

Soils of the New Hebrides islands

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This paper deals with the pedogenesis, the classification, the characteristics and the geography of New Hebrides soils, and lastly with some relationships between these soils and the vegetation.

The following pedogenetic features are emphasized: the New Hebrides soils derive mainly from basic volcanic rocks. They are often young or frequently rejuvenated by volcanic ash. They are differentiated in three main groups, according to a climatic sequence due to the tradewinds: ferrallitic soils in the wetter southeast part, fersiallitic soils in the drier northwest part, and andic soils on the 'perhumid' highlands. The wetter the climate or the younger the volcanic ash, the more andic are the soils.

A correlation is attempted between the soil units of the French pedological classification and those of the soil map of the world by the F.A.O.

Next, the characteristics and the geographical distribution of the thirteen main groups of New Hebrides soils are briefly outlined.

Finally, some relationships between some soils and the native vegetation are briefly reported.

New Hebrides soils have been studied by the Office de la Recherche Scientifique et Technique Outre-Mer from 1964 to 1970, for the New Hebrides Condominium. Since 1970, the publication of pedological maps at 1/100 000 and 1/50 000 has been undertaken: three sheets already published concern Efate, Epi and Shepherd Islands; the four following sheets, Ambrym, Aoba, Maewo and Pentecost, are now in press. Also sketch maps at 1/500 000 were drawn in 1972 with a F.A.O. legend as a contribution to the preparation of a soil map of the world.

1. FACTORS OF PEDOGENESIS

First, I shall summarize data relating to the environmental conditions that have contributed to soil formation, so that I might then specify some correlations between soils and vegetation.

(a) *Geology*

The New Hebrides islands consist mainly of eruptive volcanic rocks. Their formation began in the early Miocene and volcanic activity has continued until now. The parent rocks, basalts, andesites, volcanoclastic sediments and limestones are basic. Almost all the soils derive from volcanic ash, or at least have ash as an important component, due to recent volcanic activity. For this reason, there is a great extent of andosols or andic soils in the New Hebrides islands; in addition, the soils are often very fertile.

(b) *Geomorphology*

Two main landforms can be distinguished: the oldest 'high-islands', in the form of horsts, comprise volcanic mountains with very strong and very dissected relief and limestones or

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volcano-sedimentary plateaus; the youngest volcanic islands show well preserved volcanoes. On the oldest high-islands, the very eroded volcanic relief bears rhegosols and tropical brown earths; the plateaus or the gentle and weakly eroded slopes are covered with the most mature tropical soils, such as ferrallitic or fersiallitic soils. On the youngest volcanoes appear rhegosols and andosols. The most recent fluvio-marine terraces are covered with rendzinas and fluvisols.

(c) *Climate*

A wet tropical climate, close to the equatorial type, characterizes the greater part of the islands. Nevertheless, climatic differentiation related to altitude and exposure to the trade-winds is apparent on the high-islands. At low altitude, southeast windward slopes have a typical equatorial climate, with a rainfall of 2.50 to 4 m/year; northwest leeward slopes have a tropical climate with two seasons and a rainfall probably less than 2 m/year. At an altitude of more than 500–600 m to the south or 200–300 m to the north of the archipelago, the highlands have a 'perhumid' climate with foggy or humid weather almost all the year and rainfall probably more than 5 m/year. Related to this, the following pedological climato-sequence is apparent: ferrallitic soils on the southeast and fersiallitic soils on the northwest slopes; andic soils on the highlands and even some rankers on the highest tops of Santo Island.

2. CLASSIFICATION OF SOILS

New Hebrides soils often differ from those previously described in other tropical countries on the African or American continents. However, they present some analogies with those from the recent volcanic countries, such as the Hawaiian islands, the Andes, the West Indies and Mt Cameroon. In table 1, I have attempted to correlate the soil units for the French classification (C.P.C.S. 1967, modified 1972) with those for the soil map of the world (F.A.O. 1968, modified 1970).

TABLE 1

	French classification	F.A.O.
sols minéraux bruts	{ d'érosion d'apport volcanique	eutric rhegosols or lithosols
sols peu évolués	{ d'érosion { désaturés saturés d'apport { volcanique alluvial	rankers eutric rhegosols or lithosols vitric andosols eutric fluvisols vitric andosols mollic andosols humic andosols rendzinas calcic cambisols eutric cambisols dystric cambisols eutric - vertic cambisols dystric - vertic cambisols
ando-sols	{ peu différenciés, vitriques différenciés { saturés désaturés	
sols calcimagnésiques carbonatés	{ rendzines bruns calcaires	
sols brunifiés tropicaux	{ eutrophes désaturés	
sols fersiallitiques	{ saturés, bruns, vertiques désaturés, rouges, vertiques	
sols ferrallitiques faiblement désaturés, humifères		ferrallic cambisols or humic ferralsols?
moyennement ou fortement désaturés, humifères		rhodic or xanthic ferralsols
moyennement ou fortement désaturés, andiques		{ acric or humic ferralsols mollic or humic andosols
sols hydromorphes	{ humiques, à anmoor calcique peu humifères, à amphigley	calcaric gleysols eutric gleysols

3. CHARACTERISTICS AND GEOGRAPHY OF SOILS

(a) *Sols minéraux bruts* (= raw mineral soils = eutric rhegosols and lithosols)

Raw mineral soils formed by erosion are located on bare tectonic cliffs and occupy only very small areas. Raw mineral soils from recent volcanic deposits, like lithosols on lava flows or rhegosols on ashes, cover a large area around the active volcanoes of Ambrym, Lopevi and Tanna islands. They bear neither vegetation nor cultivation.

(b) *Sols peu évolués d'érosion* (= weakly matured soils formed by erosion = eutric rhegosols and rankers)

The weakly matured soils formed by erosion occupy large areas on the old volcanic mountains of Efate, Malekula, Santo, Maewo and Pentecost islands. They are located on steep slopes. At low altitude, the soils are saturated with bases: they are mostly eutric rhegosols or rarely lithosols. Above 1000 m, in Santo, the soils have an accumulation of acidic organic matter: they are rankers. Almost all these soils are covered with canopy forest or bush; they are seldom cultivated.

(c) *Sols peu évolués d'apport alluvial* (= weakly matured soils from alluvial deposits = eutric fluvisols)

The weakly matured soils from alluvium are located on the most recent low (+2 to +3 m) fluvio-marine terraces. Since these soils are saturated with bases, they are eutric fluvisols. Although on most islands they cover only small areas, they cover large areas on Efate and Santo. These soils have good fertility and are often cultivated.

(d) *Andosols vitriques* (= vitric andosols)

The vitric andosols are weakly matured soils. They derive from very recent volcanic deposits that surround the active volcanoes of Ambrym, Lopevi and Tanna Islands, and the recently active volcanoes of Banks Islands, southeast Epi and Shepherd Islands. These soils have a low or medium grade fertility and are rather rarely cultivated, but are more used on the Shepherd Islands.

(e) *Andosols saturés* (= saturated andosols = mollic andosols)

The saturated andosols are young soils from recent volcanic products, but they are fairly well developed and matured and are very fertile. These soils occupy large areas on Aoba, the centre of Tanna plateaus, and the northwest slopes of Banks Islands. They are very often cultivated.

(f) *Andosols désaturés* (= unsaturated andosols = humic andosols)

The unsaturated andosols are also young soils from recent volcanic products, but they are located in very wet and rainy zones, especially on the Banks Islands, southern Tanna and the top of Aoba. In comparison with the saturated ones, the unsaturated andosols are geochemically more mature, leached of silica and bases and enriched in aluminium and iron hydroxides. These soils are very hydrated, strongly desaturated and they retain phosphorus very strongly. At low altitude, the soils are less desaturated; therefore, they are fairly fertile and rather often cultivated. On the very wet highlands the soils are strongly desaturated, probably poor, and are very rarely used.

(g) *Rendzines et sols bruns calcaires* (= rendzinas and brown calcareous soils = rendzinas and calcic cambisols)

The rendzinas derive from the recently emerged coral-reef deposits. In general they cover small areas, but there are large areas along the coastline of Efate, Malekula and Santo Islands. These soils are fairly fertile, but rather lacking in potassium. They are very often used for coconut plantations.

Brown calcareous soils are especially frequent on northern Maewo, where they appear on very eroded landforms developed on volcanic and calcareous deposits. Everywhere else they are scarce and not important. These soils are fertile, but they are rather little used.

(h) *Sols bruns eutrophes tropicaux* (= tropical eutrophic brown soils = eutric cambisols)

Two subgroups of eutrophic brown soils can be distinguished: reddish brown soils with halloysitic clays and dusky brown soils with montmorillonitic clays. The first ones derive from basaltic scoriae of the recent Quaternary; they are of great extent on the Shepherd Islands and northern Epi; these soils are very fertile and they are intensively cultivated. The second ones appear on steep slopes of basic eruptive rocks when they are rejuvenated by erosion; they are especially frequent in southern Maewo, southern Pentecost, Malekula and western Santo; these soils are very fertile, but they are rarely used because of the danger of erosion.

(i) *Sols bruns désaturés ou oligotrophes* (= unsaturated or oligotrophic brown soils = dystric cambisols or humic andosols)

The unsaturated brown soils are formed, like the eutrophic ones, on steep reliefs of basic eruptive rocks that are rejuvenated strongly by erosion; however they appear at higher altitudes, usually above 500 m. These soils are typical and very frequent on southwestern Santo between 500 m and 1000 m above sea level. On the highlands of southern Malekula, Maewo and Pentecost Islands, the unsaturated brown soils have some prominent features of ando soils, due to recent volcanic ash deposits. These soils are of low fertility and are rarely cultivated.

(j) *Sols fersiallitiques saturés* (= eutric-vertic cambisols)

The saturated fersiallitic soils are the orthotype of mature soils for the tropical climatic zone located on the northwestern slopes of old high-islands like Tanna, Erromanga, Efate, Malekula, Santo and Maewo. These soils are very clayey and rich in montmorillonite; they have a dusky colour and a coarse structure, often vertic. They are fairly fertile but are rather little cultivated, owing to the dry season. These soils are often covered with a 'pyrophytic' savanna and are frequently used for extensive pastures.

(k) *Sols ferrallitiques faiblement désaturés humifères* (= humic weakly desaturated ferrallitic soils = ferrallic cambisols)

Humic and weakly desaturated ferrallitic soils cover mainly the low limestone-plateaus of old high islands, where they are located in the wet climatic zone with a southeast aspect. These soils are of great extent on Efate, Santo, Maewo, Pentecost and Torres Islands; they occupy only small areas on Erromanga and Malekula islands. On Epi they are also formed on the plateaus, although these are constituted from volcanoclastic sediments, rejuvenated by recent ash deposits. These soils are very clayey and rich in metahalloysite and goethite minerals; they

have a reddish brown colour and a medium polyhedral structure. Owing to their good fertility the soils are often used for intensive agriculture and pasture. Their natural vegetation is mainly closed bush with *Hibiscus tiliaceus* and scattered patches of rain forest, or open canopy forest.

(l) *Sols ferrallitiques moyennement ou fortement désaturés humifères* (= humic moderately or strongly desaturated ferrallitic soils = rhodic or xanthic ferralsols)

Ferrallitic soils, more or less strongly desaturated and humic, cover the oldest volcanic or volcano-sedimentary deposits. They appear in the wet climate zone, at low altitude and on fairly gentle relief. They are of great extent on Aneityum, Erromanga, Efate and Santo islands. Elsewhere they are scarce.

These soils are very clayey and rich in halloysite or kaolinite clay minerals. They have often a red colour and a fine polyhedral structure but sometimes they are brown on clay deposits. They are of low fertility and therefore are scarcely cultivated, and they are often covered with well developed rainforest like that of Erromanga and Aneityum, with kauris and tamanus.

It is noteworthy that land impoverished by previous cultivation is now covered with sclerophyll thickets or poor grassland.

(m) *Sols ferrallitiques moyennement ou fortement désaturés andiques* (= andic moderately or strongly desaturated ferrallitic soils = acric ferralsols or humic andosols)

The andic ferrallitic soils are very rich in aluminium and iron hydroxides, especially in gibbsite and fine goethite minerals, but they are poor in silica and particularly in clay minerals; they have andic and ferrallitic features at the same time. These soils are located on the high plateaus of the oldest islands, at an altitude of about 600 m in the south and above 200–300 m in the north of the archipelago. They are mainly formed on hard limestone-plateaus on Futuna, Efate, Santo, Maewo and Pentecost Islands; however they appear also, but rarely, on volcanic or volcano-sedimentary rocks in Efate and Malekula. The andic soils on the high plateaus of Efate and Santo are true ferrallites or acric ferralsols, but those of southern Pentecost, that have been strongly rejuvenated by volcanic ash, are closer to unsaturated andosols or humic andosols.

The andic ferrallitic soils are of low fertility. They are rarely cultivated and mostly covered with 'nephelophytic' closed canopy thicket, with *Metrosideros* and epiphytic species.

4. VEGETATION AND PEDOCLIMATIC RELATIONSHIPS

The climax vegetation appears to be evergreen rainforest for the greater part of the islands. However, it is often rather a closed canopy bush with scattered patches of rainforest or scattered large crowned trees. There is also an evident differentiation of vegetation associated with the age of soils, their fertility, and above all a pedoclimatic sequence.

(a) *Age of soils*

The vegetation of young soils is characterized by a peculiar and little diversified flora. In Ambrym, for example, there is an open canopy forest with *Casuarina* and *Trema* on the recent lava flow located in the southeast, an open canopy thicket with *Cyathea*, *Veitchia* and *Weinmania* on the ash plain of the caldera.

(b) *Pedoclimatic sequence*

The following sequence is observed: on the windward slopes and at low altitude, the eutrophic brown and ferrallitic soils are mostly covered by a dense bush with *Hibiscus tiliaceus* and scattered patches of rainforest. True rainforests with *Callophyllum* and *Agathis obtusa* are rare. On the leeward slopes, the vertic brown and fersiallitic soils are frequently covered by a 'pyrophytic' grassland with *Themeda* or *Imperata*. Deciduous open woodland with *Acacia spirorbis* and *Santalum austrocaledonicum* is rare and covers little area. On the 'perhumid' high plateaus and summits, the andic-ferrallitic and the unsaturated andosols are covered with a nephelophytic dense thicket with *Metrosideros*; this bush is rich in Myrtaceae, ferns, *Pandanus* and epiphytic species.

(c) *Fertility of soils*

A difference in vegetation type is observed in the same wet tropical climatic zone with one type on weakly desaturated ferrallitic and very fertile soils and the other on strongly desaturated ferrallitic and poorly fertile soils. Soils of the first group on limestone-plateaus of Efate bear a dense bush with *Hibiscus tiliaceus* and some patches of forest with *Antiaris toxicaria*; those of the second group on volcanic rocks are covered with a true rainforest, with *Callophyllum* in Efate or *Agathis obtusa* and *Callophyllum* in Erromanga and Aneityum.

On Pentecost, it is noteworthy that the forest growing on eutrophic brown soils from ultramafic rocks can not be distinguished physiognomically from that growing on soils from basaltic rocks. This is contrary to observations in New Caledonia and in the Solomon islands. Perhaps the difference could be due to the rejuvenation of soils in Pentecost by volcanic ash.

CONCLUSIONS

New Hebrides soils can be characterized by the following most prominent features: the great extent of basic eruptive rocks; the youth of soils or their rejuvenation by volcanic ash; a strongly differentiated pedoclimatic sequence that is peculiar to all tropical oceanic islands; a fairly moderate effect of geomorphological or parent-rock factors in comparison with the climate or the age of soils. In addition to the conspicuous tropical features of pedogenesis that appear in the eutrophic brown, fersiallitic or ferrallitic soils, some andic characteristics are juxtaposed or superimposed; these features are due mostly to recent volcanic ash deposits or fairly often also to the effect of a 'perhumid climate' on the highlands. The fertility of soils that are located at low altitude is often very high, owing to rejuvenation by volcanic ash, in spite of a heavy rainfall, but this is not so in some areas of strongly desaturated ferrallitic soils derived from old volcanic rocks in Aneityum, Erromanga, Efate and Santo islands. Finally, there are strong correlations between soils, vegetation and land use in the New Hebrides Archipelago.