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Landuse and Soil Catena in Jeneponto Area of South Sulawesi

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Introduction

The chain of Indonesian islands running eastward from Central Java can be considered, in simple terms, to be composed of volcanoes surrounded by coral reefs. In the gradational processes worked by heavy rainfall on the volcanoes, a series of landforms develops with specific soil covers on each. The sequence of landuse types found there also varies concomittantly with the physical background.

A good example of this phenomenon is provided by the southern coastal area of South Sulawesi (Fig. 1). The successive landform complexes are as follows. The hilly and pluvial volcano middle slopes display irrigated rice terraces on latosols. Downward, the rolling and dry upper volcanic fans have dry upland gardens for woody crops and maize on regosols. The undulating and intermittently wet lower volcanic fans have irrigated rice fields on regosols. The level and dry raised coastal terraces have rain-fed rice fields on grumusols, and the level, low-lying coastal backswamps have rain-fed rice fields on grumusols, often with fish ponds in conjunction with sand dunes and coastal complexes.

This paper describes first the general landscape in a transverse transect along the coast, and a longitudinal transect from the coast to the volcano hillslopes. Second, it describes the soil members observed in the fields and analyzed in the laboratory. Third, it tries to extract a working hypothesis with which to elucidate the soil distribution pattern, particularly that of the grumusols. Soil naming follows the local system [Soepraptohardjo *et al.* 1968].

I Landuse Pattern in the Southern Coastal Area

1. *Rainfall*

The southern coastal belt of South Sulawesi belongs traditionally to the maize cultural zone, in contrast to the Makassar–Bone area, which is a rice zone [Furukawa 1982: 29]. This is necessitated by the very dry climate, which is unsuitable even for dry rice. The average rainfall in Jeneponto, for example, is slightly over one thousand mm (Tab. 1a). The data obtained at *Dinas Pertanian Rakyat* (Agricultural Extension Office) at Jeneponto also show a great variability (Tab. 1b). The undulating to rolling topography and the pervious basement rocks consisting of limestone and

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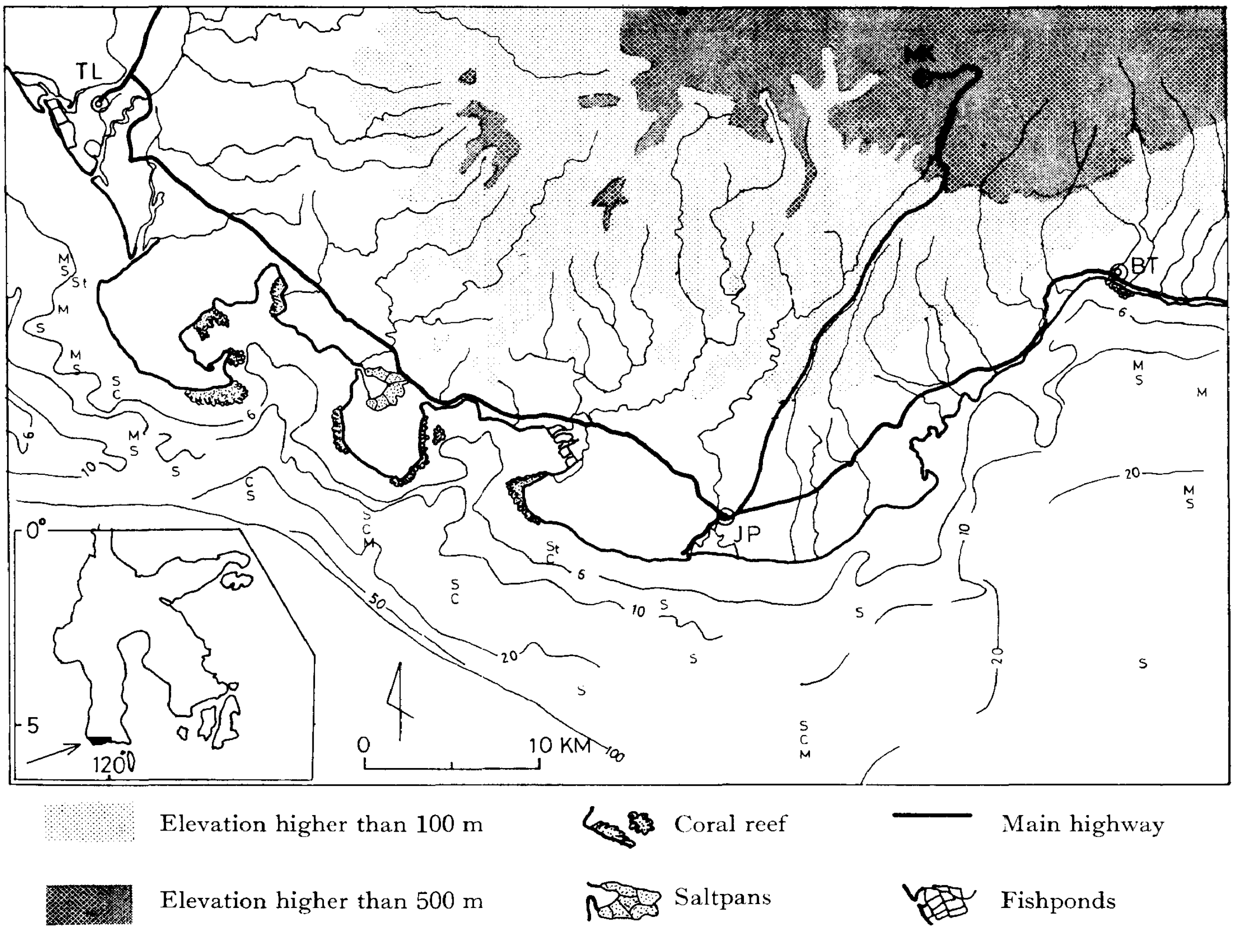
Table 1a Average Rainfall in Southern Coastal Area of South Sulawesi

Station Name	Period	Average Rainfall in mm												
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Takalar	1911–1941	575	356	384	107	70	31	18	5	10	34	140	397	2127
Jeneponto	1913–1941	267	159	139	68	81	74	45	10	10	12	43	193	1101
Bantaeng	1881–1941	147	116	125	138	212	207	122	48	24	46	76	113	1374
Bulukumba	16 years	105	93	114	154	260	193	125	28	19	47	49	91	1278
Malakaji	1913–1941	414	336	313	312	223	140	64	27	21	54	216	377	2497

Table 1b Variation of Rainfall at Jeneponto in Recent Years

Jeneponto	1976	195	34	93	18	55	37	14	—	—	24	128	58	656
	1977	172	264	101	49	7	126	—	—	—	—	14	69	802
	1978	178	142	68	34	45	62	103	17	—	23	16	152	840
	1979	159	73	149	12	56	50	5	—	26	4	16	109	659

Data Source: Table 1a is cited from Berlage [Berlage 1949: 152–154] except Bulukumba. Data for Bulukumba are cited from Mohr [Mohr 1933–38: 372]. Data in Table 1b were obtained at *Dinas Pertanian Rakyat* at Jeneponto.

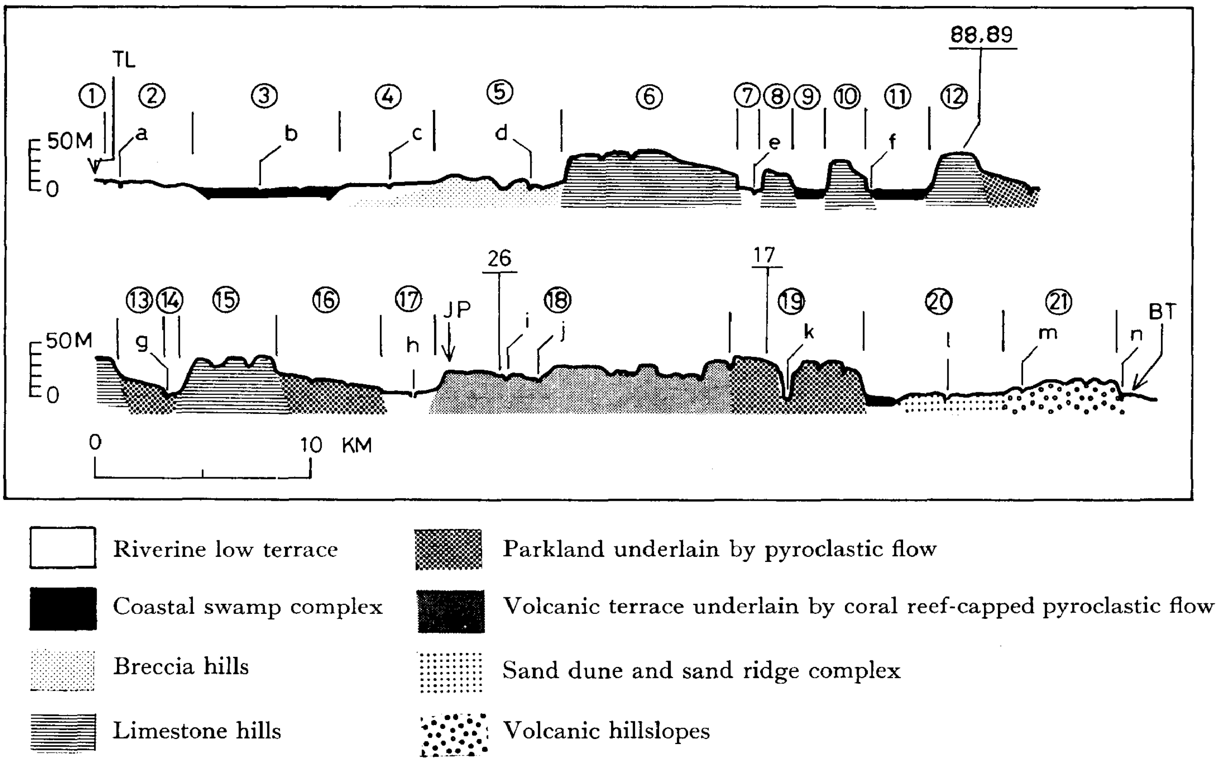


TL: Takalar, JP: Jeneponto, BT: Bantaeng, MK: Malakaji
S: Sand, C: Coral, M: Mud, St: Stone

Fig. 1 Location Map of Jeneponto Area, South Sulawesi (Prepared by simplifying topo-map sheet "Makasar," SB 50–8 series T503, AMS) pyroclastic flow also contribute to the dryness of the surface. Maize is surmised to have been the staple food in these dry circumstances. Wet rice cultivation in the Jeneponto area seems to have expanded its acreage only recently, since the introduction of the Kelara irrigation project. The cultivation method, however, deviates from the ordinary transplanting method in order to adapt to the dry circumstances. Most farmers employ the broadcasting method instead.

2. *Transect from Takalar through Jeneponto to Bantaeng*

Soils and landuse patterns observed from October to December 1980 along the highway from Takalar to Bantaeng are illustrated in Fig. 2. The predominant rocks are feldspathic breccia in the Makassar–Takalar area, limestones in the Takalar–Jeneponto area, a mixed distribution of limestone and pyroclastic flow in the eastern Jeneponto area, and pyroclastic flow and volcanic rocks in the west Bantaeng area. The numbered tract in the figure were as follows.



TL: Takalar junction, JP: Jeneponto, BT: Bantaeng

Rivers: a. J. Pappak, b. J. Pangkalang, c. J. Batunapara, d. J. Topa, e. J. Allu, f. J. Nasara, g. J. Tomonroya, h. J. Ponto, i. J. Ponara, j. J. Buntulu, k. J. Taruang, l. J. Tino, m. J. Bantimurung, n. J. Kariu

Fig. 2 Transect from Takalar through Jeneponto to Bantaeng (Circled numbers refer to the tract numbers described in the text. Lower-case letters indicate rivers. The location of soil samples is indicated by underlined numerals.)

(1) Low terrace with light gray soils. Rice fields in the Makassar–Takalar plain are cultivated by transplanting method, with a single crop of rice during the rainy season from December to May, which is preceeded by maize and mung bean in the pre-monsoon period. The soils on the level to gently undulating low terrace or fan-like lowland are light gray (10YR7/1 according to Munsell color chart) and silt loam in texture. The sand fraction is predominated by feldspar and lacking in quartz except in deeper horizons. Kaolin minerals in the clay fraction predominate in the surface horizon and montmorillonite increases with the depth.

(2) Low terrace with brown soils. About one kilometer west of J. Pappak, the surface soil becomes brownish and fine-textured. It is about one meter deep and underlain by dark sand deposits derived from andesitic breccia. Some rice fields in the lowest portion of the backswamp are deeply inundated in the rainy season. The farmers there dibble seed of a tall rice variety called *pada iri*, which sometimes grows to two meters. The deep water usually continues for three months.

(3) Coastal backswamp. This is deeply inundated during the rainy season. A tall rice variety *ase bakka putih* is transplanted in December. In the dry season the ground surface dries up and is covered by salt precipitates and algae resistant to salt intrusion. The lower land around tidal creeks is used as fish ponds for milk fish. The tidal creeks are vegetated by *Rhizophora* and *Nypa*.

(4) Abraided breccia plain. Brownish black fine-textured soils of granular structure cover the level to gently undulating plain, which is an abraided plain of breccia hills. The surface soils do not exceed one meter in depth and are underlain by weathered breccia, which is feldspathic with a small amount of quartz and contains many pumice fragments. Many manganiferous concretions thinly coated by iron oxides are involved in the subsurface horizons. Rounded concretions have concentric structure. Many farmers broadcast pre-germinated seeds on puddled rice fields, particularly in the case of glutinous rice. They also transplant *ase bakka*[1] varieties from dry seedbeds prepared on unbunded sloping grass land which is actually breccia outcrop.

(5) Breccia hills. Gently rolling low hills composed of andesitic breccia are covered by thin dark-brownish soils with many boulders of volcanic rock. Sparse stands of teak occupy the convex slopes and crest, and colluvial slopes with rather thick grumusolic soils are intercropped with maize, groundnut and dry rice planted by dibble. The coastal swamps have been developed as fish ponds.

(6) Limestone hills. The rolling to hilly limestone mass with steep cliff exhibits various phases of deposits: bedded limestone, calcareous sandstone and siltstone, etc. The thin cover of dark rendzina soils contains many calcareous stones. Palmyra palm is a predominant crop. The fluid extracted from the young inflorescences is

1) *Ase bakka* as well as *ase banda* is a name for a group of rice varieties. *Ase bakka putih* is, therefore, the name of one rice variety involved in the *ase bakka* group. *Ase bakka* varieties are inferior to *ase banda* varieties in the quality.

used for brewing *tuak* (toddy), for which Makassar is a large consumer market. Another important crop is maize, which is planted on *kebun* (upland field) only once a year in December, because of the climate, which is dry even in the southern coastal area.

(7) Low terrace. This level terrain is planted with wet rice. Broadcasting is common.

(8) Rolling limestone hills. Maize, papaya and dry rice are grown.

(9) Salt pans. Coastal marshes with rather sandy soils are parcelled into salt pans. Sea water is introduced through canals, sometimes by windmill, into bunded pans and evaporated to leave coarse salt grains. The pans are first submerged by rainwater in late December, when they are sometimes utilized for fish raising.

(10) Rolling limestone hills. Dark, coarse soil blocks on the slopes are tilled with long digging sticks in November, and planted with maize and dry rice after the soil blocks have slaked into smaller clods. Palmyra palm trees stand in abundant clumps. Gentle concave slopes have dark soils and have been made into rice terraces which are completely rain-fed.

(11) Salt pans. Similar to tract 9.

(12) Rolling limestone hills. Mango trees stand sparsely on the slopes. Dark rendzina soils with very fine granular structure are sometimes deep on colluvial slopes, but hilly slopes are mostly stony. Stone walls are built to make sloping terrace fields. Various crops including maize, sesame, cassava, mung bean, cow pea and *Crotalaria* are planted on the walled fields in the rainy season, and their prolific growth changes the barren fields of the dry season into lucrative gardens.

(13) Sloping parkland. The sloping land has numerous stands of palmyra palm and mango trees, and displays the so-called parkland landscape. At the end of the dry season, the ground surface is bare and dry with sparse maize stalks. Soils are dark brown grumusolic, with patches of grayish soils. Villagers build low stone walls of rounded breccia and platy limestones around their houses.

(14) Coastal swamps. The river course and the backswamps, which are vegetated by *Nypa*, are used as fish ponds.

(15) Rolling limestone hills. Rolling slopes are extensively used as gardens for maize intercropped with cassava, groundnut, mung bean, etc. Palmyra palm is also abundant and used for *tuak* and sugar making. The gardens are surrounded by thick brush of a thorny *Euphorbia*. The depressions in the undulating hills are developed as wet rice fields. They are completely rain-fed and cultivated by broadcasting. Some villages, *Desa* Bontotangan for example, raise water by pump from J. Binaga, one of the small streams running down from the limestone hills. There farmers transplant the new rice varieties in late December and harvest in April, and afterwards plant other crops like groundnut, onion and soybean in the rice fields.

(16) Sloping parkland. This is again a parkland landscape with abundant clumps of palmyra palm and mango trees on sloping grounds. The soils are pale brown and appear to be derived from volcanic ash flow.

In November the soils are tilled with long digging sticks, and the coarse soil blocks are left to be disintegrated by rain into smaller clods, when maize and groundnut are planted by dibbling.

(17) Gently undulating colluvial slopes and low terrace. Rice terraces on gentle slopes are rain-fed, while some rice fields on the low terrace are irrigated and double-cropped.

(18) Gently undulating volcanic terrace. The terrain is incised by several rivers which cut deeply into the pyroclastic flow. Volcanic boulders are present in abundance on the ground surface. The terrace east of the new settlement of Jeneponto is fairly level and covered by dark fine-textured grumusols. Grumusols occupy a transverse belt 4 to 5 km in width at the southern end of the volcanic terrace. In longitudinal transect to the north, grumusols are gradually replaced by grayish yellow brown soils of coarser texture and by immature soils located on volcanic fans. The catenaic change is described and discussed in the following sections.

The rolling escarpment is planted with upland crops like maize and groundnut, while level to gently undulating crest is extensively used for wet rice. Upland fields are tilled with digging sticks and maize is intercropped with groundnuts during the period from November to April or May.

Wet rice fields are traditionally rain-fed. Seed is broadcast, since rainfall is limited in amount and occurs only during the period December to March, insufficient for a nursery period. About two weeks after the onset of the monsoonal rain in December, the coarse cracks in the land seal up, and water ponds in the bunded rice fields. Farmers then plough and harrow the soil, usually only once each. Pre-germinated seeds are sown on the drained mud, and once the seedlings become established the fields are kept submerged. Weeding is done only once, one month later. Short-term varieties like *jarra, cobo, pulut leleng, bakka* and *banda* are used traditionally. The rehabilitation of the Kelara irrigation project in 1967 caused the spread of the transplanting method and the transformation of upland fields into wet rice fields.

Basement rocks here seem to involve both pyroclastic flow and limestones.

(19) Undulating volcanic terrace. Bed rocks are composed of pyroclastic flow containing subangular boulders of andesitic nature, and are covered by ash flow. The soils are silty, rather thin, and yellowish brown. The absence of calcareous deposits in bed rocks in this area seems to have caused the different soil forms. The rain-fed wet rice fields are cultivated by broadcasting. During the rainy season the steep escarpment is planted with maize and groundnut intercropped in rows. Young mandarin orange plants in gardens suffer from the severe dryness.

The mouths of the deeply incised streams are vegetated by mangroves. Fish ponds are dug in the underlying dark sand deposits.

(20) Narrow strip of sand ridges. Along the narrow sand ridges are chains of villages and dense stands of coconut palm. Mandarin oranges also appear to flourish. The mouths of small tidal creeks are used as

fish ponds. *Nener* (larva) of milk fish is netted at the sea shore.

(21) Volcanic footslopes and volcanic fans. Gently rolling footslopes have patches of irrigated rice terraces which double-crop with high yielding varieties. Soils are brown to reddish brown latosols. Groundnut sometimes replaces the second crop of rice on the rice fields.

3. Transect from Jeneponto to Malakaji

Soils and landuse along the highway from Jeneponto to Malakaji are illustrated in Fig. 3, as observed in November 1980.

(1) Sand dune complex of *Desa* Pabiringa, Jeneponto. Low sand dunes occupy the southern coast. These are favorable sites for village settlements and have abundant stands of coconut palm trees. Interdune swamps are used as fish ponds for milk fish. The sand dunes rest on a coral reef about five meters thick. Drinking water is obtained from wells which dug through the coral reef.

(2) Coastal backswamp. Despite the very low elevation, a dark grumusol has developed in which coarse cracks form to a depth of 50 cm during the dry season. This level plain has been converted into wet rice fields, but has no water source except rainfall at the site. The irrigation water delivered by the Kelara irrigation project does not reach this terminal plain but is consumed by the rice fields upstream. Thus the rice fields are all planted by broadcasting.

(3) Low terrace. This is identical with the low terrace in land tract 17 of Fig. 2.

(4) Very gently undulating volcanic

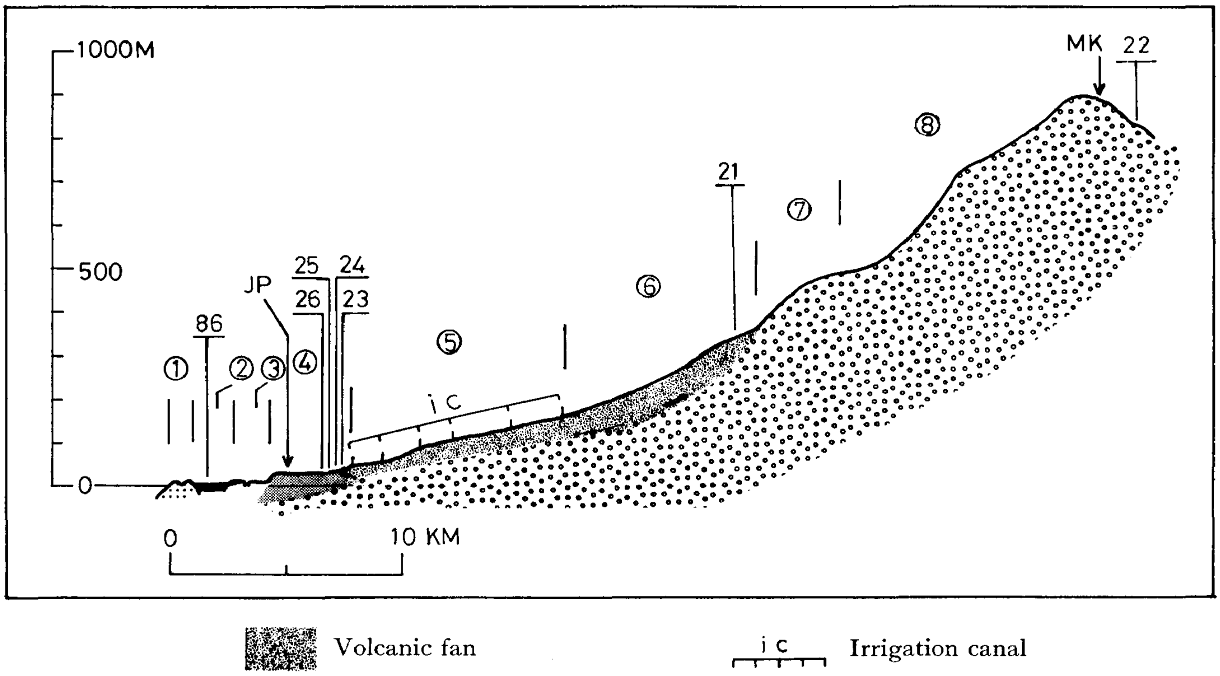


Fig. 3 Transect from Jeneponto to Malakaji (Refer for Fig. 2 for remainder of legend.)

terrace. This is almost identical to the western terrace in land tract 18 of Fig. 2. The ground surface is fairly stony with boulders of volcanic rock and covered by dark grumusol. The volcanic fan extending from the north is in the process of aggrading the grumusol terrace, onto which it abuts in an escarpment with well graded slope. The soils along this slope display gradual changes from dark grumusol on the level terrace to grayish yellow brown soils on the crest of undulation.

Insufficient irrigation water is available to allow transplanting, and pre-germinated seed is broadcast on the puddled mud surfaces.

(5) Lower volcanic fan. The volcanic fan along this transect has its apex at about 400 m height. It has well-graded slopes, rather coarse textured soils, and abundant boulders and cobbles of andesitic nature. It is divided into two tracts, the lower and upper volcanic fan. The former was irrigated to some extent by local systems before the Kelara irrigation project started, and is now covered densely by irrigation networks. Seedlings are prepared in wet nurseries and transplanted in November and December. The soils are grayish yellow brown and coarse textured. The soil becomes more brownish near the border with upper volcanic fan. Palmyra palm is common at lower sites; mango and kapok trees are dominant at higher sites.

(6) Upper volcanic fan. This differs from the lower volcanic fan in several points: the slope is steeper; irrigation is unavailable; more acreage is allotted to gardens of mango, kapok, mandarine orange, maize and cassava. The infrequent rain-fed rice terraces are stone-circled. These were converted recently from gardens previously planted with woody crops. Many mango trees still stand amidst the rice fields. Pre-germinated seed is broadcast on puddled land. The soils are grayish yellow brown regosols with a thin solum.

The soil material on the volcanic fan is subject to slow mass-wasting processes. The brown soils on the higher portion of the lower fan seem to indicate relatively stable or slower mass transport there, which results in soil material in advanced stages of weathering.

(7) Footslopes. The tract is covered rather densely by *kemiri* (*Aleurites* spp.) forest. The waxy seeds are collected and used to make candle. The soils change from regosols to reddish brown latosols with a deep weathering crust.

(8) Lower middle slopes. Rice fields again appear, first sporadically in the concave swale at the valley bottom, then extensively on the convex hillslopes. Close to *Desa* Tompobulu, Malakaji, gentle hillslopes are all occupied by rice terraces. The height of the rice terraces does not exceed one meter. Some of them are stone-walled, but most are soil-walled. Cropping patterns in the rice fields are various: rice-rice, rice-maize intercropped with cabbage and beans, and rice-tobacco.

The soil material is reddish brown and slightly smeary. The rice soils have plough-sole layer beneath which iron accumulates. Intensively weathered pyroclastic flow with coarse manganese mottlings underlies the solum.

The annual rainfall amounts to 2497 mm at Malakaji (Tab. 1), and increases further up. The middle slopes are very humid and misty and covered by dense evergreen forest.

II Volcanic-calcimorphic Soil Catenas

Soils are described below. The analytical data are summarized in Table 2. Mineralogical data in the table were obtained by X-ray diffraction. Microscopic observation supplement the results in the following descriptions.

1. *Soils on the Volcanic Slopes*

Soil sample No. 22 represents a latosol. It was taken at a site located on the volcano middle slope at an elevation of ca. 850 m, and cultivated for wet rice.

22–1 A1p 0–15 cm Brownish black (10YR3/2) when wet and brown (10YR4/4) when dry; SiC in field texture and LiC by analysis; abundant, distinct iron mottles (7.5 YR5/6); medium humus content; weak coarse blocky; smeary consistence; no stones.

22–2 B2ir 25–65 cm Brown (7.5YR4/4) when dry; SiC in field texture and LiC by analysis; many faint iron mottles (5YR5/6); low humus content; moderate fine granular; smeary consistence; common, moderately weathered andesitic gravel.

22–3 B3mn 65 cm Brown (7.5YR3/4) when dry; HC; many, distinct coarse manganese mottles; moderate fine granular; few stones; remnant structure of pyroclastic flow is visible.

Leaching is more advanced in the surface and sub-surface horizons, while clay formation increases downward. Quartz content is different in A1–B2 horizons and B3 horizon. The dominant primary minerals are feldspars, which are transformed into pseudomorphs and weathered to clay (kaolin minerals) and gibbsite. Under the microscope, clay-coated sand grains account for 60% in A1 and B2 horizons and almost 100% (on grain basis) of sand grains in B3 horizon. Volcanic glass is present (ca. 2%) in A1 and B2 horizons. These are considered to be mixed with aeolian deposits. There is a lithologic discontinuity between A1–B2 and B3 horizons. Clay fraction is composed exclusively of kaolin minerals, presumably meta-halloysite throughout the profile (Fig. 4).

A regosol (soil No. 21) on the lower volcanic fan (Fig. 3) is described below.

21–1 A1p 0–10 cm Dull yellowish brown (10YR5/3) when moist; SiC in field texture and CL by analysis; common, faint, filmy iron mottles; low humus content; moderate medium blocky; very friable; many, slightly weathered, subangular andesitic pebbles.

This thin soil material rests on cobble and boulder layer. The matrix of andesitic rock is light brownish gray (7.5YR7/1), and contains many phenocrysts of feldspar, mostly of plagioclase. It has a high content of exchangeable calcium derived from these feldspars. Quartz and mica also accompany the feldspars. Some heavy minerals like augite, magnetite, are noticed. Clay fraction is dominated by kaolin

Table 2 Analytical Data of Soil Samples

Sample No.	EC μ℧/cm	pH	Exchangeable Cations (meq/100g)				Particle Size Distribution (%)					Minerals in FS1 Fraction					Minerals in Clay Fraction							
			Ca	Mg	K	Na	CS	FS1	FS2	Silt	Clay	Qu(%)	Fl	Mi	Gi	Clay	Kl	Mi	Mt	Vr	Qu	Gi	Fl	Go
Volcanic Soils																								
22-1	200	4.55	4.20	2.07	0.34	0.30	7.4	5.9	10.5	41.6	34.7	0	−	−	+	+++	++++	−	−	−	−	+	−	−
22-2	56	5.63	5.53	3.17	0.33	0.16	8.9	7.2	7.8	37.1	39.0	0	−	−	+	+++	++++	−	−	−	−	−	−	−
22-3	42	6.13	4.01	2.70	0.46	0.15	11.5	12.1	4.1	19.0	53.2	7	−	−	±	+++	++++	−	−	−	−	−	−	+
21-1	140	6.30	14.7	6.43	1.08	0.23	20.6	7.5	18.1	33.5	20.3	5	+++	+	−	−	+++	+	++	±	−	−	+	−
17-1	140	7.00	20.4	6.21	1.10	0.18	24.9	9.2	6.1	27.8	32.0	7	+++	+	−	−	+++	+	++	−	−	−	−	−
17-2	95	6.80	20.0	5.74	0.19	1.68	21.3	16.7	11.6	16.3	34.0	5	−	−	−	+++	++++	−	±	−	−	−	−	−
Volcanic-calcimorphic Soils																								
23-1	43	5.60	12.2	5.46	0.62	0.34	7.2	7.8	9.9	38.0	37.0	21	+++	+	−	−	+++	−	+++	±	−	−	−	−
24-1	74	6.18	17.9	9.57	0.83	0.60	4.4	7.8	9.5	26.6	51.7	24	+++	±	−	−	+++	−	+++	±	−	−	−	−
25-1	32	5.45	16.0	8.32	0.46	0.35	9.5	4.5	6.9	29.1	50.0	26	+++	−	−	−	++	−	+++	−	−	−	−	−
26-1	69	5.50	25.2	11.8	0.92	0.39	4.5	4.0	5.2	27.4	58.8	25	+++	−	−	−	+	−	++++	−	−	−	−	−
26-2	51	6.30	26.5	13.2	0.48	0.45	2.0	4.7	5.7	27.5	60.0	29	+++	−	−	−	+	−	++++	−	−	−	−	−
86-1	120	7.08	49.6	19.5	1.13	5.19	0.4	0.4	0.7	26.0	72.6			——nd——			−	−	++++	−	−	−	−	−
86-2	610	7.42	59.2	20.9	1.20	7.58			——nd——															
86-3	1200	7.80	69.1	22.9	1.54	20.2			——nd——															
88-1	290	7.50	103.0	2.29	0.43	0.39	0.9	2.0	1.8	2.6	92.6			——nd——			−	−	++++	−	−	−	−	−

Remarks: 1. Electric conductivity and pH were measured with 1 : 5 suspensions.
2. Exchangeable cations were extracted with N-ammonium acetate solution.
3. Abbreviations for particle size distribution.
CS coarse sand 2000–200 μm, FS1 fine sand 200–50 μm, FS2 fine sand 50–20 μm, Silt 20–2 μm, Clay <2 μm
4. Abbreviations for mineral composition.
Qu quartz, Fl feldspar, Mi mica, Gi gibbsite, Kl kaolin, Mi mica-illite, Mt montmorillonite, Vr vermiculite, Go goethite, − absent, ± a few, + common, ++ many, +++ abundant, ++++ dominant

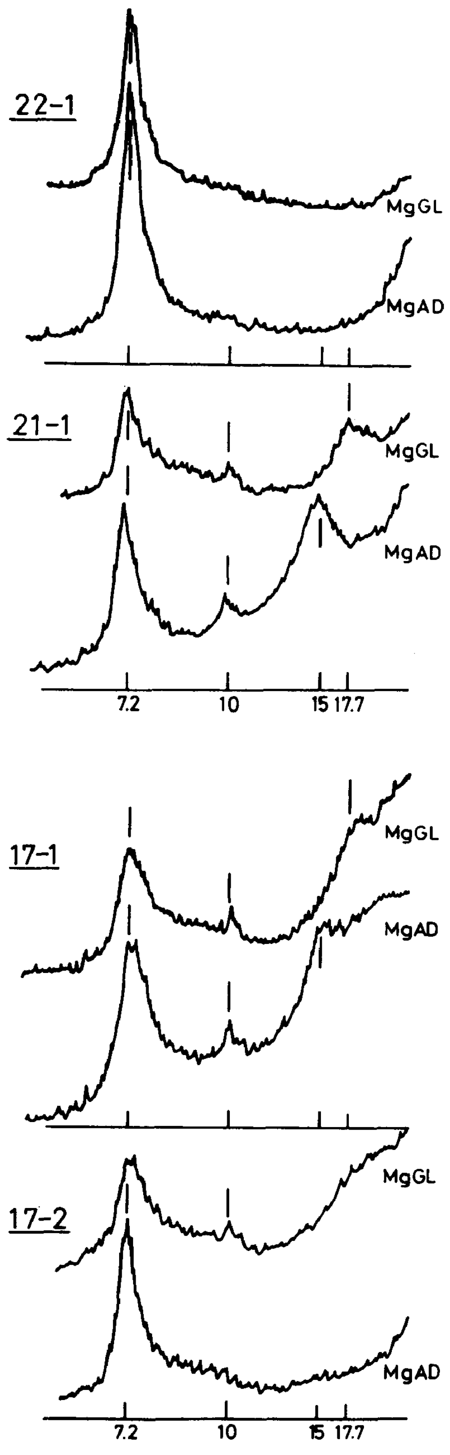


Fig. 4 Clay Minerals of Volcanic Soils as Seen in X-ray Diffractograms (The peak position is indicated by the basal distance in Å. MgAD: Mg-saturated and air-dried clay. MgGL: Mg-saturated and glycerated clay.)

minerals and accompanied by montmorillonite, mica-illite, vermiculite and feldspar (Fig. 4).

Another sample of regosol (soil No. 17) resting on weathered ash flow is described below.

17–1 A1p 0–10 cm Grayish yellow brown (10YR5/2) when dry; LiC; low humus content; weak coarse blocky; pulverulent consistence when dry; abundant, moderately weathered pebbles.

17–2 C1 10–30 cm Dull yellow orange (10YR6/4) when dry; LiC; weathered ash flow.

17–3 C2 30–100 cm Light gray (10YR 7/1); fresh, consolidated ash flow.

The ash flow is resting on another pyroclastic flow with boulders. The pH of soil material and ash flow is neutral. Exchangeable calcium is high. Fine sand fraction of A1p is dominated by plagioclase, with a small amount of quartz and mica. Augite (ca. 3%) and common hornblende (ca. 1%) are also noticed. The clay fraction is dominated by kaolin minerals, and accompanied by montmorillonite of low crystallinity and mica.

The weathered ash flow layer retains sand grains, which, however, are pseudomorphs consisting of kaolin minerals.

Although the starting materials described so far are surmised to have similar lithological compositions, that is, plagioclase-rich eruptiva, the soil materials separate into two groups on the basis of sand and clay composition. One involves the horizons of 22–1, –2, –3, and 17–2; the other, 21–1 and 17–1. The former group has sand pseudomorphs which are actually transformed into clay and gibbsite. The presence of sand pseudomorphs is important in keeping the water percolation rate relatively high. This will lead to the intensive leaching of bases released by primary minerals and to the formation of clay in acidic media. Kaolin minerals are the metastable product in this case.

The latter group shows the disintegration of sand pseudomorphs into separate clay particles. This situation leads to a decreased rate of water percolation and sometimes waterlogging in depressions, and to clay formation in calcium-rich media. Montmorillonite minerals are the metastable product.

The process resulting in the former group is *in situ* weathering; the latter, however, is the product of some sort of mass transport which causes the disintegration of the sand pseudomorphs into clay particles.

2. *Soils on the Volcanic Terrace and Coastal Swamp*

The location of catenaic soils Nos. 23 to 26 and No. 86 is indicated in Fig. 3. These are cultivated for wet rice. Soils Nos. 23 to 26 are located on a very gentle undulation with height defference of 5 m in ca. 600 m distance on the volcanic terrace, and soil No. 86 is located on the coastal backswamp. The elevation at No. 26 is ca. 30 m. According to the soil map of South Sulawesi, soil No. 23 falls in the area demarcated as regosol, while soils Nos. 26 and 86 are in grumusol areas.

23–1 A1p sample from 0–10 cm depth. Brownish gray (10YR5/1) when dry; LiC; many distinct, medium iron mottles (10YR5/6); low humus content; strong, very coarse blocky; extremely wide fissure, many pores caused by bubbling; hard consistence when dry.

24–1 A1p sample from 0–10 cm depth. Grayish yellow brown (10YR4/2) when dry; HC; common, faint iron mottles (10YR5/6); low humus content; strong, very coarse blocky; extremely wide fissure, many pores caused by bubbling; extremely hard when dry; few gravels.

25–1 A1p sample from 0–10 cm depth. Brownish gray (10YR4/1) when dry; HC; common, faint iron mottles (10 YR4/6); low humus content; strong, very coarse blocky; extremely wide fissure, many fine pores; extremely hard when dry; few gravels.

26–1 A1p 0–10 cm Brownish black (10YR3/1) when dry; HC; few faint mottles (10YR6/6); low humus content; strong, very coarse blocky; extremely wide fissure, many fine pores; extremely hard when dry; few, slightly weathered gravels.

26–2 B2 30–60 cm Black (10YR2/1) when dry; HC; low humus content; no mottles; strong very coarse angular blocky; continuous slickensides; extremely wide fissure; few fine pores; extremely hard when dry; few, slightly weathered gravels.

86–1 A1p 0–10 cm Black (10YR2/1) when moist; HC; common, faint iron mottles; medium humus content; weak, medium blocky; wide fissure; no stones.

86–2 B2 10–30 cm Black (10YR2/1)

when moist; HC; no mottles; low humus content; no stones.

86–3 B3 30–60 cm Black (2.5Y3/1) when moist; HC; low humus content; no stones.

Remarks: Soil No. 86 was sampled by auger on Dec. 24, 1980, when rainwater had soaked and slaked the surface soil to some extent. Farmers said that coarse cracks develop deeper than 50 cm during the dry season. Other soils were sampled on Nov. 18, 1980, before the onset of the rain.

As described above, the soil color changes gradually from brownish gray to black along the undulation. Soil texture also varies from LiC to HC. Clay content changes from 37 to 60%. When observed with a magnifier, the soil clod of 23–1 appears of silty fabric, while that of 26–1 appears of waxy fabric. Silty fabric shows a pulverulent matrix and mottlings with diffuse boundaries which fade into the matrix. The waxy fabric shows a translucent lustre like that of a porcelain and mottlings with distinct boundaries. The soil reaction ranges from acidic to weakly acidic. No soils contain free lime concretions. The sand fraction, when observed under the microscope, appears cleaner than that of volcanic soils. The dominant primary mineral is plagioclase, while alkali feldspar (ca. 2 to 5%) and heavy minerals like augite (ca. 2%) and hornblendes (ca. 2%) are also present in all samples. The fine sand fraction (20 to 50 μm) contains abundant plant opal grains and a few zircon grains in all samples, and their quartz content is almost constant. Thus, the data on primary minerals seem to indicate the lithological similarity of the catena on the volcanic terrace.

On the other hand, the clay fraction gradually changes in composition from Nos. 23 to 26 (Fig. 5). Although kaolin and montmorillonite of low crystallinity are present in equal amounts in No. 23, montmorillonite clay increases in content and crystallinity successively toward No. 26.

Since soil No. 86 is located in the low-lying coastal backswamp, it is high in exchangeable sodium as well as calcium and magnesium. Its pH is alkaline, and the subsoil contains free salts. The clay fraction is composed exclusively of montmorillonite of high crystallinity.

3. *Soils on Limestone Hills*

Rendzina soils formed on limestone hills are described below. The location is illustrated in Fig. 2. The soils were sampled in stone-walled gardens as described in tract 12. Soil No. 88 was sampled on rolling col, and No. 89 on the steep slope above.

88–1 A1p 0–20 cm Black (10YR2/1) when dry; HC; medium humus content; strong fine granular; very friable, and hard on drying; abundant, subangular pebbles of white siltstone and limestone; effervescent with HCl.

This horizon is underlain by pebbles and cobbles.

89–1 A1p 0–10 cm Black (10YR2/1) when dry; HC; medium humus content; strong fine granular; very friable, and very hard on drying; dominant amount of angular and platy

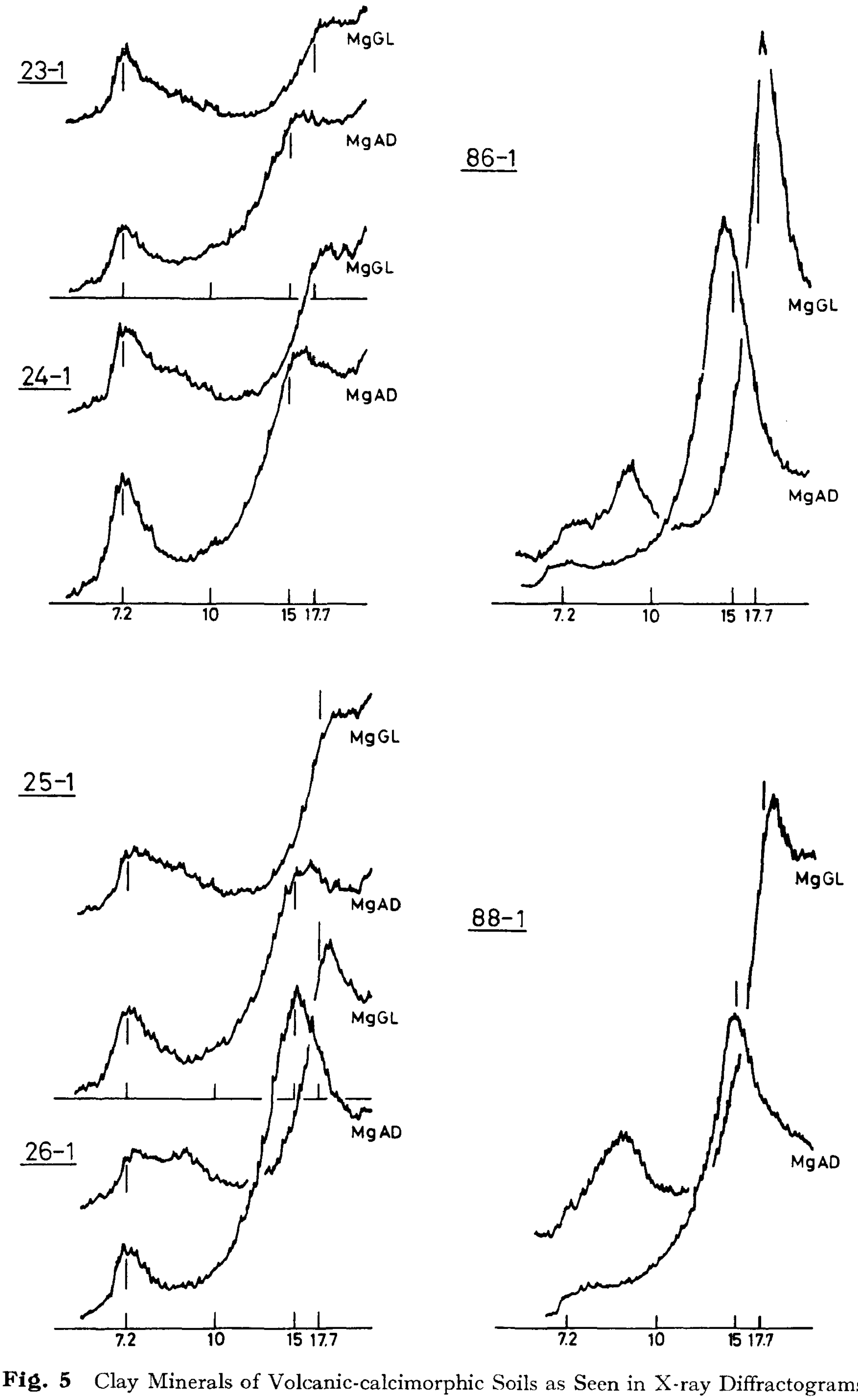


Fig. 5 Clay Minerals of Volcanic-calcimorphic Soils as Seen in X-ray Diffractograms (See the explanation for Fig. 4.)

limestone pebbles (matrix color 10YR8/1); effervescent with HCl.

The soil material is irregularly mixed with stones and does not form a regular horizon.

Analysis of No. 88 shows a very high clay content, composed exclusively of montmorillonite (Fig. 5).

The rocks of limestone hills are of various types. While some are composed purely of calcite, some are only partly calcareous and others are non-calcareous. The soil material is finely mixed with calcite particles. This environment is favorable for the formation of montmorillonite and the prevention of its degradation.

III Discussion

The huge amount of calcium which is released from plagioclase-rich eruptive through weathering processes is fixed by coral and other biomes which make reefs around the islands. Uplifted coral reefs have an important effect on the direction of neoformation of clay particles on the ground surface. Montmorillonite in rendzina soil is probably a new formation on the Ca-saturated environments, although partly it may inherit from deposits themselves. On the other hand kaolin minerals are formed in latosols on leached eruptiva.

It is questionable, however, whether the montmorillonite in the grumusols resting on the level volcanic terrace is a neoformation. It is not consistent with the observed facts to suppose the high clay content of No. 26, which is 20% more than that of No. 23 and 40% more than that of No. 21, is caused by weathering *in situ*. The sand grains are clean-surfaced and not altered to sand pseudomorphs. Readily weatherable minerals also remain.

A more probable origin is through transport. Three interpretations are possible. One is a differential mass flow under terrestrial conditions. The montmorillonite clay particles are usually finer than those of kaolin minerals. Finer montmorillonite particles, when washed out from the soil cover or weathering crust on the volcanic fans, will be differentially transported greater distances than the larger kaolin particles. This consideration, thus, assumes an avalanche of montmorillonite particles moving down the volcanic fan slopes, resulting in their progressive build-up at lower sites.

A second interpretation is fluvial transport, by which the finer montmorillonite particles are differentially deposited on the coastal backswamp under lagoonal conditions. The grumusol represented by soil No. 86 on the backswamp is considered to have formed in this way. After emerging above the water level, the deposits were flushed by surface runoff resulting in the leaching of sodium from the upper horizons, accumulated some humus, and were transformed into a grumusol. The high content of exchangeable calcium is also noteworthy. It is probably attributable to capillary rise from the basement rocks, since the soil contains no lime nodules. It is reasonable to suppose that the coral limestone, which outcrops in the sand dunes, extends under the grumusol, since this is a common phenomenon in the tidal flats of South Sulawesi other than Luwu.

This interpretation involves, therefore, the assumption that the level volcanic terrace was formerly a coral-bearing tidal flat underlain by pyroclastic flow. These tidal flat deposits were uplifted and transformed into the grumusol. This interpretation, however, has the drawback that the period needed for the uplift, even in a tectonically very active area, would be over 10,000 years, and it is not certain if the grumusol could retain its form for this long period.

The third and most probable interpretation is intermediate between the former two. It is that the montmorillonite avalanche fell onto the coral-bearing tidal flat which had been already uplifted. The soil leaching would be counter-balanced by the uprise of calcium-rich capillary water, which works to retain the montmorillonite clay. It is also consistent with the gradational processes working on the volcanic fans and volcanic terrace.

This process, if the assumption is correct, may be called a latent calcimorphism coupled with differential mass flow. It is different from the explicit calcimorphism that operates in limestone hills, and results in the formation of rendzina soils.

References

Berlage, H. P. 1949. *Regenval in Indonesie.* Verhandelingen Koninklijk Magnetisch en Meteorologisch Obervatorium No. 37. Batavia.

Furukawa, H. 1982. Rice Culture in South Sulawesi. In *Villages and the Agricultural Landscape in South Sulawesi*, edited by Mattulada and N. Maeda, pp. 29–72. Kyoto: The Center for Southeast Asian Studies, Kyoto Univ.

Mohr, E. C. J. 1933–38. *De Bodem der Tropen in het Algemeen, en die van Nederlandsch-Indië in het Bijzonder.* Koninklijk Vereeniging Koloniaal Instituut, Amsterdam. Mededeeling 31. Translated by Pendleton, R. L. 1944. *The Soils of Equatorial Regions with Special Reference to the Netherlands East Indies.* Part II. Washington, D. C.

Soepraptohardjo, M.; Soekirno, D.; Hardjono, A. S.; Junus Dai; and Murdani, compiled. 1968. Reconnaissance Soil Map, Province South Sulawesi, Scale 1 : 500,000. Bogor: Soil Research Institute.