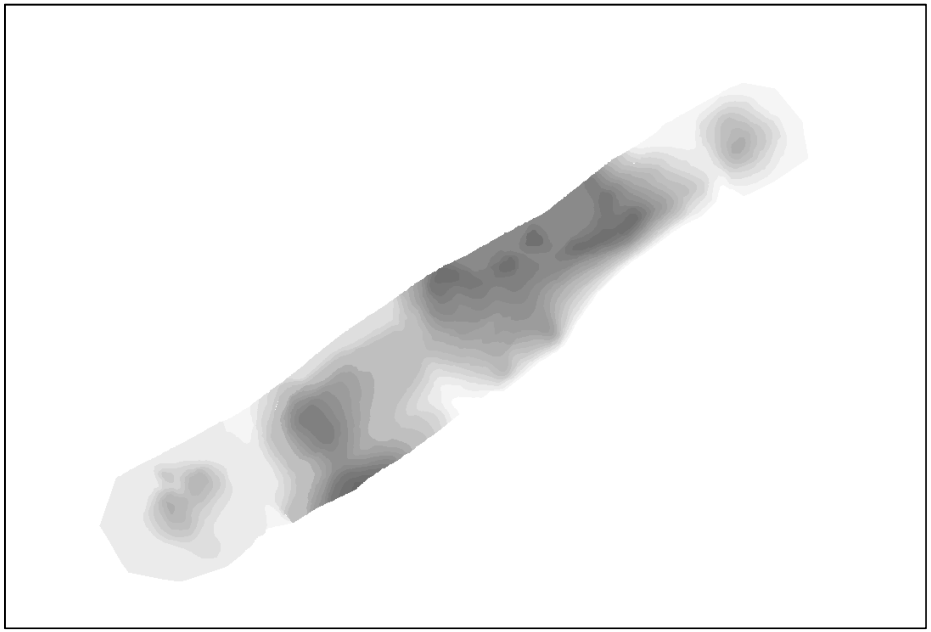


Using Rhinoceros® to develop a 3-D model

Contours of Taubaté Basin 30% gray



Contours of Taubaté Basin 60% gray



Images by **Thiago Rivaben Lopes**

A 3-D model ready to print

Model of the Taubaté Basin imported on 3Dmax and exported as .stl format

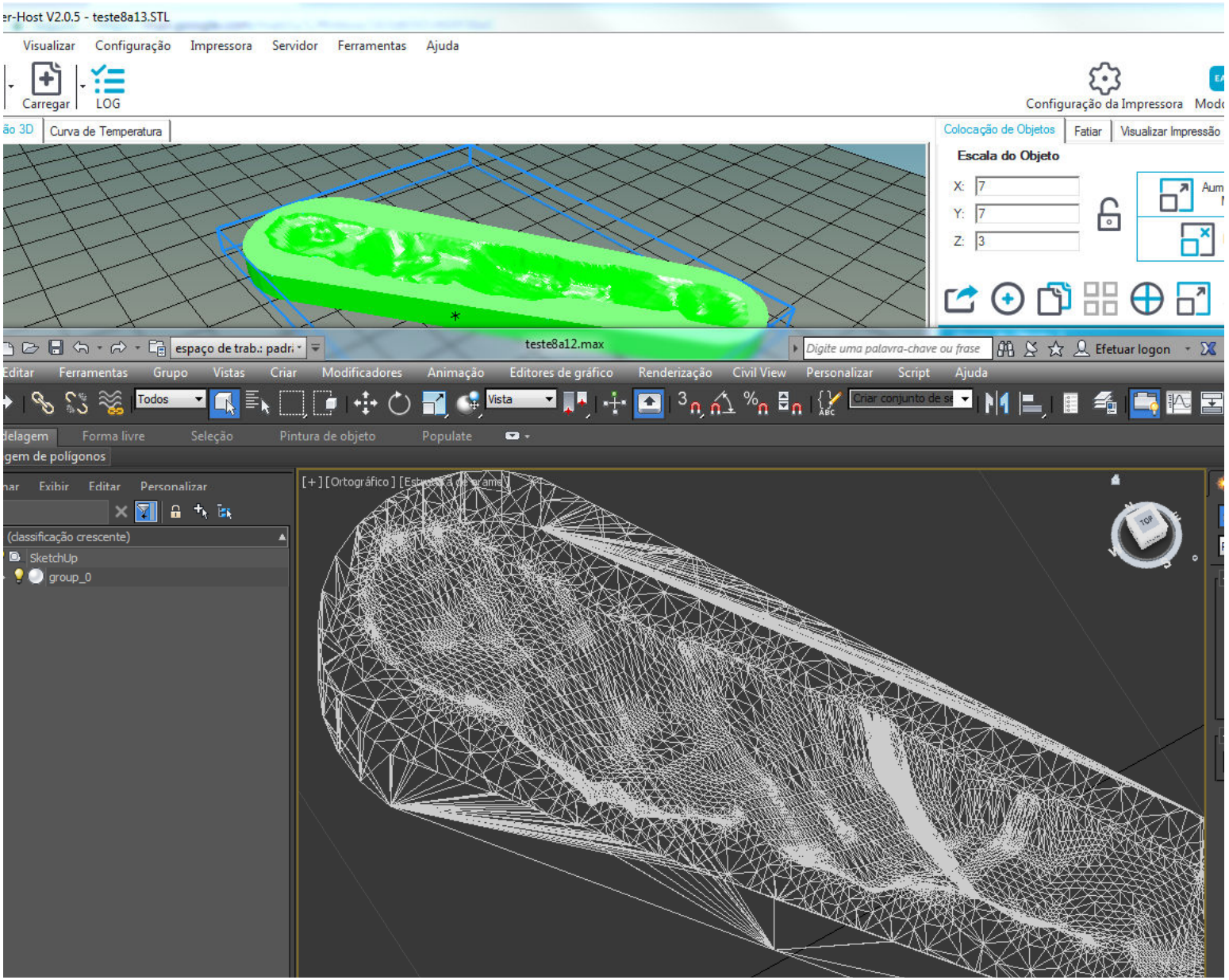
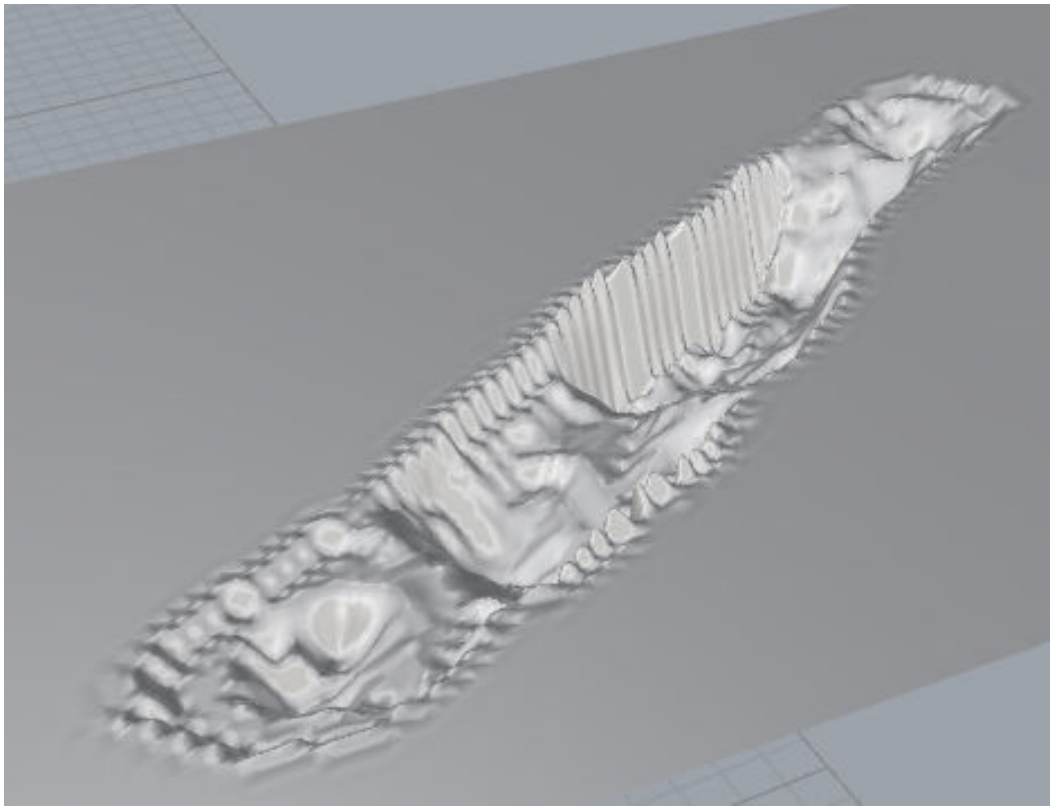


Image by **Ana Lucia N. C. Harris**

Stereology and 3D visualization

- Kastens et al. (2014) claim that the USA educational system rarely includes the ability of spatial reasoning in the contents treated in Earth Sciences
  - Geosciences contents in Brazil are fragmented in a few disciplines
  - **Stronger barriers** to develop skills



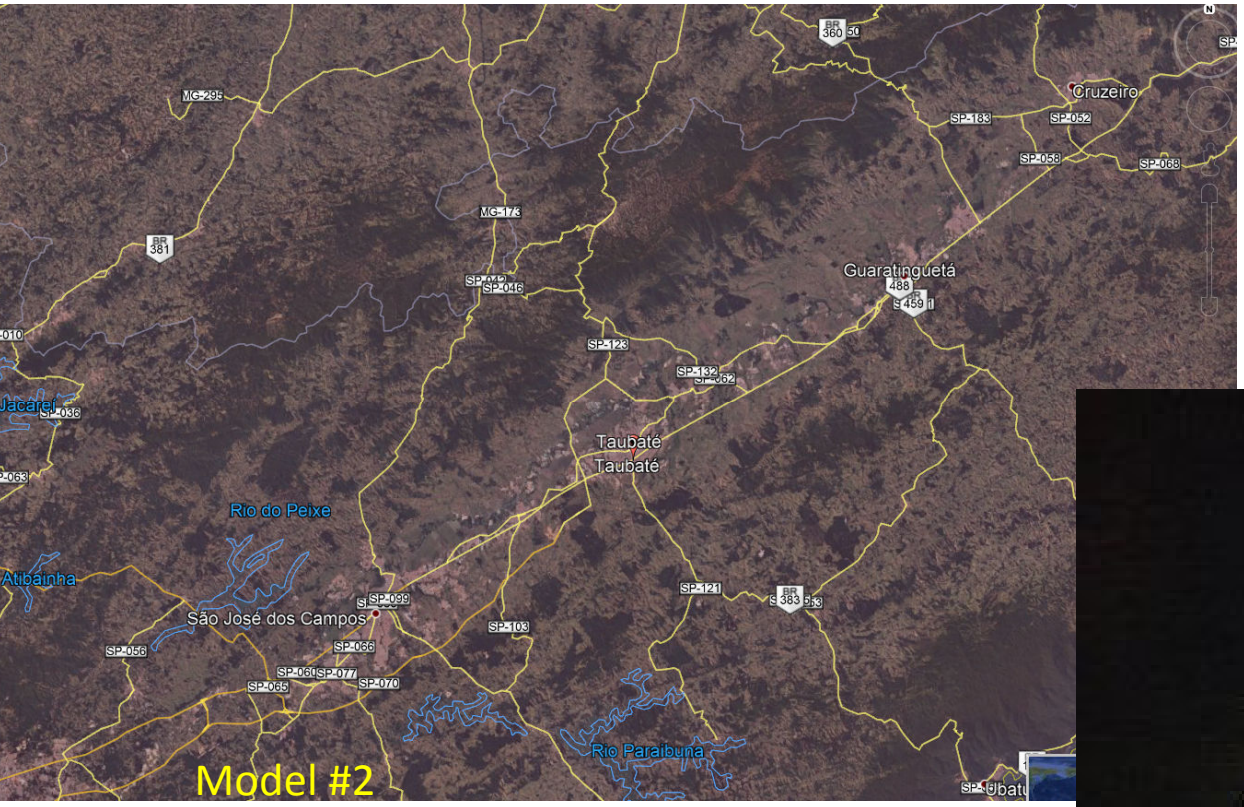


Image Landsat / Copernicus (C)2018 Google Data SIO NOAA. U.S. Navy, HGA, GEECO

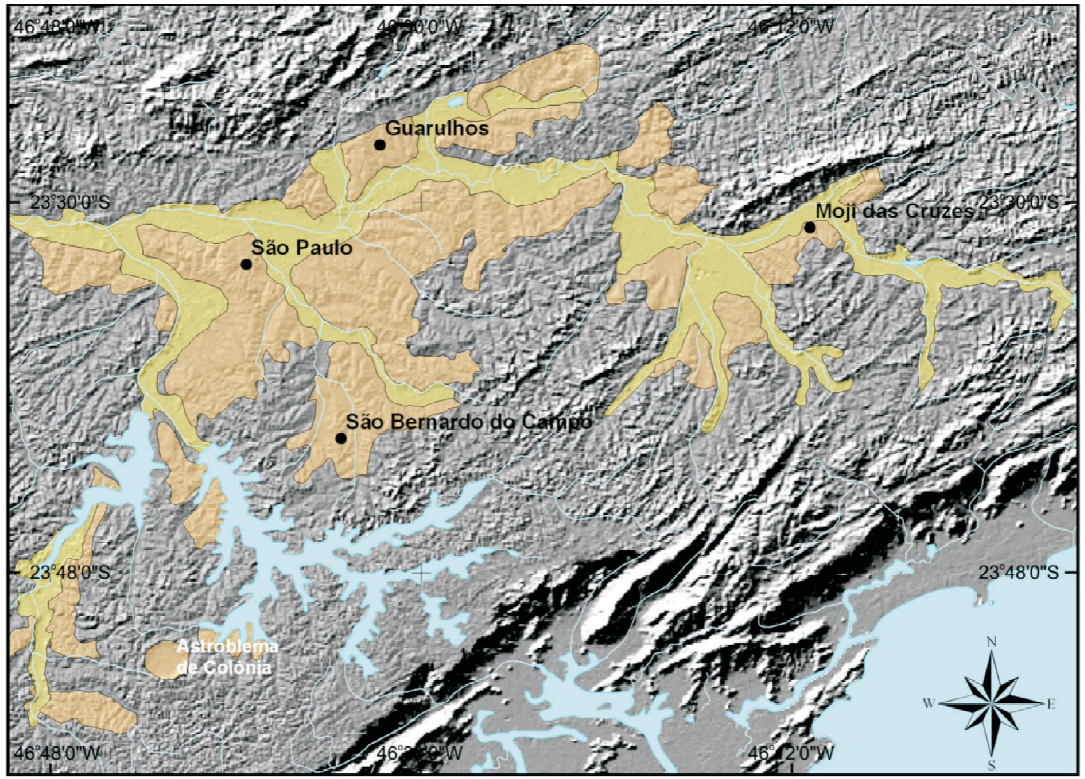
TAUBATÉ BASIN

3-D model by **Ana Lucia Nogueira de Camargo Harris**

http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-40142017000100237&lng=en&nrm=iso&tlng=pt

Model #3

SÃO PAULO BASIN



City
Drainage channel
Reservoir
Neogene sediments
Quaternary sediments
Basement (3D elevation model)

0 10 20 km

3-D model in the pipeline

Research challenges

a) To recover the available resources for 3D modeling

b) To evaluate their potential, characteristics, advantages and limitations for applications in Geology and Geosciences

c) To create computational models of the basins

d) To produce at least one physical model of each basin based on a computational model

The quality of a model is a direct function of the quality and quantity of the available data from bore-holes or fieldwork. The difficulty increases if the data are poorly distributed or insufficient (Pollard & Fletcher 2005)

Topics for a Geoscience training workshop

- Use the supplied Geologic Time Scale to find the corresponding time interval for the physical model: From_____Ma to _____Ma

Please select one of the basin models. Questions:

- What are the dimensions of the basin in km?
- What is the total thickness of accumulated material?
- The total thickness corresponds to _____% of the basin length
- Is the vertical scale the same as the horizontal scale? Please explain
- Hypothezise how a basin “creates” space when a new sedimentary bed is deposited
- Explain with your own words the meaning of **subsidence**

Conclusions

- Didactic use of 3D models may attract teachers and students for research and educational work
- Easy visualization provided by 3D print capabilities can yield:
  - New educational methods
  - New functions
  - Refinement of the models
- Basin models (**PR**, **TT**, **SP**) may improve subsurface geological data processing at the University of Campinas
- Models will be tested and refined before reaching any full public domain

Acknowledgements

- The authors thank the National Council for Scientific and Technological Development (**CNPq**) for:
  - Research Productivity grant to one of the authors (CDRC)
  - Scientific Initiation Scholarship Program for undergraduate students
- The authors acknowledge the stimulating opinion of two **FAPESP** anonymous referees, who decided that the project is **obsolete**

References

Almeida F.F.M.de 1980. *Tectônica da Bacia do Paraná no Brasil.* São Paulo, IPT, 187 p. (Report nº 14.091).

Carneiro C.D.R., Hasui Y., Giancursi F.D. 1976. Estrutura da Bacia de Taubaté na região de São José dos Campos. *In:* SBG, Congr. Bras. Geol., 29, Ouro Preto, 1976. *Anais...*, v. 4, p. 247-256.

Carvalho A.M.A.de, Vidal A.C., Kiang C.H. 2011. Delimitação do embasamento da Bacia de Taubaté. *eol. USP, Sér. cient.*, 11(1):19-32. DOI: http://dx.doi.org/10.5327/Z1519-874X2011000100002.

Fernandes F.L., Chang H.K. 1992. Compartimentação e evolução tectônica da Bacia de Taubaté. In: SBG, Congr. Bras. Geol., 37, São Paulo, 1992. *B. Res. Expand...,* São Paulo, v. 1, p. 570-572.

Fernandes F.L., Chang H.K. 2001. Modelagem gravimétrica da Bacia de Taubaté. Vale do Rio Paraíba do Sul, leste do Estado de São Paulo. *Rev. Bras. Geof.*, 19:131-144. URL: http://www.scielo.br/pdf/rbg/v19n2/v19n2a2.

Fernandes F.L., Chang H.K. 2003. Arcabouço estrutural da Bacia de Taubaté - SP. *In:* SBG, Simp. Nac. Est. Tect., 9, Intern. Symp. on Tectonics, 3, Armação de Búzios, 2003. *B. Res...,* p. 367-370.

Fries M., Malagutti Filho W., Dourado J.C., Fernandes M.A. 2017. Gravimetric survey and modeling of the basement morphology in the sedimentary thickness characterization, NE portion of Paraná Sedimentary Basin - Brazil. Braz. J. Geol. [online]. 47(2):249-260. DOI: http://dx.doi.org/10.1590/2317-4889201720160117.

Kastens K.A., Pistolesi L. Passow M.J., 2011. *Spatial Thinking.* Professional Development to Improve the Spatial Thinking of Earth Science Teachers and Students. Supported by National Science Foundation GEO-1034994. URL: http://earth2class.org/site/?_page_id=2957. Accessed 09.11.2017.

Mantesso Neto V., Bartorelli A., Carneiro C.D.R., Brito-Neves B.B.de. orgs. 2004. *Geologia do Continente Sul-Americano*: Evolução da obra de Fernando Flávio Marques de Almeida. São Paulo: Ed. Beca. 673p.

Marques A. 1990. Evolução tectono-sedimentar e perspectivas exploratórias da Bacia de Taubaté, São Paulo, Brasil. *B. Geoci. PETROBRAS*, 4:253-262.

Milani E.J., França A.B., Schneider R. 1994. Bacia do Paraná. *B. Geoci. PETROBRAS*, 8(1):69-82.

Oliveira H.V.B.de, Carneiro, C.D.R. 2008. *Representação em 3D do Aqüífero Guarani na Borda da Bacia do Paraná*. Campinas: IG-UNICAMP. 4p. (PIBIC/CNPq, Rel. Cient. Final).

Pollard D.D., Fletcher R.C. 2005. *Fundamentals of Structural Geology*. Cambridge: Cambridge Univ. Press. ISBN-10 0-521-83927-3.

Sketchfab 2016. *About Sketchfab*. URL: https://sketchfab.com/about.

Soares A.P., Soares P.C., Holz M. 2008. Heterogeneidades hidroestratigráficas no Sistema Aquífero Guarani. *Rev. Bras. Geoc.*, 38(4):598-617. URL: http://ppegeo.igc.usp.br/index.php/rbg/article/view/7611/7038. Accessed 03.01.2018.

Takiya H., Peloggia A.U.G., Tokutake L.R., Campos J.E., Ogawa A.T., Koga H., Misawa W.J., Riccomini C. 1989. Arcabouço estrutural da Bacia de São Paulo. *In:* SBG/IGc-USP, Workshop Geologia da Bacia de São Paulo, São Paulo, 1989. *Coletânea das Comunicações...*, São Paulo, p. 16-27.

Volpato N. org. 2017. *Manufatura aditiva*: tecnologias e aplicações da impressão 3D. Org. Neri Volpato. São Paulo: Blücher. 400p. [ISBN 978-85-212-1150-1].

Zalán P.V., Conceição J.C., Wolff S., Astolfi M.A.M., Vieira I.S., Appi V.T., Neto E.V.S., Cerqueira J.R., Zanotto O.A., Paumer M.L., Marques A. 1986. *Análise da Bacia do Paraná*. PETROBRAS-DEPEX-CENPES, Rio de Janeiro, 195 p. (Rel. Int. Gt-Os-009/85).

Zalán P.V., Wolff S., Conceição J.C.J., Marques A., Astolfi M.A.M., Vieira I.S., Appi V.T., Zanotto O.A. 1991. Bacia do Paraná. In: Gabaglia G.P.R., Milani E.J. (Coords.). *Origem e evolução de bacias sedimentares*. Petrobrás, Rio de Janeiro, p. 135-168.

VIII GeoSciEd 2018 – 8th Quadrennial Conference of the International Geoscience Education Organisation (IGEO)
– *Geosciences for Everyone* –
VIII Simpósio Nacional de Ensino e História de Ciências da Terra / EnsinoGEO-2018
– Geociências para Todos –
Campinas – Sao Paulo – Brazil, July 2018

Thank you for your attention!

Three-dimensional physical models of sedimentary basins as a resource for teaching-learning of Geology

Celso Dal Ré Carneiro
Kauan Martins dos Santos
Thiago Rivaben Lopes
Filipe Constantino dos Santos
Jorge Vicente Lopes da Silva
Ana Lucia Nogueira de Camargo Harris

Universidade Estadual de Campinas

Programa de Pós-Graduação em Ensino e História de Ciências da Terra (PEHCT), Instituto de Geociências, Unicamp

Trecho de floresta às margens do Rio Tapajós, 2010