

The influence of geology on the urban development of São Paulo City, Brazil

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Abstract: The paper discusses the city of São Paulo, one of the largest cities in the world, situated at the head of a basin drained by the Tietê River. This important river played a major role in the exploration and colonization of a large portion of South America by Europeans in the XVI and XVII centuries. Some of the geological characteristics in this region are quite unique. The paper is an attempt to analyse the relationship between these characteristics and São Paulo's tremendous growth in population, reviewing the urban development of the city and showing how the hydro-geological factors affected its growth. A historical overview, from its foundation to the present day, is then presented in terms of: environment, site selection, natural resources and social factors.

Résumé: L'étude aborde le thème de la ville de São Paulo, une des plus grandes villes du monde, située à l'amont du bassin arrosé par le fleuve Tietê. Cet important fleuve a joué un rôle primordial dans l'exploitation et la colonisation par les Européens aux XVIe et XVIIe siècles d'une grande partie de l'Amérique du Sud. Quelques-unes des caractéristiques géographiques de cette région sont tout à fait exceptionnelles. Il s'agit dans l'étude d'analyser le rapport entre ces caractéristiques et la formidable croissance de São Paulo.

L'étude passe en revue le développement urbain de la ville de São Paulo, montrant comment les facteurs hydrogéologiques affectèrent sa croissance et un tour d'horizon historique de la ville y est présenté, à partir de sa fondation jusqu'à nos jours : l'environnement découvert, le choix de l'emplacement, les ressources naturelles et les éléments sociaux sont dûment pris en compte.

Les caractéristiques géologiques et hydrologiques sont mises en exergue, montrant comment les particularités géologiques conduisirent les colonisateurs portugais à ce lieu, et, de là, les poussèrent à aller à des milliers de kilomètres de distance pour ensuite les y faire revenir avec les richesses obtenues.

Keywords: geology of cities, geomorphology and urban geosciences.

GEOLOGY OF THE SÃO PAULO REGION AND THE "BAIXADA SANTISTA"

The geological outcrops in the regions of São Paulo and Santos region can be considered in three groups: the Precambrian crystalline basement, the Cenozoic sediments of the São Paulo Basin, and the Quaternary deposits (Figures 1, 2, and 3).

Lithostratigraphic units of the crystalline basement

The lithostratigraphic units of the crystalline basement are as follows: Coastal Complex, Embu Complex, São Roque and Itaberaba Ridge Groups and the Undifferentiated Granitic Suite (Morais 1999, IPT 1981). The Coastal Complex is formed of migmatite, gneiss and quartzite. Their age is Lower Proterozoic, forming the mountains and scarps of the "Baixada Santista". The Embu Complex formed in the Upper Proterozoic, comprising schist, phyllite and migmatite, forming mountains with deep valleys meeting in the South and East Zones of the city of São Paulo. The shear zone of Cubatão (also known as the Cubatão Fault) occurs between the Coastal Complex and the Embu Complex wherein bands of intense deformation have been produced by transcurrent faulting. To the northeast of the city of Cubatão, the valley of the Mogi River has grown within the Cubatão (Hasui *et al.* 1994). The São Roque and Itaberaba Ridge Groups are formed of phyllite, schist, meta-arenite and meta-basic rocks, of Middle Proterozoic age. In this region there are mountains and deep valleys, to the north and the northwest of the city of São Paulo. The undifferentiated Granitic Suite is represented by granite, granodiorite and monzogranite, forming mountains with elongated scarps in the Cantareira Ridge, Itaquí Ridge, Itapeti Ridge and Caucaia Ridge (Rodrigues & Takiya 2004).

Cenozoic sediments of the São Paulo Basin

The Cenozoic sediments that occur in the São Paulo Basin, can be considered in three groups: the Resende Formation, the Tremembé Formation and the São Paulo Formation (Morais 1999, IPT 1981, Rodrigues & Takiya 2004). The Resende Formation comprises conglomerate, arenite and argillite, forming hilly ground covering the largest area in the Basin of São Paulo. The Tremembé Formation is composed of argillite, occurring in the quarters of Barra Funda, Perdizes and Brás as hills. The São Paulo Formation comprises arenite and argillite. Its relief forms elongated ridges in the middle of São Paulo, along the Avenues Paulista and Heitor Penteado, and the Sapopemba Avenue in the East Zone of the city.

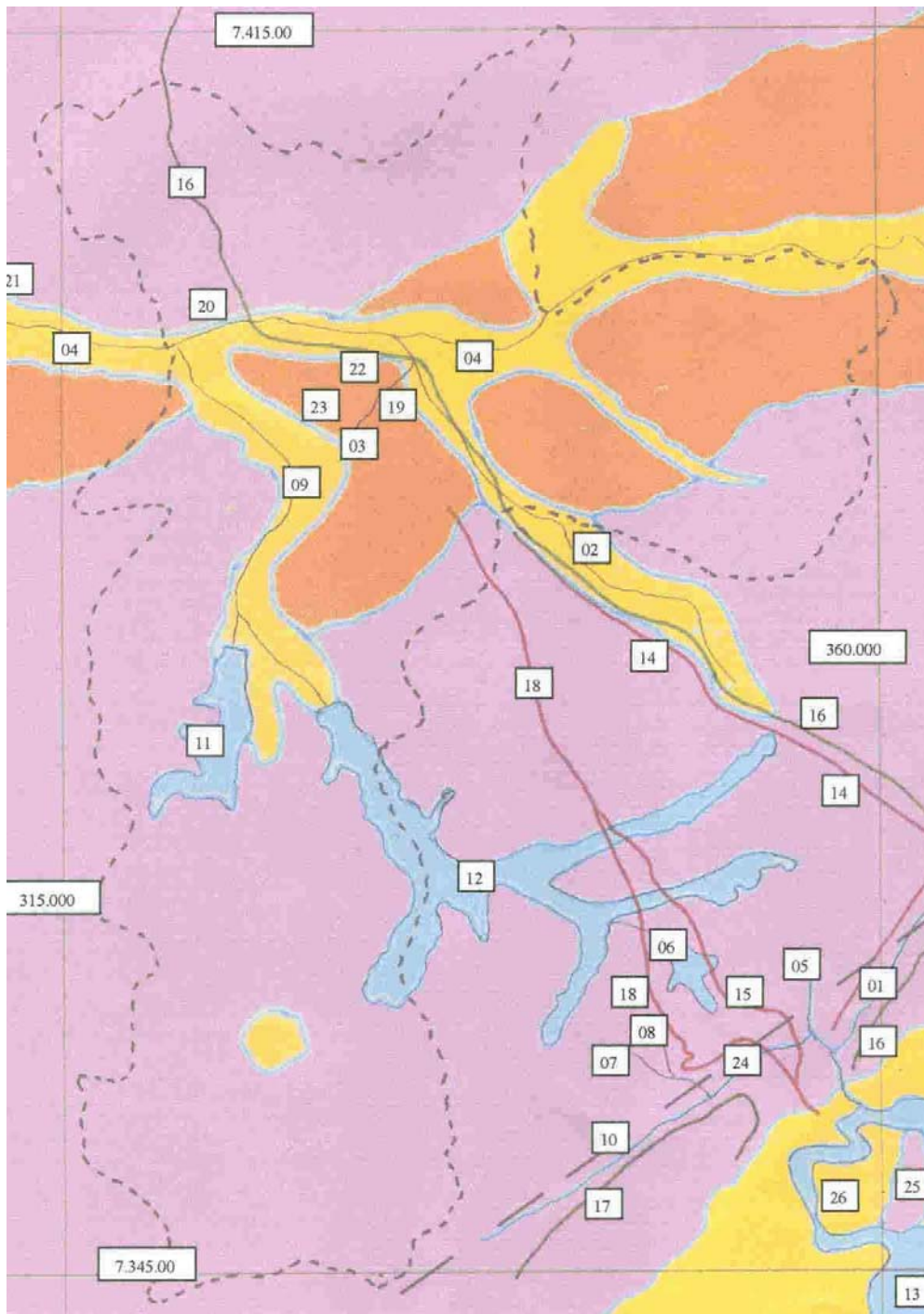
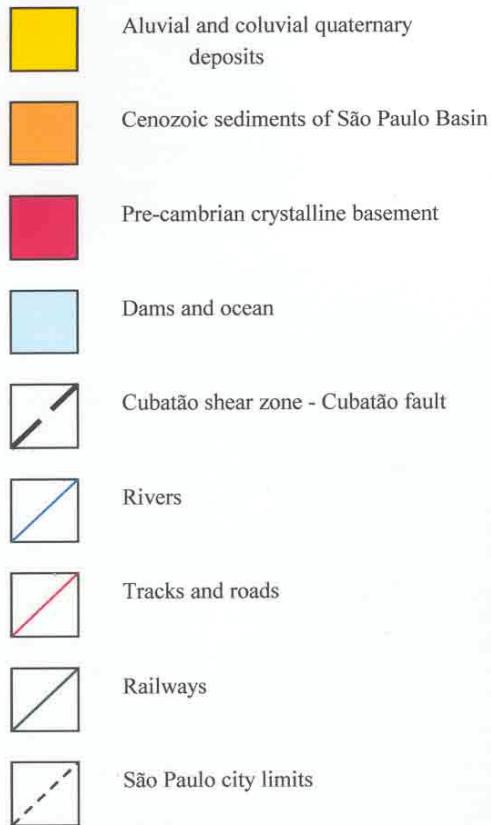


Figure 1. Geological sketch map

GEOLOGICAL SKETCH OF SÃO PAULO REGION AND "BAIXADA SANTISTA"
(HASUI, et al 1994) (MORAIS, 1999) (RODRIGUES & TAKIYA, 2004)

Geological legend



Approach escala 1:400.000

Universal projection mercator - Spindle 23

Rivers and dams

- 1 - Mogi river
- 2 - Tamanduateí river
- 3 - Anhangabaú river
- 4 - Tietê river
- 5 - Perequê river
- 6 - Pedras river
- 7 - Pilões river
- 8 - Grande river
- 9 - Pinheiros river
- 10 - Cubatão river
- 11 - Guarapiranga dam
- 12 - Billings dam
- 13 - Atlantic ocean

Tracks, roads and railways

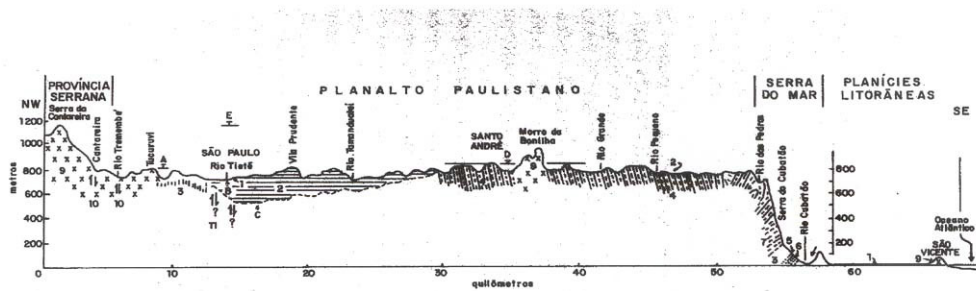
- 14 - Tupiniquins trail
- 15 - Majority road - "Caminho do mar"
- 16 - Santos-Jundiaí railway
- 17 - Sorocabana railway
- 18 - Anchieta road

Localities

- 19 - "Pátio do colégio"
- 20 - "Pico do Jaraguá"
- 21 - "Morro Voturuna"
- 22 - "Campos Elíseos"
- 23 - Paulista avenue
- 24 - Henry Borden eletric plant (Cubatão)
- 25 - Santos
- 26 - São Vicente

Figure 2. Legend for Figure 1.

GEOLOGICAL SECTION OF SÃO PAULO PLATEAU AND "BAIXADA SANTISTA"
(IPT, 1981)



- | | |
|---|-----------------------|
| 1 - Quaternary deposits | 6 - Limestones |
| 2 - Cenozoic sediments of São Paulo Basin | 7 - Biotite-gneisses |
| 3 - Phyllites | 8 - Migmatites |
| 4 - Micaschists and gneisses | 9 - Faults |
| 5 - Quartzites | 10 - Probables faults |

Figure 3. Geological section

Quaternary Deposits

The Quaternary Superficial Deposits comprise clay, sand and gravel, forming spreads of alluvium and colluvium. Alluvial gold occurs close to the Pico do Jaraguá in São Paulo, and to the Morro Voturuna in Santana do Parnaíba, west of São Paulo (Abreu, 1973).

HISTORICAL DEVELOPMENT OF SÃO PAULO CITY

The Portuguese colonialists arrived on April 22nd, 1500. There were initially few settlements, one of which was later to become the city of São Paulo. However, the region had few natural resources (poor land, no valuable minerals), without any important agriculture. The coast is relatively narrow, some 15 km from the sea to the mountain front. Beyond, the plateau provided a high and healthy temperate climate, similar to Europe.

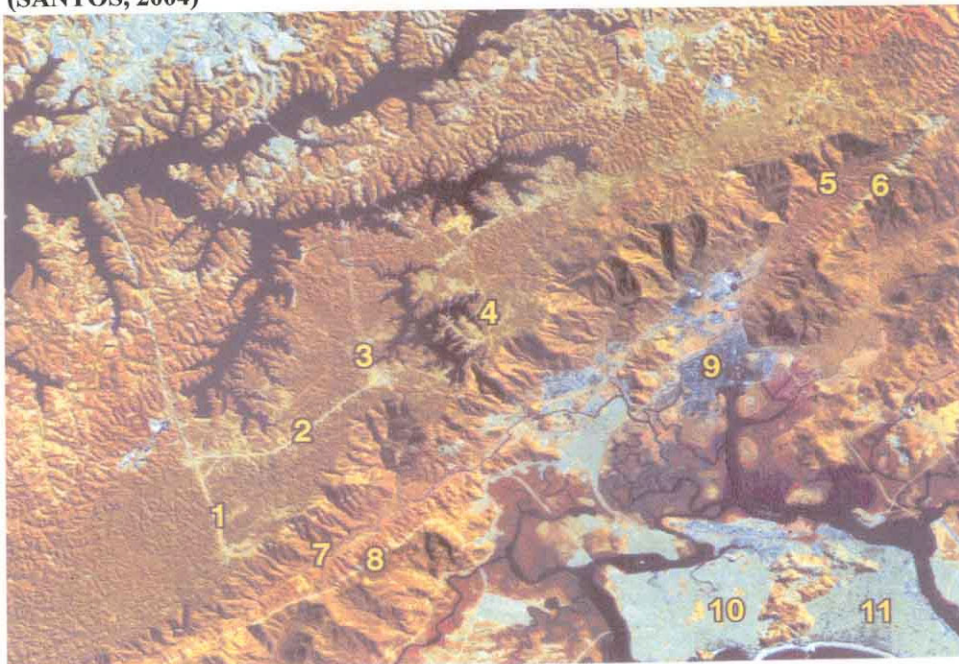
To the northeast, the Serra do Mar mountain range rises abruptly to 900 m, forming a continuous barrier; the plateau is wide and hilly, with mountains reaching 1500 to 2000 m. To the southwest, the Serra do Mar is less abrupt and several rivers cut through it. Some of the factors helped select this location as the city of São Paulo were the Serra do Mar forming a saddle (at 800 m) which the Indians had been using for centuries; the plateau was rather flat and, due to its poor soil conditions, the tropical forest was thin which helped the entry to the territories beyond. Thus São Paulo was founded on January 25th, 1554, in the region called Campos de Piratininga between the Tamanduateí and Anhangabaú Rivers.

In the early years the most common building technique was “taipa de pilão”, a mixture of clay and stone obtained from the river. The city grew irregularly, expansion following pre-existing paths; these can still be traced today. Poorer neighborhoods then developed in the lowland along the Tamanduateí River, close to railway.

Between 1850 and 1900 the city underwent a massive transformation: coffee expanded, the railway system grew, and immigration increasingly played an important role in the development of the city (Rolnik, 2001). From 1875 reconstruction of good quality building, new streets, public works, and reclamation of the Carmo marshes (by the Tamanduateí River) took place.

INTERRELATIONSHIP BETWEEN HISTORICAL AND GEOLOGICAL FACTORS

AERIAL IMAGE OF SÃO PAULO PLATEAU AND "BAIXADA SANTISTA" (SANTOS, 2004)



- | | |
|--------------------------------------|------------------------|
| 1 - Imigrantes road | 7 - Cubatão river |
| 2 - Connection Imigrantes-Anchieta | 8 - Sorocabana railway |
| 3 - Anchieta road | 9 - Cubatão |
| 4 - "Caminho do mar" - Majority road | 10 - São Vicente |
| 5 - Mogi river | 11 - Santos |
| 6 - Santos-Jundiaí railway | |

Figure 4. Aerial image

CONCLUSIONS

The main geological and geomorphological aspects that influenced the development of the city of São Paulo are the occurrence of Cubatão fault in the valley of the Mogi River, creating a breach that made possible the opening of the Tupiniquins trail and access to the São Paulo plateau.

Where the Resende Formation occurs in São Paulo, the relief facilitated transportation of supplies. However, the crystalline basement and the São Paulo Formation has relief which is too high and steep for urban development, and the regions of Quaternary deposits are prone to flooding, and thus also unsuitable.

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