Report on the Workshop “Soils and Paleosols of Brazil”

24-29 August in Campinas/Cananéia, with field trips in the states São Paulo and Minas Gerais

Organizers and field trip leaders: Alessandro Batezelli and Francisco Ladeira (UNICAMP, Campinas)
Additional field trip leaders: Pedro H. de Moraes Martinez and Pablo Vidal Torrado (USP, São Paulo)

General Overview of the program (see map on last page – Fig. 16 – for locations)

Mon (24 Aug)	8 am - Departure from Hotel Opala Avenida (Campinas) for field trip. Arrival in Cananéia at 6 pm. Overnight in Cananéia - Hotel Golfinho Plaza. Evening talk by Alessandro Batezelli giving an overview about geology and landscape development of the region
Tue (25 Aug)	7:45 am - Departure from Hotel Golfinho Plaza for Ilha Comprida. Return at 6 pm to Cananéia. Evening talk by Pedro H. de Moraes Martinez on the formation and evolution of Ilha Comprida and soil formation in relation to relief and hydrology
Wed (26 Aug)	8 am to 4 pm – Workshop presentations at Hotel Golfinho Plaza (Cananéia). 4 pm to 5 pm – Introduction to the region and soils of the post-workshop excursion by Francisco S. B. Ladeira and Alessandro Batezelli 5 pm - Departure from Cananéia to Hotel Opala Avenida (Campinas)
Thu (27 Aug)	8 am - Departure from Hotel Opala Avenida (Campinas) to Piracicaba and Itaqueri da Serra (SP). Return to Hotel Opala Avenida (Campinas) at 10 pm
Fri (28 Aug)	8 am - Departure from Hotel Opala Avenida (Campinas) to Pocos de Caldas (MG). Return to Hotel Opala Avenida (Campinas) at 10 pm
Sat (29 Aug)	9 am to 11 am - Final discussion

Pre-workshop excursion (24-25 August): Spatial variability of Podzols on Ilha Comprida, depending on soil age, relief and hydrology

Ilha Comprida is a Holocene sandy barrier island (except for one hill that is made up of a Mesozoic alkaline intrusion). It is 3-5 km wide and 70 km long and stretches along the Cananéia-Iguape coastal plain, from which it is separated by the “Mar Pequeno”, a 400-1200 m wide estuarine channel. The climate is humid-tropical, with 2261 mm MAP and no season with real water deficit.

The island developed along a longitudinal vector (ENE-wards) and a transversal vector (SES-wards) into a long and narrow island running parallel to the coastline. Wave action has created a cliff at the southern coast of the island that is continuously retreating. Along the south cliff, the age of parent material decreases from West to East (see OSL ages indicated in yellow in Fig. 1). The original plan had been to walk along the beach below the cliff to study the soil chrono-toposequence that is exposed in the cliff. However, due to an unexpected storm tide (Fig. 1) this was impossible. Hence, the two westernmost soil profiles were approached from the West (Stops 1 and 2) and the easternmost profile from the East (Fig. 2, Stop 5).

Instead of visiting the profiles along the central part of the south cliff, another profile exposed in the west cliff was included in the excursion program (Fig. 2, Stop 3), and in addition we augered beach ridge highs and lows in the inner part of the island in order to compare the soils in the inner part of the island (not influenced by cliff dynamics) to those exposed in the cliffs.

In addition to the soil-forming factor time, the factor relief was a key topic in the discussions, with a special emphasis on hydrology. Soils in the inner part of the island are less well-drained than those exposed in the cliffs. The groundwater level under the swales between the beach ridges is high, and even peat formation can be observed in places. The soil profiles exposed in the cliffs must have started forming as inland soils, thus under less well-drained conditions, too. They got under better drainage conditions when the retreating cliff got closer and finally cut through them. Well-developed Podzols with Ortstein occur especially in the western zones of the island that are characterized by high beach ridges separated by narrow swales, whereas less developed hydromorphic Podzols and Histosols occur in areas with lower beach ridges and wider swales. Apparently, interflow running down from the beach ridges, carrying abundant dissolved organic carbon (DOC) concentrates especially in narrow swales and leads to the formation of thick Ortstein horizons there. This effect is less pronounced in the wider, flatter ridge-swale systems further east.

Fig. 1 (above). Excursion participants making their way to the easternmost profile exposed in the south cliff (stop 5, see Fig. 1). An unexpected storm tide made observation of the soils exposed in the central part of the south cliff impossible and turned the visit of stop 5 into a somewhat wet and adventurous experience. However, these people really WANTED to see the iron humus Podzol at stop 5; thus these challenges could not keep them away from the profile!

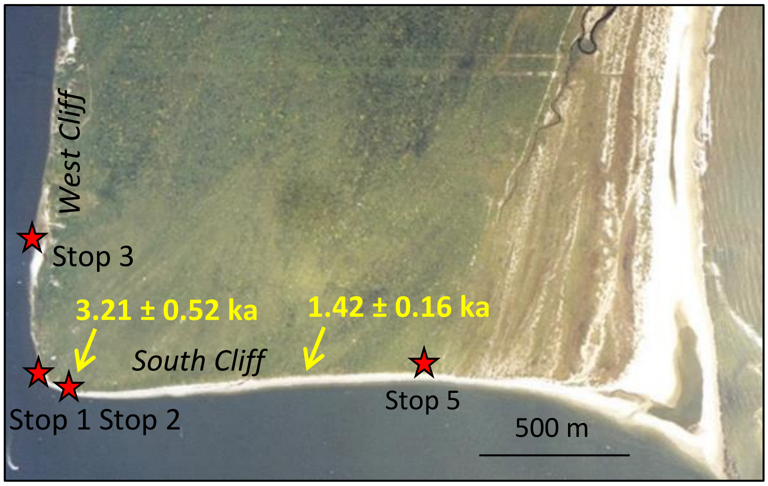

Fig. 2 (left). Southern end of Ilha Comprida with locations of the profiles that the group visited during the pre-workshop excursion.

Fig. 3a. Stop 1 (profile PF04): Western part of the south cliff of Ilha Comprida: The sharp, even E/Bh boundary indicates Podzol formation under poorly drained conditions.

Fig. 3b. The southern coast of Ilha Comprida is subject to severe retreat due to strong wave action. Ortstein protects the coast from even more rapid erosion.

Fig. 4a. Stop 2 (profile PF01): Podzol that originally formed under poorly drained conditions; cliff formation then improved drainage.

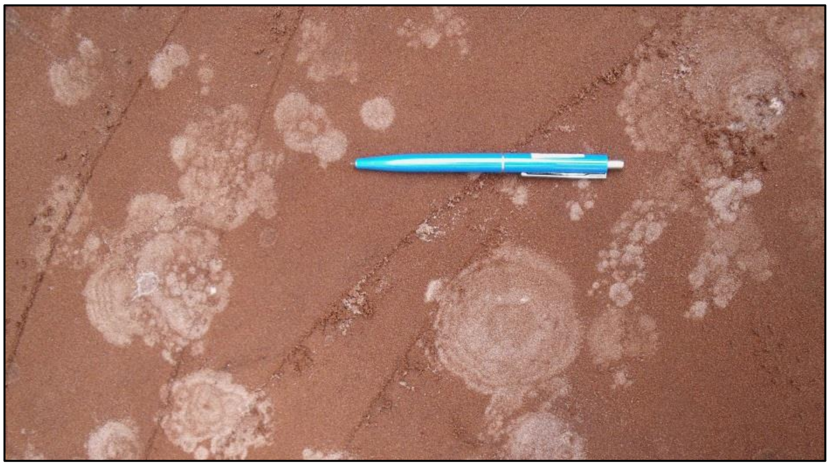

Fig. 4b. Detail of the horizontal section at the bottom of Fig. 4a: Under the well-aerated conditions created by the cliff, microbes start decomposing soil organic matter of the Bh horizons.

Fig. 5a. Stop3: Well-aerated Podzols like this one exposed in the west cliff show an irregular E/Bh boundary, with white tongues penetrating into the Bh. Tongues develop due to preferential flow, e.g. along former tree roots .

Fig. 5b. Detail from the same soil. Well-aerated Podzols are also influenced by considerable bioturbation (in addition to microbial activity as shown above).

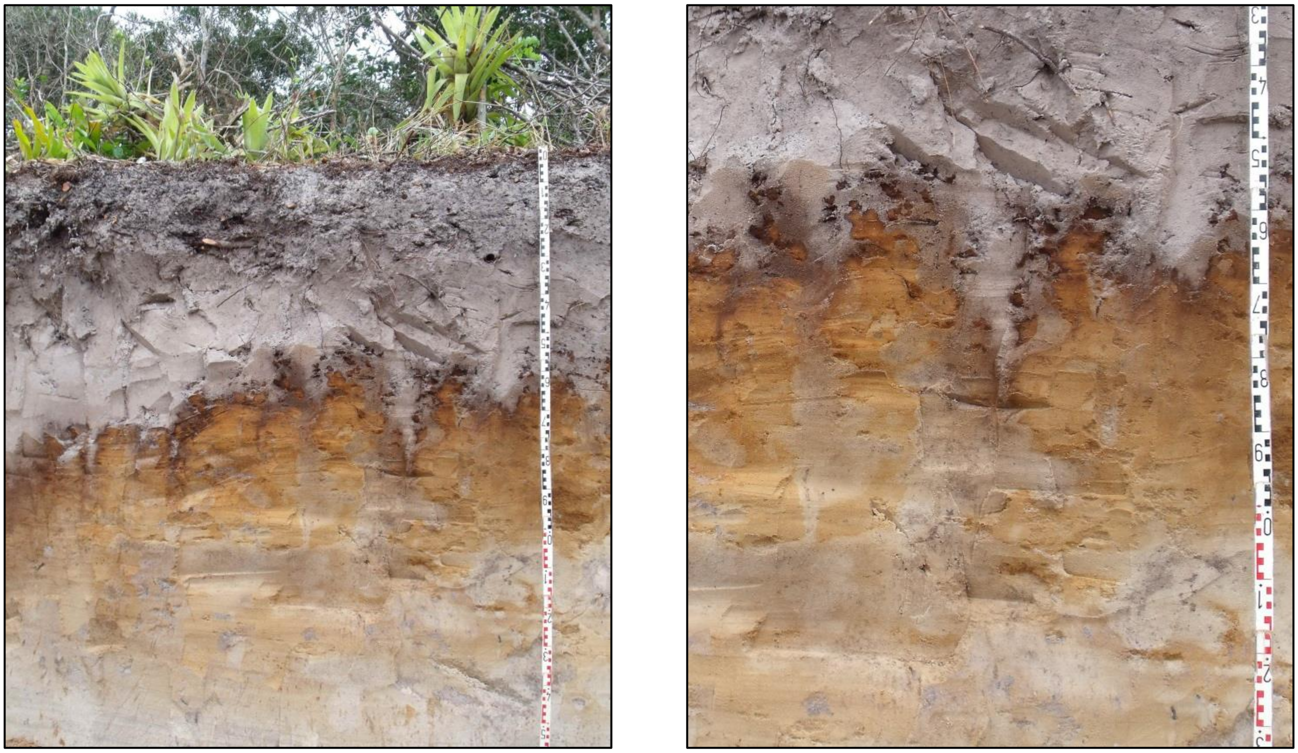

Fig. 6. Podzol at Stop 5 (profile PF35): This was the only Podzol observed during the field trip that shows also iron accumulation besides accumulation of organic substances. The iron indicates that this soil, in contrast to the one at stop 3 (exposed in the west cliff; Fig. 5a, 5b), did not start developing under poorly drained conditions but was always well-drained. The Podzol at stop 3 must have started forming under poorly drained conditions that led to reduction and removal of iron from the profile. Later, under well-drained conditions, root growth and bioturbation occurred leading to the present profile morphology (Fig. 5a, 5b).

Key issues that were discussed based on the Ilha Comprida Podzols and take-home messages

- Hydrology and relief influence the spatial pattern of the morphology of Podzols at a similar order of magnitude as soil age!
- Spatial distribution of Ortstein is largely controlled by DOC fluxes leading to concentration and precipitation of organic compounds in lower landscape positions.
- Rates of soil formation: The age of the parent material of profile PF01 (Stop 2; see Figs. 2 and 4) was only 3.21 ka, the age of the parent material of profile PF35 (Stop 5; see Figs. 2 and 6) was even less than 1.42 ka; thus under the given conditions (texture: 96-97% sand, climate: humid-tropical) mature Podzols may develop within about one thousand years.
- Model of progressive/regressive pedogenesis that was discussed during the indoor workshop is applicable here: Micro-organisms eat up SOM after aeration (regressive process).
- There is a close link between the geomorphological development of the island and the soils; erosion changes the hydrology, leads to aeration of soils that were formerly poorly drained
- Influence of parent material: very pure quartz sand together with high permeability of sandy material lead to rapid acidification.
- Vegetation is adapted to acid and nutrient-poor conditions; litter also contains only low amounts of bases and nutrients, resulting in incomplete decomposition.
- Podzols that developed under poorly drained conditions are characterized by sharp, even boundary between E and Bh horizon; they lack a Bs horizon because iron has been reduced and removed under poorly drained conditions.

Presentations held during the workshop

➢ Introductory lectures related to the pre-workshop excursion (24-25 August)

Alessandro Batezelli (evening of 24 August):

Quaternary evolution of the Cananéia and Ilha Comprida Complex

Pedro Henrique Rodrigues de Moraes Martinez, Josiane Milane Lopes, Paulo Cesar Fonseca Giannini, Peter Buurman, Pablo Vidal Torrado (evening of 25 August):

Relationship between geomorphology, sedimentology and hydrology and its effect on Podzol genesis under Restinga vegetation at Ilha Comprida, SP, Brazil

➢ Regular workshop presentations (26 August)

Jean Pierre Nguetnkam, Elisabeth Solleiro Rebolledo, Alembert Alexandre Ganwa and Dieudonné Lucien Bitom

Morphological and geochemical characterization of Buried paleosols and its covers in the Adamoua region of Cameroon (Central Africa): evidence of slope inversion

Izuchukwu Mike Akaegbobi, Daniela Sauer and Reginald C. Njokuocha

Geomorphological and Paleopedological Development on Cretaceous Parent Source Rock around Nsukka Southeastern Nigeria

Pauline Y.D. Da Costa and Kodzo A. Togbé

Pedologic cover and landscape evolution in northern Togo: a tropical weathering evidences since the Precambrian

Carlos Hinojosa, Kees Nooren, Elizabeth Solleiro-Rebolledo and Sergey Sedov

Holocene soil chronosequence on beach ridges in the coastal plain of the Gulf of Mexico: an insight into landscape development

Reinhold Jahn and Karl Stahr

Soil formation and soil forming rates on volcanic materials of the Canary Islands

Tobias Sprafke, Christine Thiel, Birgit Terhorst and Sergey Sedov

Moisture vs. time – Evaluating the development of polygenetic loess palaeosols in the Krems region, Lower Austria

Daniela Sauer

Soil chronosequences and pedological concepts

Marcia Regina Calegari and Pablo Vidal Torrado

Occurrence and palaeoenvironmental significance of humic horizon in Latosols (Oxisols)

➢ Lectures preparing for the post-workshop excursion on 27-28 August (afternoon of 26 August)

Francisco S. B. Ladeira and Alessandro Batezelli

Soils of Brazil

Alessandro Batezelli

Preparing for the Post-workshop field trip: Geological settings, paleosols and soils

Francisco S. B. Ladeira

Lateritic Profiles - chronology and importance in geomorphological evolution

Post-Workshop excursion (27-28 August): Paleosols in the Itaqueri Hill and Poços de Caldas region, including Ferricretes, Silcretes and Bauxite

The first part of the post-workshop excursion focused on the typical paleosol sequence of the Itaqueri Hill region (Fig. 7), studied by Ladeira and dos Santos (2006). It includes a sequence of Oxisol (Ferralsol) – Laterite (Ferricrete) – Silcrete. Several sites, where typical sections of this sequence are exposed, were visited. The first stop was a lookout point on the landscape that is strongly influenced by the ferricretes and silcretes that belong to this sequence (Fig. 7), protecting the underlying parts of the landscape from erosion (Figs. 8, 9). At this stop also the yellow laterite, forming the surface at the lookout point, was examined (Fig. 10).

In addition, a profile exhibiting silicified root channels (Fig. 11) and a thick, dark red Oxisol (Ferralsol) near Piracicaba (Fig. 12) were visited (see Fig. 7 for the stratigraphical positions of the mentioned sections within the main paleosol sequence of the Itaqueri Hill region).

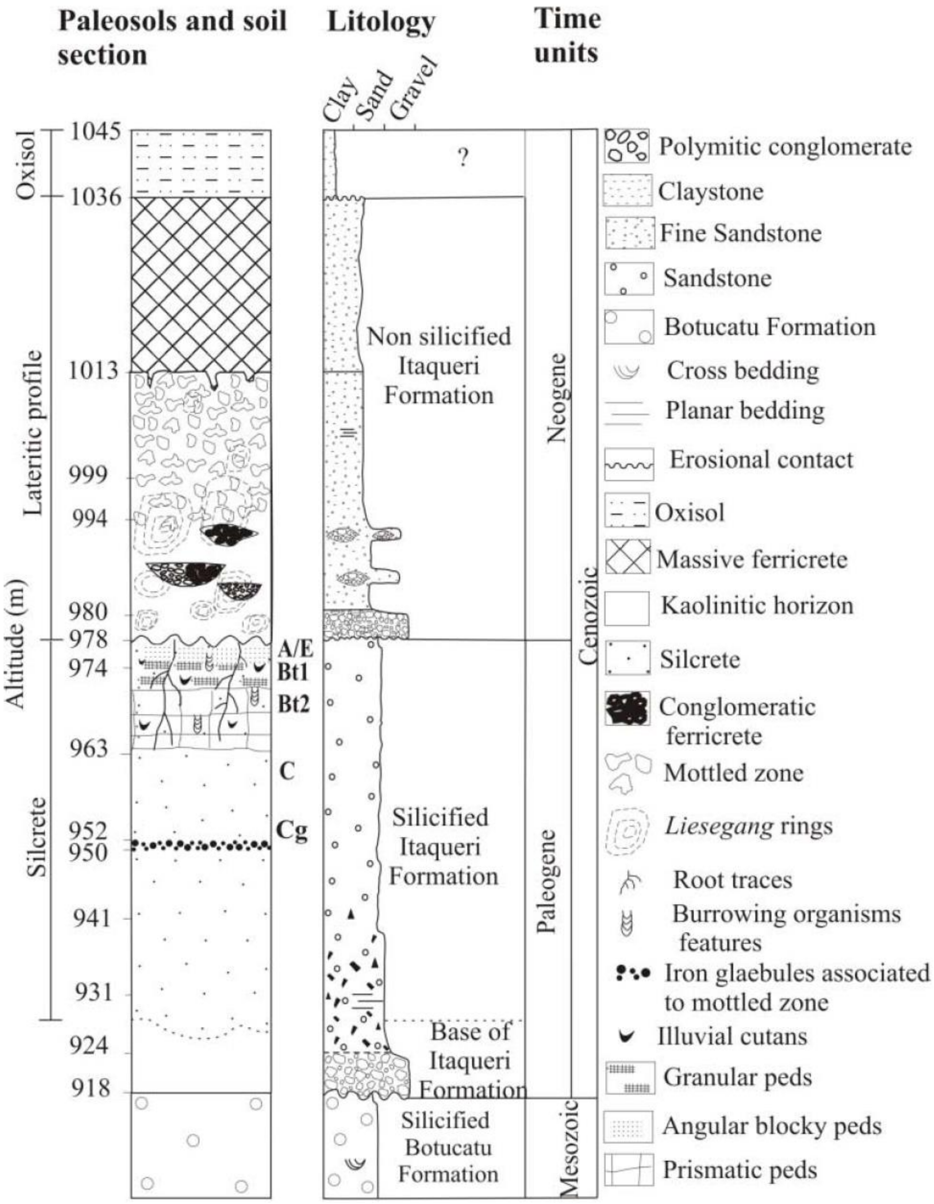

Fig. 7. Typical vertical sequence of paleosols in the Itaqueri Hill region (Fig. 4 in Ladeira and dos Santos, 2006).

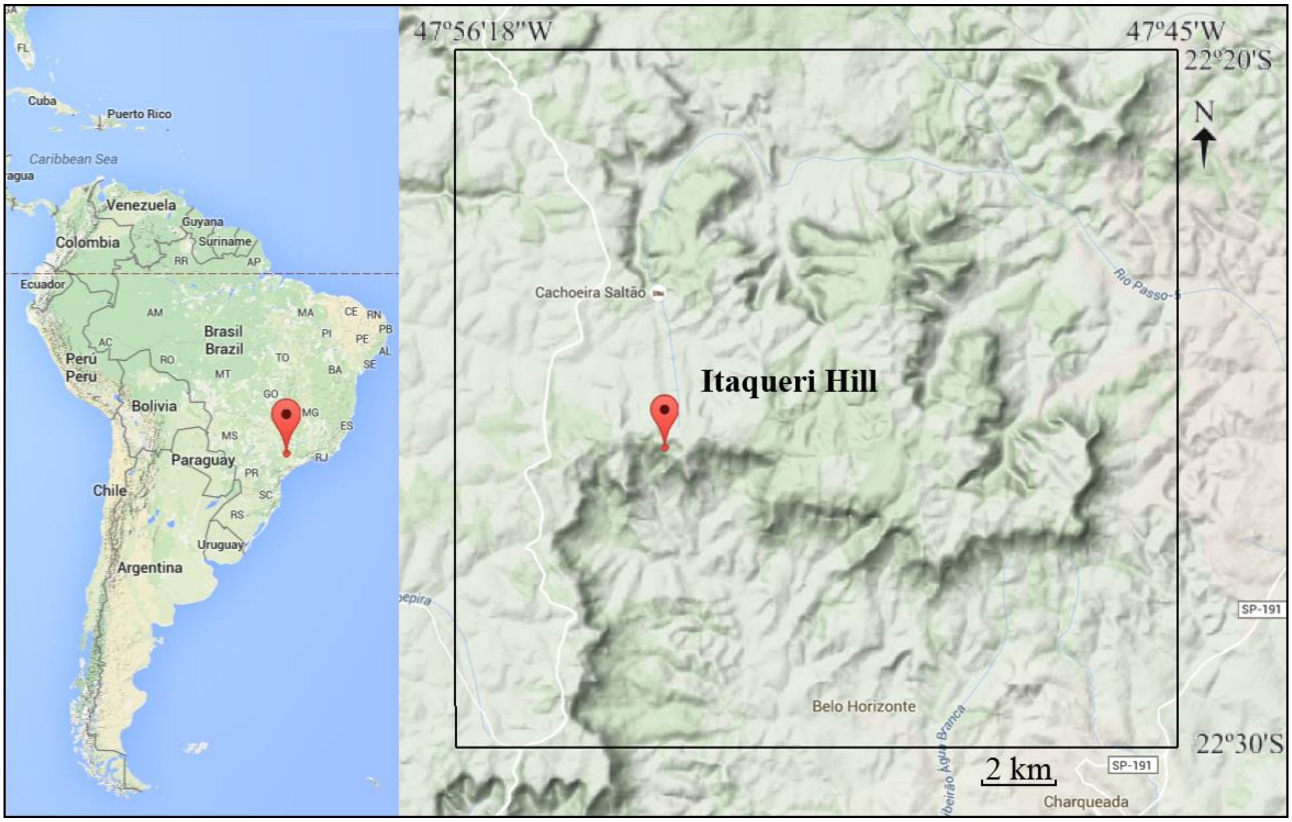

Fig. 8. Location of the lookout point where the group examined the yellow Ferricrete. Map produced by Reinhold Jahn.

Fig. 9. View from the lookout point on the landscape whose morphology is largely influenced by the persistence of Ferricretes and Silcretes against erosion. Photo and labeling by Reinhold Jahn.

Surface composed of Laterite (Ferricrete).

Yellow Laterite (Ferricrete).

On that day the water came from above (in contrast to the day of the storm tide, where the water came from below).

Fig. 10. Laterite (Ferricrete) forming the surface at the lookout point.

Fig. 11. Silicified root channels (see Fig. 7 for stratigraphical position within the general profile of the Itaqueri Hill region).

Fig. 12. Thick, dark red Oxisol (Ferralsol) near Piracicaba (see Fig. 7 for stratigraphical position within the general profile of the Itaqueri Hill region).

Fig. 13. Hill bauxite ("Bauxita de Serra") profile.

The second focus of the post-workshop excursion was on bauxite profiles in the Poços de Caldas area, at the boundary between the states São Paulo and Minas Gerais. Both, hill bauxite ("Bauxita de Serra") and field bauxite ("Bauxita de Campo") profiles were examined and intensively discussed (Fig. 14). Hill bauxite profiles occur in the higher areas of the plateau of Poços de Caldas; they contain thick bauxite horizons that are rich in Al. Field bauxite profiles occur in the inner part of the plateau; their bauxite horizons are not as thick as those of the hill bauxite profiles; they have a higher content of reactive silica compared to hill bauxite profiles. Groundwater has leached soluble elements from the field bauxite profiles.

Fig. 14. The field trips were characterized by intensive discussions on landscape evolution and soil formation.

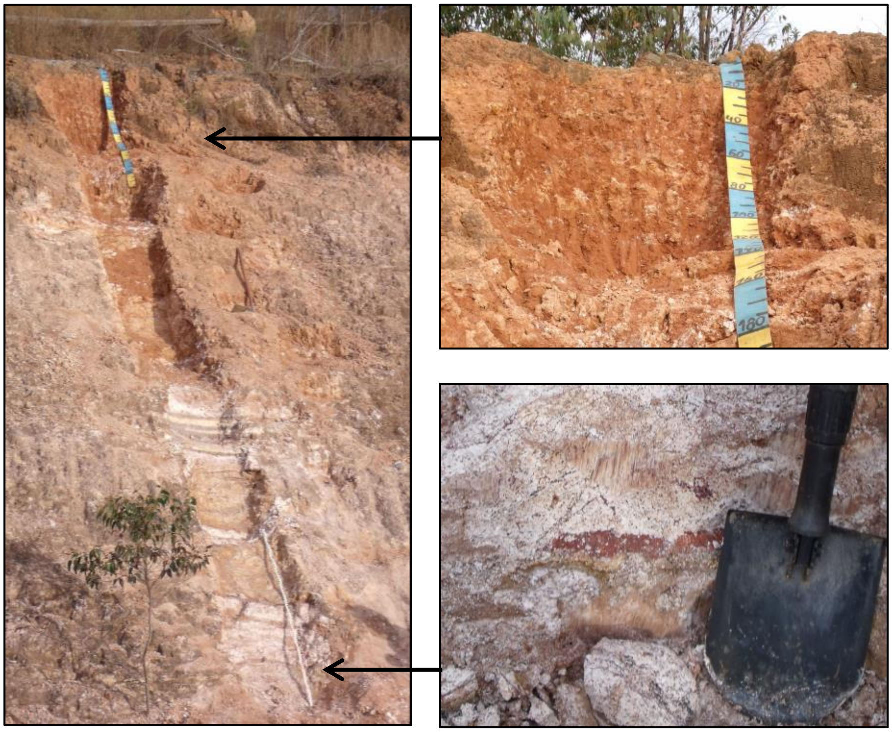

Fig. 15. Field bauxite (“Bauxita de Campo”) profile. This profile does not represent one single soil. Its lower part consists of soft, white and brown saprolite with red clay films and infillings coating shear faces and voids. This part of the profile represents the remains of a truncated paleosol. The reddish-brown solum on top formed later. Patches of white saprolite inside the present-day solum indicate that the saprolite of the paleosol served as parent material for the present-day soil formation.

Key issues that were discussed based on the soils visited during the post-workshop excursion

- Many tropical soils developed in reworked soil sediments or in saprolite of older soils.
- The solum and saprolite of a tropical soil profile do not necessarily belong to the same cycle of soil formation; the solum may have formed much later, just representing the very last cycle of soil formation; an unknown number of soil formation cycles may not be recorded because its products have been completely eroded.
- Laterite formation does not occur at present in this region.
- Rates of soil formation are extremely difficult to assess in tropical landscapes.
- Tertiary lateritic paleosols are widespread in Brazil; they formed from different parent materials, through same processes; lateritic soils do not form today in this region.
- Intensity of biological activity in Ferralsols (termites, ants, microorganisms) is important: slight changes will lead to a different profile.
- Factors that control iron oxide formation towards red (hematitic) soils vs. yellow (goethitic) soils:
    1) Strong micro-aggregates lead to very good aeration and water permeability, thus supporting pedogenesis towards red soils; less permeable soils tend to be yellow.
    2) Hematite favors the development of stabile micro-aggregates more than goethite; thus, there is a positive feedback between micro-aggregate development and hematite formation (1⇔2).
    3) In addition, iron availability and original mineralogy are important.
    4) Aggregate formation moreover depends on drainage that in turn also depends on mineralogy and slope morphology.
    5) The same parent material under differing temperature conditions (tropical vs. subtropical climate) has produced same soil type (Oxisol/Ferralsol), but with different mineralogy (tropical = hematite vs. subtropical = goethite).

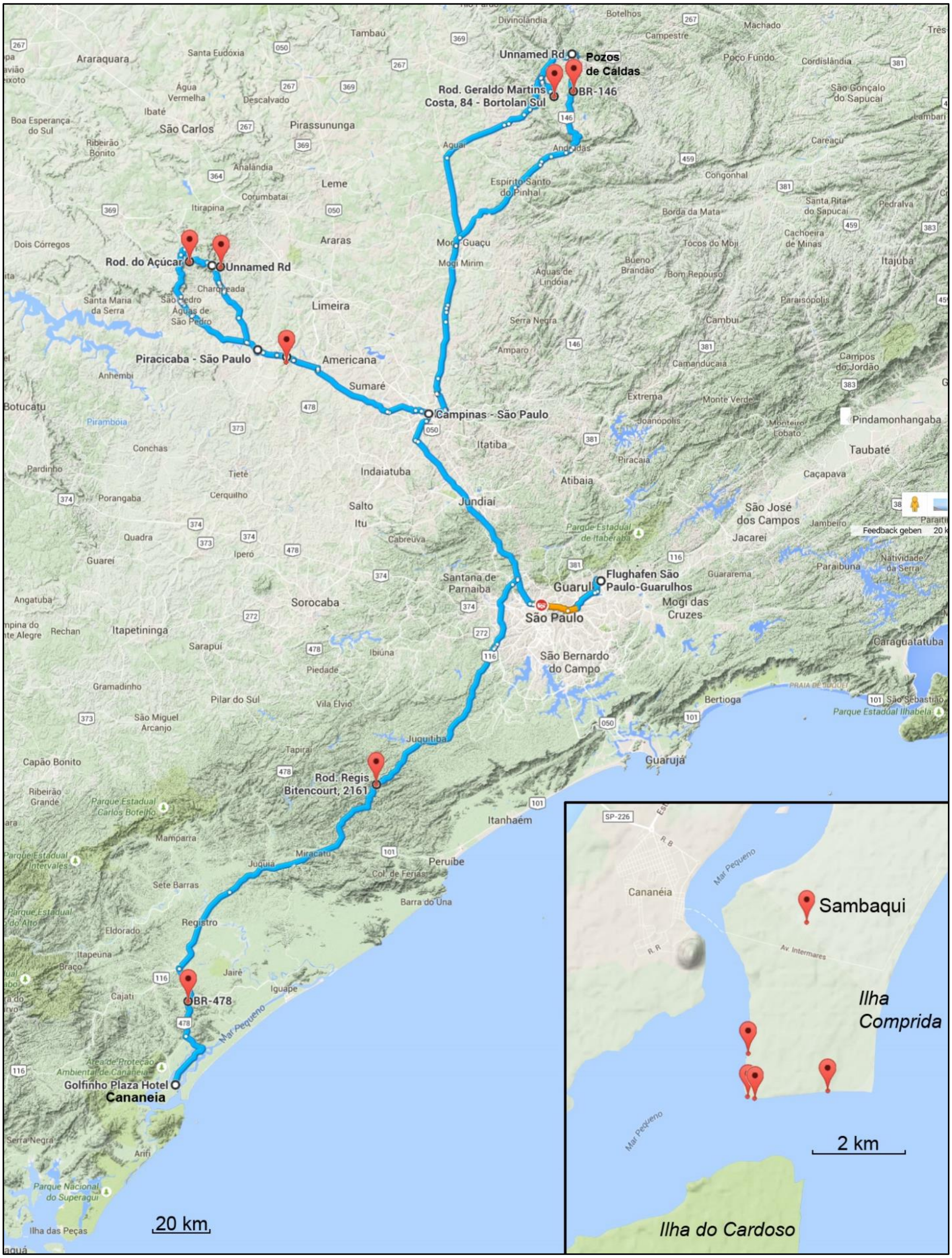

Fig. 16. Map showing the sites visited during the field trips to Ilha Comprida (a Quaternary barrier island located in front of Cananeia, SW of Campinas), Piracicaba and Itaqueri da Serra (NW of Campinas), and Pocos de Caldas (NE of Campinas). The map was created by Reinhold Jahn.