LATERITISATION PROCESSES

Thin section of a bauxitic hardened crust from Ivory Coast (Orumbo Bocca) showing a succession of gibbsitic, hematitic and goethitic crystalliplasmas (Photomicrograph of J. Delvigne).

LATERITISATION PROCESSES

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GEOLOGICAL ASPECTS OF LATERITISATION AND SUPERFICIAL GEOLOGY OF A MAFIC-ULTRAMAFIC ALKALINE COMPLEX IN CENTRAL BRAZIL

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ABSTRACT

This paper deals with the lateritisation of a subcircular mafic-ultramafic body with dunites at the center and an irregular ring of peridotites and pyroxenites at the border. Minor alkaline intrusions occur throughout the body.

Nickeliferous laterites overlying the weathered complex are mainly composed of reddish-brown oolitic and pisolitic soft laterites with local ferruginous and chalcedonic crusts. Small sporadic eluvial concentrations of opaque minerals include magnetite, chromite, maghemite, ilmenite, titaniferous magnetite, hematite, rutile, goethite and galena. Granulometric distribution of concretions in the vertical section is indicative of a continuous colluvial process of transportation from higher to lower topographic areas.

Duricrusts developed upon an exhumed peneplain occur at elevations ranging from 420 to 490 m above sea level. Vesicular textures predominate at higher and pisolitic textures at lower elevations of the peneplain. Incrusted and soft laterites are classified according to their Fe_2O_3, Al_2O_3 and SiO_2 content, and parent rock. Lateritic crusts are the result of a quite recent process and are presently undergoing mechanical destruction.

INTRODUCTION

Nickeliferous laterites and vermiculite in a mafic-ultramafic alkaline complex in central Brazil called the attention of mining companies to the potential of mineralization of such a complex. Three different companies carried out research for Ni, Co, Pt, rare-earth elements, Cu and vermiculite. As a result of prospecting research, a reserve of 61 million metric tons averaging1.6% Ni was proved. Together with this research, observations on lateritisation and superficial geology have been made, which constitute the subject of this paper.

It must be emphasized that this paper will deal mainly with superficial geology. There will be no considerations about the vertical profile and its different facies of alteration. Those interested in the vertical profile with subsurface data on the Santa Fé complex should refer to Melfi et al. (1979).

The Sanfa Fé mafic-ultramafic alkaline complex is located 3 km NW of the small town of Santa Fé, Goiás, about 1,220 km NW of São Paulo. The present climate of this district is a savannah like, humid to sub-humid tropical climate with sharply contrasting seasons, a dry winter (April to September) and a rainy season (October to March). Eighty percent of the precipitation occurs in the summer. Monthly average temperature

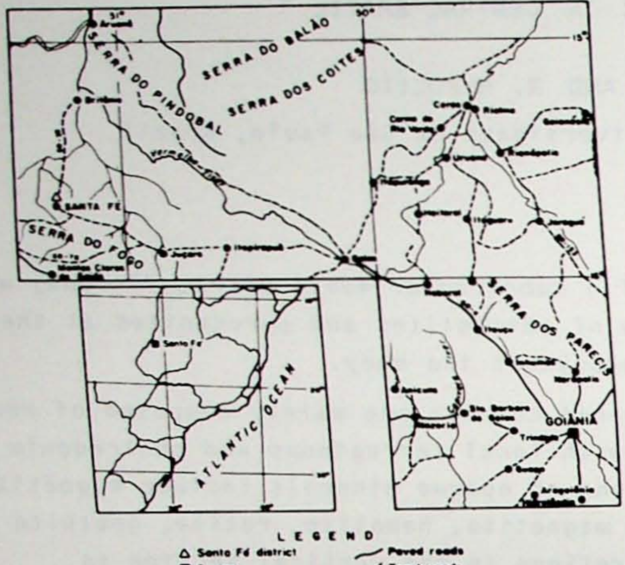


FIGURE 1

Index map showing the location of Santa Fé District, Brazil.

is around 20^{o}C. The alternation of dry and rainy seasons seems fairly certain to us to be an important factor in the lateritisation process in central Goiás, as shown in Table 1.

TABLE 1. PLUVIOMETRIC STATIONS AT GOIÁS AND ARAGARÇAS, STATE OF GOIÁS PERIOD: 1971 TO 1975.

	Pluviosity in mm		Driest months		Rainy season	
	Summer	Winter	June	July	November	December
Goiás	1,274.3	197.1	0.0	4.3	214.4	284.6
Aragarças	1,316.4	161.7	1.2	1.7	228.6	282.8

Savannah like vegetation with local small wooded areas called "cerrado", covers the entire area. This vegetation predominates irrespective of lithology and is controlled mainly by local soil conditions.

The wooded areas predominantly contain medium sized trees with an average height of 4.0 m. At elevations between 420 and 490 m, covered by a crust, a different type of vegetation predominates, mostly grass with scattered low brush. Grasslands are common along the tops of high ridges.

The Santa Fé mafic-ultramafic alkaline complex, is a subcircular body with an irregular concentric zoning of rock type, exhibiting dunites at the center and peridotites and pyroxenites at the border. Minor rock types associated with the major units are missourites, malignites and phonolites. Country rocks are leucocratic quartz-feldspathic gneisses with rare amphibolite bands. K-Ar determinations on essexite,

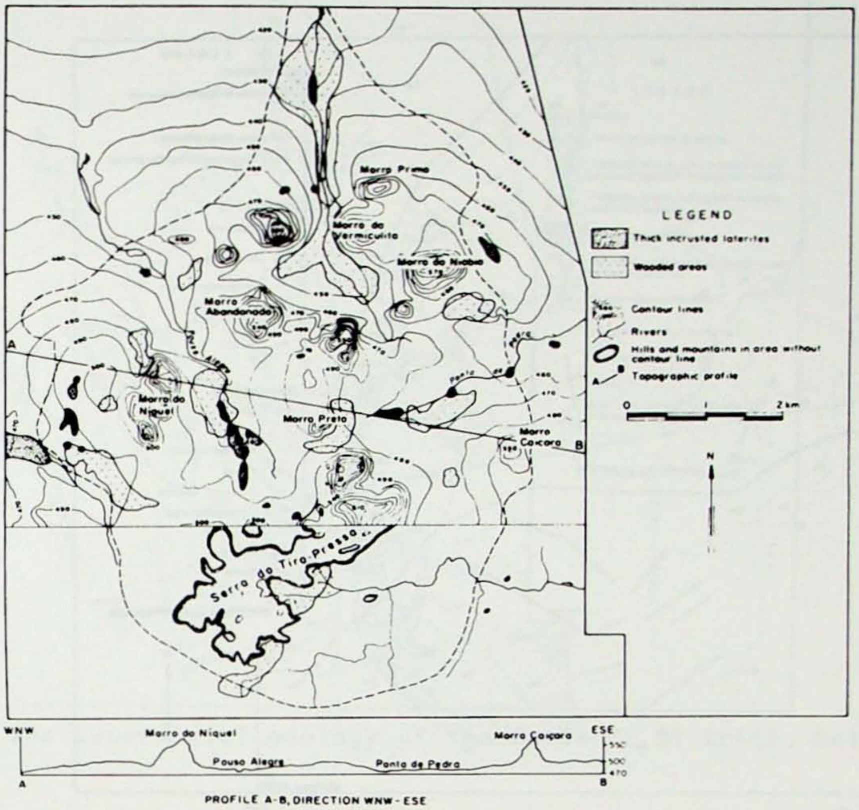
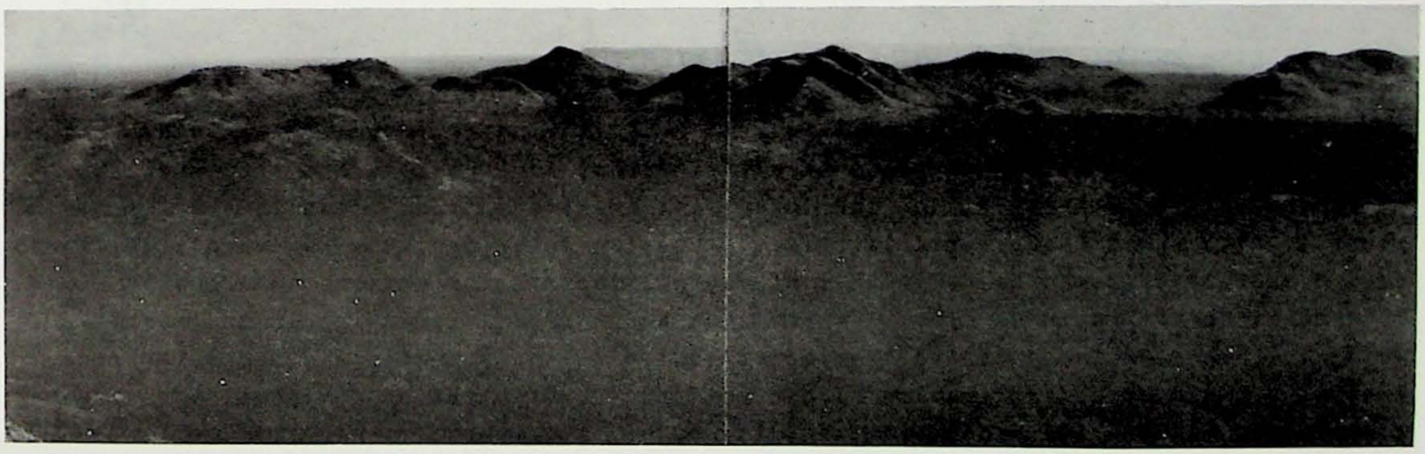


FIG. 2. Contour lines, lateritic crusts and wooded areas of the Santa Fé District, Goiás, Brazil.



PICTURE 1. Santa Fé Complex, represented by exhumed remnants of an old surface, peneplain covered by savannah like vegetation and lateritic crust indicating the course of Pouso Alegre river.

missourite and malignite, yielded ages around the Late Cretaceous, like many other mafic-ultramafic intrusions in southern Brazil. The surrounding gneisses show a whole rock Rb/Sr age of 467 (± 10) m.y., thus corresponding to the Brasiliano Cycle.

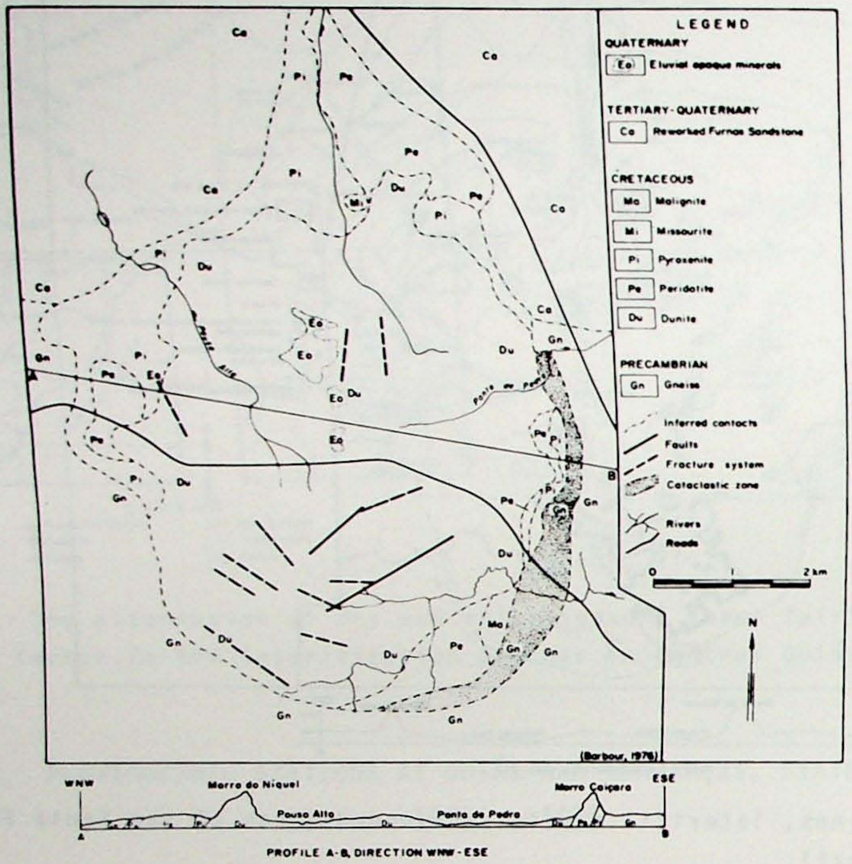


FIG. 3. Geological map of the Santa Fē District, Goiās, Brazil.

SOFT, REDDISH-BROWN, PREDOMINANTLY OOLITIC LATERITES

Figure 4 sets forth the general distribution of this kind of laterite throughout the Santa Fē District. It covers the entire area except for the tops and slopes of the hills (saprolitic material), and the lower flat areas along and close to the small rivers, which exhibit pisolitic laterites. Oolitic laterites show an average thickness of 4 m and are composed predominantly of sub-millimetric concretions immersed in a fine matrix of ferruginous clay. Concretions are rounded, ferruginous, and highly magnetic. Three representative samples collected in the superficial topograhic zone exhibit a grain size distribution of concretions in which the predominant sizes are distributed between +32 and +115 mesh (Fig. 5).

The granulometric distribution of concretions in a vertical profile is represented in Figure 6. In this profile the same predominant granulometric size of oolite is manifested, independent of depth, a fact which indicates that there is a continuous transportation of oolites from higher to lower topographic levels; thus, this material is colluvial in nature. The nuclei of concretions under the microscope showed the following compositions:

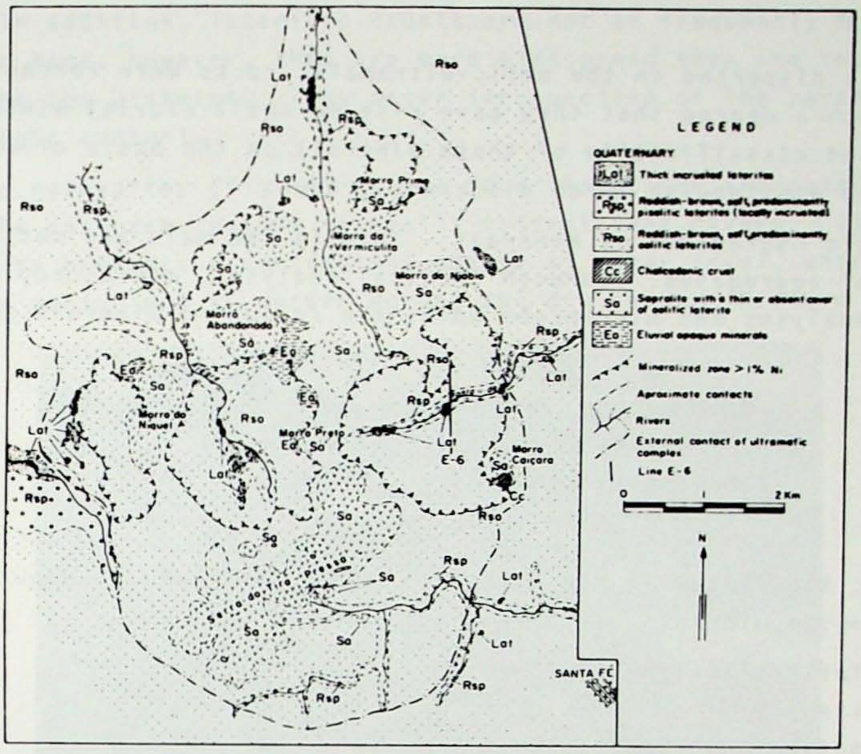


FIG. 4. Map of the superficial geology of the Santa Fé District, Goiás, Brazil

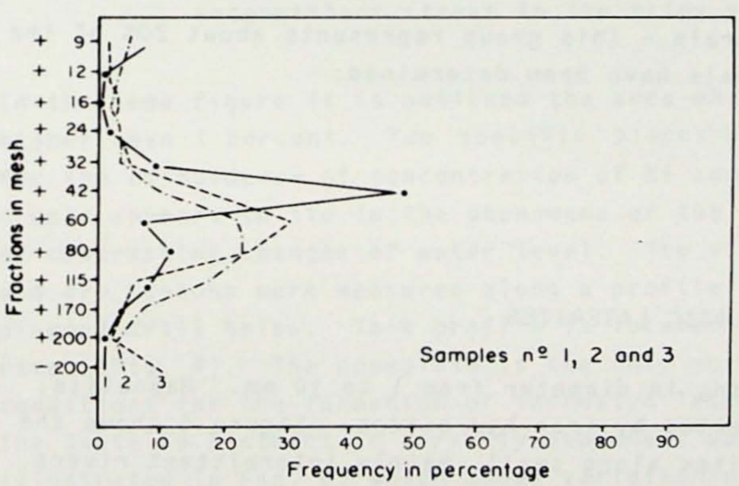


Fig.5 - GRANULOMETRIC DISTRIBUTION OF CONCRETIONS IN THE SUPERFICIAL TOPOGRAPHIC ZONE

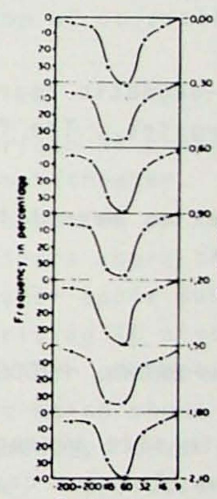


FIG. 6. Granulometric distribution of concretions in a vertical profile.

Magnetite crystals (without martitisation)	25%
No visible nuclei (homogeneous)	61%
Fragments of concretions	14%

Nuclei with magnetite crystals show ilmenite lamellae and are not usually oxidized to martite (martitisation).

Opaque primary minerals dispersed in the mafic-ultramafic rocks were concentrated in the soil horizon to such a degree that they gave rise to small eluvial mineral deposits (Fig. 4). The study and classification of these minerals on the basis of degree of magnetism allowed us to distinguish three different groups:

Group 1: Strong Magnetic Aggregates of Minerals - This is the main and most representative group of aggregates. Through chemical analyses, microscopy, differential thermal analyses and microprobe work, the following minerals have been determined:

Most common	Rare
Magnetite	Ilmenite
Maghemite	Chromite
	Rutile

Group 2: Weak Magnetic Aggregates of Minerals - This group represents about 30% of the aggregates. The following minerals have been determined:

. Magnetite with exsolution lamellae of ilmenite
. Titaniferous magnetite
. Hematite (after magnetite and ilmenite)
. Ilmenite
. Rutile (after ilmenite)
. Galena

Group 3: Non-magnetic Aggregates of Minerals - This group represents about 20% of the mineral aggregates. The following minerals have been determined:

. Chromite
. Hematite (after magnetite)
. Rutile
. Goethite

SOFT, REDDISH-BROWN, PREDOMINANTLY PISOLITIC LATERITES

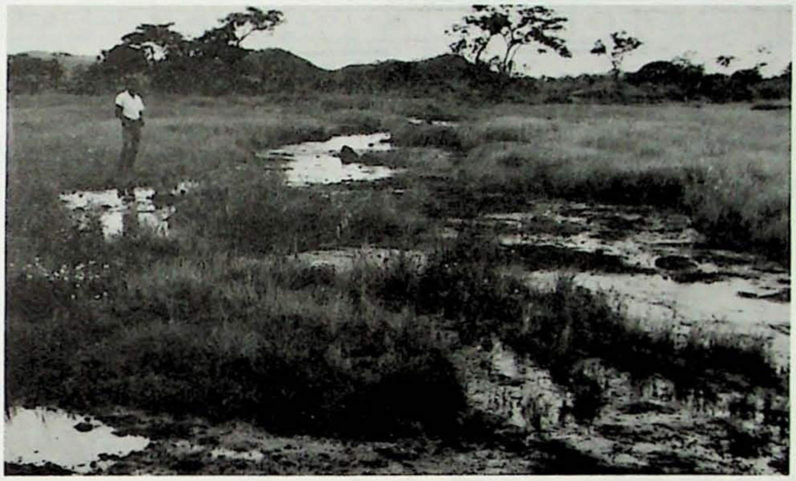
Pisolite grain size averages 3 mm, ranging in diameter from 1 to 10 mm. Magnetite, chromite, and ilmenite crystals are cemented by iron hydroxides. Figure 4 shows the general distribution of pisolitic laterites along small, mainly intermittent rivers.

Microprobe analyses show that the elements Cr, Fe, Ni, Co, Al, Mn and Si are found dispersed as part of the homogeneous cement throughout the concentric layers without any preferential distribution.

CRUSTS

Crusts are not areally extensive, at Santa Fé District but certainly provide a clue to understanding paleo and present morphoclimatic conditions imposed on the rocks of the district. In addition, lateritic crusts are not as frequently found as one might wish. On the other hand, however, they are more widespread than one could expect in the region around the District. They occur irrespective of the parent rocks and do not show lithologic control.

Particularly noteworthy (Fig. 4) is the fact that thick incrusted laterites are more common in the upstream regions of small, intermittent rivers. It must be emphasized that this area presents a contrasting change of water level, which reaches the surface in the rainy season and is deeper during the dry season (Picture 2).



PICTURE 2. Superficial lateritic crust in the upstream region of an small, intermittent stream in the rainy season.

In the same figure it is outlined the area which shows subsurface Ni concentrations higher than 1 percent. Two specific places configure an amphitheater. The reason for the coincidence of concentration of Ni and superficial formation of lateritic crusts appears to lie in the phenomena of the intermittent rivers where there are zones of contrasting changes of water level. The values for the water table during the rainy and dry seasons were measured along a profile (Fig. 7), comprising 16 pits and 2 diamond drill holes. This profile is located in the amphitheater of Ponta de Pedras river (Fig. 4). The peneplain is the only morphological unit which shows adequate conditions for the formation of incrusted laterites. Consequently, crust formation in the Santa Fé District is directly dependent upon the altitude. This observation is illustrated in Fig. 8, which shows variation of topographic altitude along the peneplain, from 410 to 490 m (a); lateritic crusts from 420 to 490 m altitude (b); and total absence of crusts above 490 m, even at the smooth almost horizontal foot or base of the hills (c). It is interesting to emphasize that lateritic crusts have a tendency to be vesicular toward the upper parts of the peneplain (490 m), and coarsely pisolitic toward the lower parts of the peneplain (420 m).

On the basis of regional geology Melfi et al. (1979) proposed several stages of rejuvenation documented by ancient erosion surfaces. Table 2 shows chemical analyses of crusts, soft pisolitic and oolitic laterites. The first sample of lateritic crusts

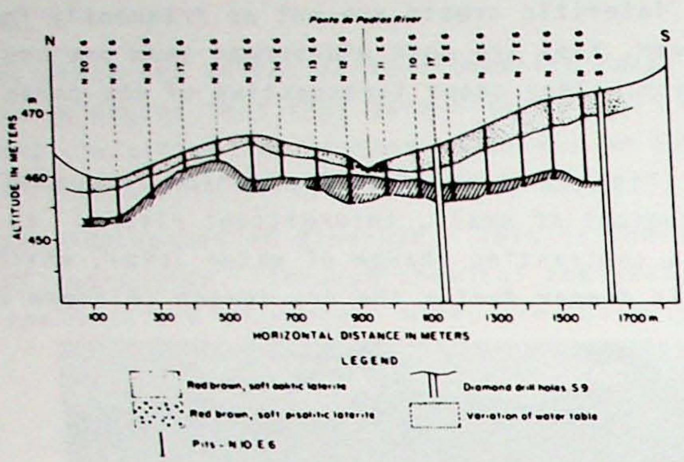


FIG. 7. Water table position along the line E-6, measured in dry season (lowest level) and the beginning of rainy season (highest level).

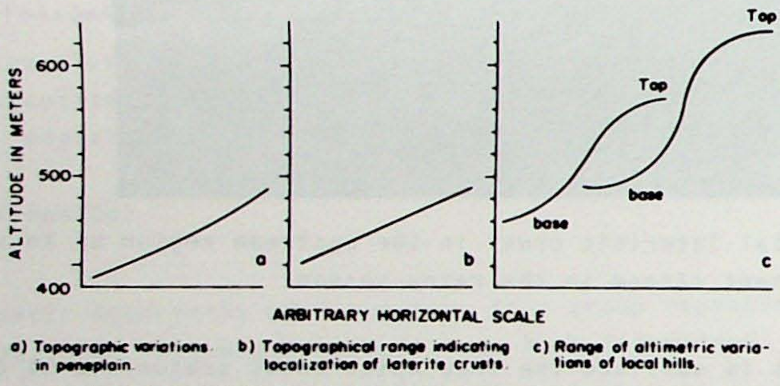


Fig.8-PROFILES SHOWING THE ALTIMETRIC RELATIONSHIP BETWEEN TOPOGRAPHY AND INCRUSTED LATERITES.

is representative of pisolitic crusts. Due to the fact that crusts and pisolitic soft laterite are predominantly of chemical origin, average values for ferric iron are higher. On the other hand, soft oolitic laterites, which show a tendency to be partially clastic in composition, exhibit a higher percentage of ferrous iron, TiO_2, Cr and Al_2O_3 due to the presence of crystals of magnetite, ilmenite and chromite. No further conclusion on this will be ventured because of the small number of chemical analyses.

The results of chemical analyses for SiO_2, Al_2O_3, and Fe_2O_3 were plotted on the triangular graph of Schellman, 1981 (Fig. 9).

Values for peridotite, serpentinite and kaolinised peridotite were taken from Schellman. This figure indicates the dominion of moderate to strong lateritisation for crusts and soft, reddish-brown laterites.

TABLE 2. CHEMICAL ANALYSES OF CRUSTS, SOFT PISOLITIC AND OOLITIC LATERITE.

Nº	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	FeO %	MnO %	CaO %	K_2O %	Na_2O %	TiO_2 %	MgO %	Cr %	Ni %	H_2O^- %	H_2O^+ %	Co ppm	Sr ppm	Pb ppm	Zn ppm	Cu ppm
CRUSTS																			
01*	12.20	6.72	64.59	0.89	0.26	0.06	0.07	0.27	0.45	0.16	0.49	0.06	0.95	12.75	122	170	103	58	20
02*	7.26	4.92	66.15	0.36	0.80	0.26	0.16	0.47	0.38	2.17	3.73	0.50	1.04	11.68	623	056	032	155	09
03*	10.3	3.16	64.9	n.a.	1.94	n.a.	n.a.	n.a.	n.a.	0.8	3.60	0.90	n.a.	12.80	3.820	n.a.	n.a.	n.a.	60
SOFT, PISOLITIC LATERITE																			
01	5.36	5.84	72.67	n.d.	0.66	0.39	0.07	0.98	0.31	1.27	0.97	0.34	1.84	9.19	590	237	n.d.	92	12
SOFT, OOLITIC LATERITE																			
01	10.58	8.16	54.21	2.93	0.77	0.20	0.07	0.90	1.29	4.99	12.92	0.32	0.79	1.77	254	n.d.	209	403	99
02	6.93	6.88	57.05	n.d.	2.66	n.d.	n.d.	0.23	3.10	n.d.	8.70	0.33	2.35	10.19	400	13	<30	380	<32
03	4.74	22.48	52.35	4.27	0.97	n.d.	0.02	0.05	3.60	n.d.	6.60	0.37	0.64	2.26	400	21	<30	310	<34

01* = Vesicular lateritic crust; 02* = Pisolitic lateritic crust; 03* = Pisolitic lateritic crust (Barros de Oliveira, S.M., 1980)

n.d. = not detected; n.a. = not analyzed

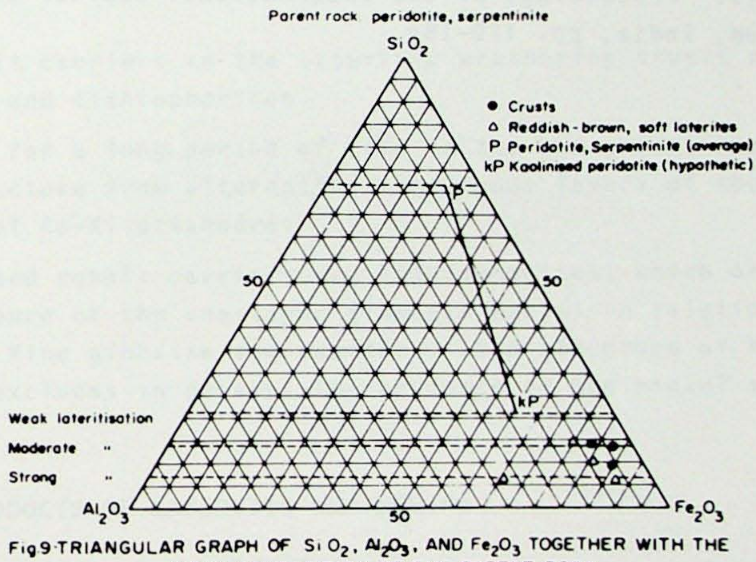


Fig9 TRIANGULAR GRAPH OF SiO_2, Al_2O_3, AND Fe_2O_3 TOGETHER WITH THE MEAN COMPOSITION OF THE PARENT ROCK
(After Schellmann 1981, modified)

CONCLUSIONS

. The vegetation and the formation of crusts are independent of the underlying rock type.

. Soft, red-brown oolitic laterite is of colluvial nature, as a product of mechanical/chemical transportation from the hill slopes to the peneplain surface.

. Intense concentration of Ni and incrustation are related mainly to upstream zones of intermittent rivers.

. Incrustation is a quite recent process, which takes place after or simultaneously with the peneplanation of the present lower surface.

. Crusts and soft reddish-brown laterites are both under the dominion of moderate to strong lateritisation processes.

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