Ferrallitisation in an Oceanian Tropical Environmnet

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Abstract

Two well drained ferrallitic soil types have been observed on Lakeba, an andesitic island located in the South East of the Fiji group, exposed to a tropical climate characterized by a mean annual rainfall of 20000 mm:

- *Kaolinic ferrallitic soils with a low gibbsite content on the eroded summits and slopes of the island.*
- *Ferrallitic soils rich in metallic oxydes and hydroxydes on plateaux, relicts of an older gemorphology.*

On comparison, it is observed that, in the Suva region, soils on the same type of andesite as those of Lakeba but under a mean annual rainfall of 3.5 m, though highly rejuvenated by erosion, have shown a clear gibbsite ferrallitic evolution.

These facts allow to establish on andesite a pedogenetic limit between ferrallitic soils with a moderate allitic evolution of Lakeba and ferrallitic soils with a high allitic evolution of the Suva region. Therefore, a paleoclimatic explanation is considered to elucidate the formation on the Lakeba plateaux of ferrallitic soils rich in metallic oxydes and hydroxydes.

Lakeba is located in the southeast of the Fiji Islands in the Lau archipelago at 178° East by 18° South. It is a subcircular andesitic mass of eight to nine kilometers in diameter overlain in its western and southern parts by Miocene limestone scraps (Ladd and Hoffmeister, 1945). Brookfield and Hart (1966) give the annual mean rainfall for Lakeba as about 2000 mm. with no strongly marked dry season. As the highest point is at 230 m, changes of climate throughout the island may not be very important. This island looks like a single massif with round shaped summits, drained by a subradial hydrographic network. Some plateaux – relicts of an older morphology occur on the island, at altitudes varying from 50 m to 200 m. According to Twiford and Wright (1966) the majority of the soils could be classified as ferrugineous latosols or "Talasiga soils". Talasiga means in Fijian sunburnt land (Parham, 1972).

Taking part in the UNESCO/UNFPA population and environment project in the eastern island of Fiji, a recent pedological prospecting of this island has found among Talasiga soils, in well drained conditions, two major pedogenetic units: ferrallitic soils with kaolinite and low gibbsite individualization and ferrallitic soils with high metallic oxydes and hydroxydes individualization (Latham et al., 1977).

In this note after indicating the major characteristics of these soils we will try to

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clear up their genesis with regard to their present evolution as well as their past evolutions under perhaps different climates. That is why we will do a compared study with the soils located in the Suva surroundings, on the main Fiji island, in Mendrausutu range. This area which has an andesitic substratum similar to Lakeba's receives a mean annual rainfall of more than 3500 mm.

Main Characteristics of the Soils

Kaolinic soils of Lakeba occupy the eroded slopes and summits which shape the frame of the island. Their depth is variable, their A and B horizons do not exceed 20 to 30 cm in the most truncated areas, where elsewhere their C horizon may occur at about 1 m or 1.5 m. Their brownish red colour is normally redder than 5 YR. Truncated soils have a medium texture while the deepest have a fine one. They are acid soils with a low, highly unsaturated, cation exchange capacity (Table 1). Triacid total analysis indicates high amount of silica, aluminium and iron. Silica and alumina are mainly tied up in phyllites. X-ray diffraction allows to state them as pseudo monoclinic kaolinite or fire clay (Table 2). In the C horizons, fire clay may be associated with metahalloysite. Few gibbsite have been evidenced in A and B horizons. This mineral may lack in the C weathered horizon. Iron individualizes itself as magnetite, hematite and goethite. So these kaolinite rich ferrallitic soils have only little amounts of gibbsite.

Ferrallitic soils with high metallic oxydes and hydroxydes individualization are observed on plateaux, as indicators of an older morphology. They are deep (5 to 6 m deep), dusky red (10 R) soils, showing a very fragile structure in their upper horizons. Ferromanganesiferous concretions and a coarse texture rich in pseudo sands are observed in these upper horizons. Some small millstone fragments have also been noticed. In the deeper horizons, an important microporosity and very low bulk density has been noted, giving to the soil a smeary consistance. Chemically these soils are acid. Their base saturation except for A horizon is very low. The cation exchange capacity of their mineral matter is very weak. Triacid total analysis indicate low to very low amounts of silica and high iron and very high aluminium percentage in A and B horizons. From a mineralogical point of view, gibbsite and hematite are the predominating minerals; boehmite and goethite have also to be noticed. Among lattice clay, when present which is exceptional, metahalloysite is the only mineral identified. Its percentage increases with the depth. X ray diagrams indicate also a certain amount of amorphous products. So these soils are developed soils in which metallic oxydes and hydroxydes either predominate over phyllites, or are the only soil constituent.

The soils of the Mendrausutu range occur on a very dissected landscape. They are highly truncated. Weathered rock elements occur since 30 to 50 cm deep, when continuous weathered rock becomes visible at 80 cm. Their (B) horizons have brownish red (5 YR 5/6) colour. They have a medium texture and a clear blocky structure. Chemically these soils are acid, with a mean, highly unsaturated, cation exchange capacity. Among total elements, silica, alumina and iron are abundant. Silica percentages increase with depth and the SiO_2/Al_2O_3 ratio which is close to 1 in A and B reaches 1,67 in the C horizon. Hence free alumina amounts are high in A and B horizons. X ray diffraction emphasizes an abundance of gibbsite and a rather high quantity of hematite, goethite and magnetite. Among phyllites, metahalloysite is the only discernible mineral. A certain amount of amorphous products is also present. Unlike soils of Lakeba plateaux these soils are poorly developed. However, the importance of metallic oxydes and hydroxydes and particularly gibbsite must be emphasized.

TABLE 1 – PHYSICO-CHEMICAL CHARACTERISTICS

Kind of profile	Lakeba plateaux soils				Lakeba eroded soils				Mendrausutu range eroded soils			
Sample	LS 43	LS 71	LS 73	LS 75	LS 101	LS 103	LS 104	LS 113	VL 11	VL 12	VL 13	VL 14
Deepness in cm	80–100	0–5	90–100	180–200	0–10	50–60	120–130	90–100	0–8	30–40	60–70	150–160
Horizon	B2	A1	B2	B3C	A1	(B)	(B) C	Weathered rock	A1	(B)	(B) C	C
Clay %	14,0	10,5	52,0	66,0	28,5	33,0	19,0	–	21,0	40,0	28,0	19,5
Organic matters %	0,3	4,6	0,3	–	7,2	0,5	–	–	16,9	1,0	0,6	0,2
pH	5,3	5,5	5,9	5,8	5,6	4,8	4,5	4,0	4,5	4,5	4,6	4,5
Cation exchange capacity in me/100g	5,1	20,8	5,1	11,4	26,6	7,8	10,6	5,2	88,3	15,8	15,8	15,9
Base saturation in me/100g	0,31	5,23	1,29	8,65	13,5	1,7	1,6	0,84	6,2	0,6	1,0	0.9
Triacid total analysis %												
Loss on ignation	22,0	20,2	18,3	16,4	20,0	13,9	14,3	13,3	33,6	18,8	18,9	15,4
Insoluble	0,95	0,90	0,45	0,40	0,50	0,40	0,50	0,70	2,0	0,20	0,15	0,20
SiO_2	1,50	15,8	12,5	22,9	34,0	36,7	39,6	38,4	18,4	23,2	24,4	31,0
Al_2O_3	33,5	30,5	35,6	32,0	28,5	32,0	34,5	31,2	29,4	34,4	36,0	31,5
Fe_2O_3	23,5	22,5	25,0	23,8	12,5	14,0	9,1	13,5	13,5	19,8	17,5	18,5
TiO_2	1,90	2,40	2,57	2,7	2,02	1,67	1,90	1,42	1,57	1,87	1,59	1,56
MnO_2	16,8	5,9	4,75	0,04	0,27	0,24	0,18	0,08	0,14	0,11	0,17	0,33
P_2O_5	0,01	0,1	0,1	0,03	0,2	0,2	0,1	0,05	0,3	0,3	0,2	0,3
SiO_2/Al_2O_3	0,08	0,88	0,60	1,21	2,02	1,94	1,94	2,08	1,06	1,14	1,15	1,67

TABLE 2 – MINERALOGICAL CHARACTERISTICS

Kind of profile	Lakeba plateaux soils				Lakeba eroded soils				Mendrausutu range eroded soils			
Sample	LS 42	LS 71	LS 73	LS 75	LS 101	LS 103	LS 104	LS 113	VL 11	VL 12	VL 13	VL 14
Seepness in cm	20–30	0–5	90–100	180–200	0–10	50–60	120–130	90–100	0–8	40–50	60–70	150–160
Horizon	B2	A1	B2	B3C	A1	(B)	(B) C	Weather-ed rock	A1	(B)	(B) C	C
Gibbsite	†††	†††	††††	†††	††	††	†		††††	††††	††††	†††
Boehmite	††	††	††									
Hematite	†††	†††	†††	††††				††	†††	†††	†††	†††
Goethite	†	††	††	††	††	††	†	†	††	††	††	††
Magnetite					†††	†††	†	††	†††	†		
Metahalloysite		††	††	†††		††	††		†††	†††	†††	†††
Fire clay					†††	††	††	†††				
Montmorillonite												
Amorphous products	††	††	††	††	†	†			††	††	††	††

†††† abundant   ††† rather abundant   †† a little   † traces

Therefore we can notice the difference between the mainly kaolinic composition of eroded soils of Lakeba and the essentially metallic oxyde and hydroxyde constitution of Mendrausutu range eroded soils and of Lakeba plateaux.

Discussion

The genesis of soils from eroded areas of Lakeba seems linked to a slow removal of silica in the present geochemical context. This slow desilicification of the upper part of profiles which goes with the formation of a little gibbsite is unceasingly questioned by the surface erosion. So an equilibrium of the erosion weathering couple is settled, which allows kaolinisation to develop in spite of quartz absence. This kind of evolution which could be called a moderate allitisation†† in the Pedro (1968) scheme is rather normal under these climates. It can be compared with what is observed on similar rocks in French Antilles (Colmet-Daage and Lagache, 1965), in the New Hebrides (Quantin, 1972) and in La Reunion island (Zebrowski, 1975).

On the other hand eroded soils of Mendrausutu range indicate a fast desilicification of their profiles. A fall in the SiO_2/Al_2O_3 ratio and an important increase of free alumina may be noticed in the upper horizons of these soils continually rejuvenated by erosion. This kind of intense allitisation of soils through amorphous products and metahalloysite has been well described by Tercinier (1974) in his study of the Taravao peninsula in Tahiti.

So there seems to exist, on andesite and in well drained conditions, a climatic limit between Lakeba and Mendrausutu range which parts the moderate allitic field from the intense allitic one.

†† The term allitisation which was created by HARRASSOWITZ in 1926, means an intense desilicification of the profile linked to an individualization of metallic oxydes and hydroxydes specially gibbsite and boehmite. SEGALEN et al. (1976) propose for the definition of allitic horizon the limit of 70% of oxydes and hydroxydes mainly aluminous.

The nearly complete desilicification of soils of the Lakeba plateaux and the individualization of metallic oxydes and hydroxydes raise in these conditions the problem of their genesis.

Two hypotheses may be put forward:

- a slow action of a climate close to the present one during a long period of time.
- or the action of a more humid paleoclimate followed by a kind of fossilization of these soils.

These plateaux might be relicts of an older geomorphology. Dickinson (1965) considered for similar levels in Viti Levu, the main Fiji island, an age lasting between the end of Pliocene and the beginning of Pleistocene. So pedogenesis has been able to operate during a very long period. However the present moderate allitisation which allows kaolinite to predominate in their constitution even on matured soils, does not look very consistent with so deep an allitisation. More, the clear discontinuity between allitic soils of the plateaux and kaolinic soils of the slopes does not fit very well with the slow action of a rather unchanged climate.

On the other hand this intense allitisation looks like the normal way of pedogenesis on this type of rock under a perhumid climate. In fact it is very unlikely that the present climate would have gone on without any changes till the Pliocene. The paleoclimatic scheme as it was considered for New Caledonia (Latham, 1976) or for Australia (Mulcahy and Churchward, 1973) could very well be applied to Lakeba: a perhumid period at the end of the tertiary which would have allowed this allitisation, followed by more contrasted and dryer periods during which these plateaux would have individualized after an intense erosive phase and by the present kaolinisation of the rejuvenated landscape. A demonstrating factor would be the absence of relict plateaux and very probably of allitic soils on Nairai, another Fijian island comparable in climate and size to Lakeba but having a Pliocene basalto andesitic substratum (Latham, 1975). However this absence should be investigated on other Pliocene andesitic islands to be more conclusive. Thus the soils of the Lakeba plateaux seem to be relict soils made during a perhumid period which would have taken place at the end of the Tertiary.

Conclusion

Therefore the comparative study between well drained Talasiga soils of Lakeba and of Mendrausutu range eroded soils has allowed us to raise again the problems of the influence of climate on pedogenesis and of paleoclimatic heritage.

A pedogenetic limit has been evidence between kaolinic eroded soils of Lakeba which receive a mean annual rainfall of two 2 meters, and gibbsitic eroded soils of Mendrausutu range where it falls more than 3.5 m. of rain. This limit is the boundary between moderate and intense allitisation. The presence of soils with marked allitic characteristics on the Lakeba relict plateaux, suggests a paleoclimatic explanation. That point supports the hypothesis advanced for New Caledonia and Australia of a perhumid climate at the end of Tertiary in this region. This period would have been followed by more contrasted and dryer episodes which would have fossilized soils of these plateaux.

This differenciated ferrallitisation between Lakeba and Mendrausutu range sets once more the problem of the age of soils and of paleoclimatic influence on their composition.

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