Some Soils and Surficial Deposits in the Kokoda Valley, Papua and New Guinea[1]

C. F. PAIN[2]

ABSTRACT: The upper two of a series of four fan surfaces in the Kokoda Valley, Papua and New Guinea, are covered with volcanic ash. Soils on these two surfaces have fine-grained textures and well-developed structural characteristics. The plasma of these soils is isotropic in thin section. Differences in color and in the kinds of clay minerals present in these two soils are attributed to the drainage conditions of the underlying material.

The lower two of the four fan surfaces have soils developed mainly from alluvium. Some soil profiles on the older of these two surfaces are partially derived from reworked volcanic ash. The alluvial soils are coarser grained and shallower than the volcanic ash soils. The plasma of the alluvial soils exhibits increasing birefringence with decreasing amounts of volcanic ash.

The soil pattern proved useful in interpreting aspects of the geomorphic history of the study area.

THE YODDA-KOKODA FAULT TROUGH, in the Northern District of Papua and New Guinea, contains a number of depositional surfaces, some of which are covered by volcanic ash. The fault trough lies at about 400 m above sea level. It is bounded on the southwest by a sharply defined fault scarp that borders the Owen Stanley Ranges and on the northeast by the Ajule Kajale Range. The Mambare River and its tributaries drain the fault trough (Fig. 1).

In this area the Owen Stanley Ranges are composed of Owen Stanley Metamorphics, which are highly altered schists and gneisses (Paterson, 1964). The Ajule Kajale Range consists of gabbro and dolerite intrusions called the Ajule Kajale Complex (Paterson, 1964).

Kokoda falls into Köppen's tropical rain forest climatic type (Slayter, 1964). It has an average annual rainfall of 3,620 mm, most of which falls in the December to March period. No month has less than 100 mm. Temperatures range from about 18° to 30° C. According to Slayter (1964) Kokoda rarely experiences a growing season of less than 12 months. Soil formation under these conditions is likely to be a continuous process.

Vegetation in the Kokoda fault trough consists mainly of regrowth rain forest. Taylor (1964) noted that forests with *Syzygium* sp.-*Flindersia* spp. associations occur on higher terraces, and flood plains have regrowth stages of *Pometia pinnata-Alstonia scholaris-Octomeles sumatrana* rain forest. These regrowth forests —dense masses of trees reaching up to 20 m—indicate the importance of native gardening. The area studied in detail was almost certainly cleared from forests such as these. At present, however, the area around the Kokoda Sub-district Headquarters consists of rubber plantations and pasture grasses, with minor native gardening and some regrowth forest. It is unlikely that this recently introduced land use has had any marked effect on soil morphology.

About 38 km^2 of depositional surfaces surrounding the Kokoda Sub-district Headquarters and west of it were chosen, and the soils and surficial deposits studied in detail. This paper describes the results of the study, and considers some relationships between the soils and the nature and origin of the surficial deposits.

---

[1] Manuscript received 13 November 1971.

[2] The Australian National University, Research School of Pacific Studies, Department of Biogeography and Geomorphology, P.O. Box 4, Canberra, A.C.T. 2600, Australia.

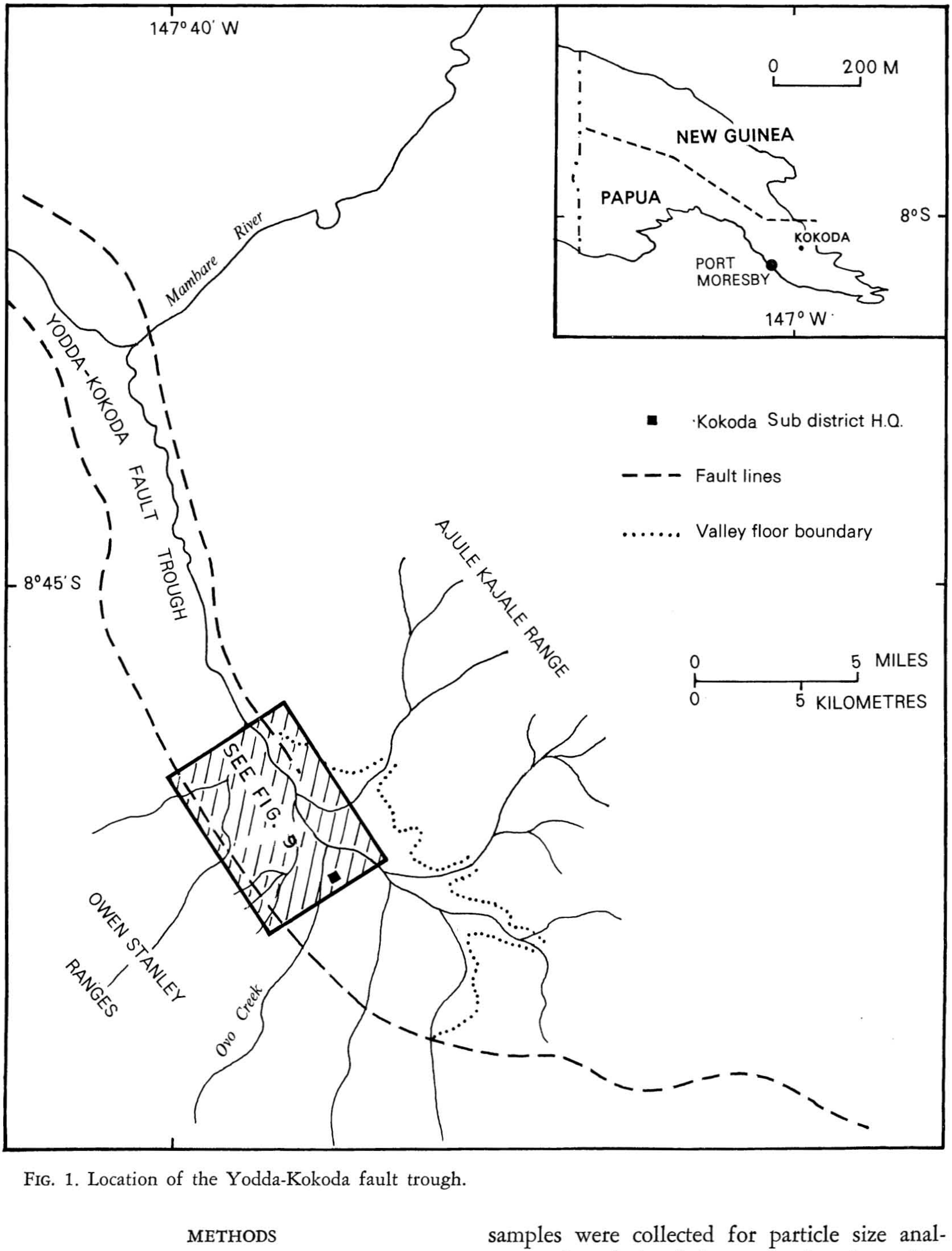

FIG. 1. Location of the Yodda-Kokoda fault trough.

METHODS

The soils were studied in detail in the field along road cuttings, artificial drains, the scarps between surfaces, stream banks, and pits. Bulk samples were collected for particle size analyses and analysis of the sand mineralogy. Undisturbed samples were collected for preparation of thin sections.

Dr. R. L. Parfitt, University of Papua and

New Guinea, collected samples of the Savaia and Mamba soils and analyzed them for clay mineralogy.

Particle size analyses were carried out by Professor D. P. Drover, University of Papua and New Guinea. The sand fraction was studied under a polarizing microscope. Thin sections of the undisturbed samples were prepared using the method outlined by Dalrymple (1957).

LAND SURFACE FORM

The Kokoda Valley has a complex history of aggradation and degradation. Deposits on the southwestern side of the valley have come from the Owen Stanley Ranges, whereas very small amounts of basic volcanic rocks from the Ajule Kajale Range are found in terrace deposits on the northeastern side. Because of this inequality of debris supply the Mambare River has been confined to the northeastern side of the valley since the formation of a large fan just northwest of the Kokoda Sub-district Headquarters.

The depositional surfaces in the study area are largely the result of aggradation of deposits from the Owen Stanley Ranges and the subsequent degradation of the Mambare River and tributaries to their present level. The large fan debouching from the Ovo Creek onto the floor of the valley dominates the depositional landforms of the study area (Fig. 2). Four surfaces are distinguished on the fan, and are named from oldest to youngest: Savaia, Mamba, Komo, and Faiawani. The fan is truncated by the Mambare River and its tributary, Fala Creek. The Savaia and Mamba surfaces are incised by streams flowing down the fan slope toward Fala Creek. The Komo surface is undulating with occasional large boulders and prior fan distributaries. The Faiawani surface consists of floodplains and floodplain steps.

SURFICIAL DEPOSITS

The deposits under the four surfaces are varied. Highly weathered coarse boulders and gravels of Owen Stanley Metamorphics underlie the Savaia surface. Even the largest boulders are strongly weathered and no core stones were found. Gravels underlying the Mamba surface are more varied, the lower ones being highly weathered and similar to the Savaia gravels. Above these weathered gravels occur virtually unweathered gravels through which flows a considerable amount of groundwater. This groundwater emerges and supplies streams along the base of the scarp between the Mamba and Komo surfaces. Both the Savaia and Mamba surfaces are covered by dacitic volcanic ash from Mount Lamington (Ruxton, 1966), over 2 m occurring on the Savaia surface and 1 m on the Mamba surface.

Deposits underlying the Komo surface vary from large unweathered boulders to alluvial silt and sand. At some sites on this surface boulders occur on the surface. At about 2 m below the surface the amount of sand and silt in relation to gravels falls sharply. Soil micromorphological evidence suggests that volcanic ash is mixed with the alluvium in the upper horizons of the Komo soil (see below).

The Faiawani surface, or complex of surfaces, is underlain by extremely varied sediments ranging from fresh coarse gravels and sands to weakly weathered sands and silts overlying fresh gravels.

Figure 3 illustrates the stratigraphic relationships between the various bodies of fan deposits and overlying volcanic ash. The relationships between the Savaia and Mamba surfaces and the Mamba and Komo surfaces are clear and represent downcutting with an alluvial cap, and downcutting and subsequent filling, respectively. The relationships between the Komo and Faiawani surfaces are not so clear. The field evidence is not sufficiently detailed to suggest either downcutting only, or downcutting and subsequent filling.

Table 1 summarizes the events that have led to the present distribution of surficial deposits and soil parent materials.

SOILS

Soils on the depositional surfaces fall into four types corresponding to the depositional surfaces delimited above. For convenience the soils are named after the surface on which they occur.

Soils on the Savaia and Mamba surfaces belong to the Higatura family of Haantjens

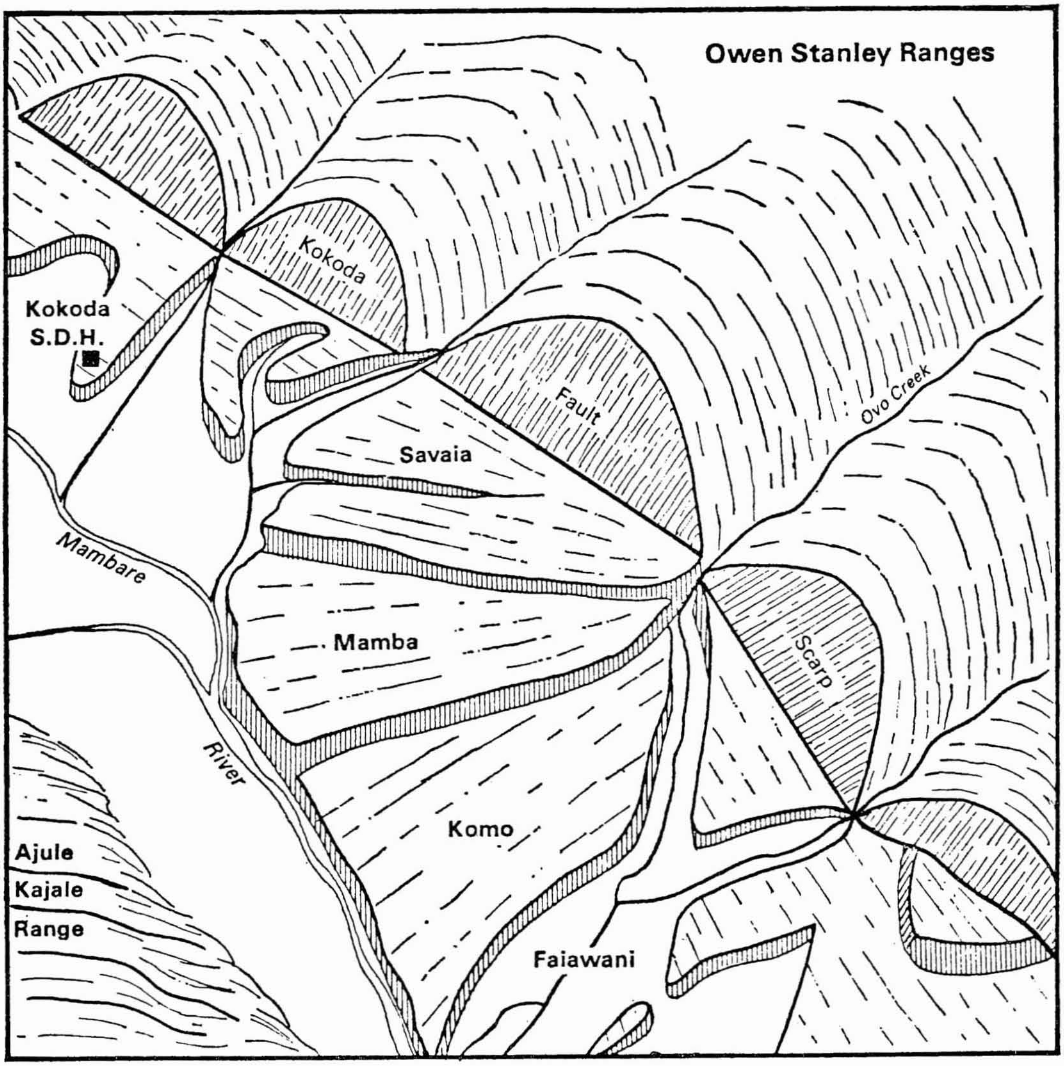

FIG. 2. The Kokoda Valley, showing the fan debouching from the valley of the Ovo Creek and the position of the four surfaces on the fan.

(1964); they are moderately weathered brown volcanic ash soils. The Mamba soils are similar to the Andosols described by Haantjens et al. (1967). The Savaia soils are more highly weathered and are perhaps transitional between the Andosols and Lateritic Andosols of Haantjens et al. (1967). Komo and Faiawani soils are classified as alluvial soils by Haantjens (1964). Table 1 gives the relative duration of pedogenesis for the four soil types while Table 2 gives representative profiles.

The isotropic nature of the Savaia and Mamba soils in thin section is important. All known volcanic ash soils in the Kokoda Valley that were sampled for thin sections exhibited isotropic plasmas, whereas all soils sampled from other known parent materials (e.g., Owen Stanley Metamorphics) were birefringent in thin section (Pain, 1971). On this basis the whole Savaia soil profile is formed from volcanic ash, whereas only the upper 1 m of the Mamba soil is formed from ash. Content of clay-sized material supports this, with much higher clay content in the lower horizons of

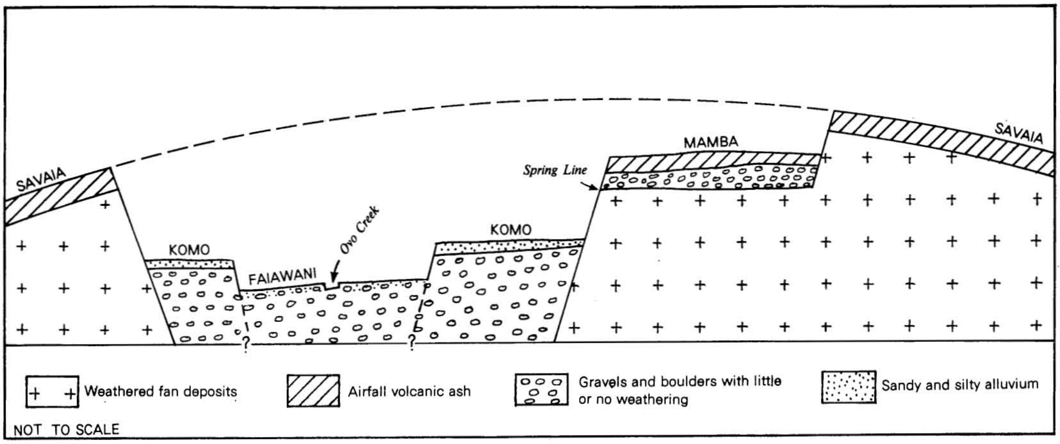

FIG. 3. Diagrammatic cross section of the Ovo Fan showing the relationships between the various bodies of alluvium and volcanic ash.

the Savaia soil than at equivalent depths in the Mamba soil (Fig. 4). The values shown in Fig. 4 were checked by observation of the sand-sized material under a microscope. The values for the Savaia uB and uC horizons would appear to be low, since a high percentage (> 50 percent) of the sand-sized particles left after dispersion were aggregates of smaller particles, probably clay. The sand fraction of the Mamba C horizon had very few clay aggregates, these consisting largely of quartz (> 50 percent), indicating an origin in the Owen Stanley Metamorphics.

The macromorphology of the Savaia and Mamba soils is also different. The Savaia soil is much lighter in color and has a coarser structured A horizon than the Mamba soil (Table 2, Fig. 5 and 6). The Mamba soil is more friable than the Savaia soil, the latter being slightly cemented in its upper horizons.

Clay mineral differences are also present. Dr. Parfitt found that the clay mineral assemblage of the Savaia soil is dominated by hydrated halloysite, whereas that of the Mamba soil is dominated by imogolite and allophane.

The lower two horizons of the Savaia repre-

TABLE 1

RELATIVE CHRONOLOGY FOR THE OVO FAN

EVENTS	SOILS			
1. Building of fan to Savaia alluvial surface*	?			
2. Deposition of airfall volcanic ash				
3. Hiatus in ash deposition	Savaia buried soil			
4. Degradation of fan to Mamba alluvial surface	↓			
5. Deposition of airfall volcanic ash on Savaia buried soil and Mamba alluvial cap	Savaia soil	Mamba soil		
6. Degradation of Mamba surface				
7. Aggradation, with formation of Komo surface during last stages of ash deposition (event 5)			Komo soil	
8. Formation of Faiawani surface				Faiawani soil
	↓	↓	↓	↓

* The 2-m accumulation of volcanic ash on the Savaia alluvial surface may indicate an age between 30,000 and 50,000 years B.P. for that surface (B. P. Ruxton, personal communication). This estimate is based on rates of ash accumulation on the Hydrographers Range, southeast of Mount Lamington.

TABLE 2

REPRESENTATIVE SOIL PROFILES

HORIZON*	THICKNESS (cm)	FIELD DESCRIPTION	MICROMORPHOLOGY†
Savaia			
A_1	15	silty clay; 2.5 YR 2/4; hard; moderately developed medium blocky structure; organic staining of peds and many roots; few, fine interstitular pores; diffuse boundary	glaebular (discrete sesquioxide accumulations) vughy, isotic fabric
A_3	17	silty clay; 10 YR 2/4; hard to slightly friable; well-developed medium blocky structures; organic staining; many fine interstitular pores; sharp boundary	glaebular (grouped sesquioxidic nodules) isotic fabric
B_1	26	clay; 5 YR 3/4; friable to sticky; massive; few tubular many vesicular pores; sharp boundary	cutanic (argillans) planey isotic fabric
B_2	34	clay; 5 YR 4/8; slightly friable; weakly developed medium blocks; few discontinuous cutans on ped faces; fine tubular pores; sharp boundary	cutanic (vugh, channel, and plane argillans) vugh/plane isotic fabric
uA? uB	46	silty clay; 7.5 YR 5/8; friable; weakly developed medium blocks; root channels; worm casts up to 1 cm diameter; fine to medium tubular pores; sharp boundary	cutanic (vugh and plane argillans) vugay isotic fabric
uC	40+	clay; 5 YR 4/8; friable; massive; many fine vesicular pores	glaebular/cutanic (sesquioxidic/argillans) vugh/plane isotic fabric
Mamba			
A_1	38	silty clay; 5 YR 3/2; friable to sticky; well-developed fine blocky structure; strong organic staining; many fine, interstitular pores; sharp boundary	glaebular (sesquioxidic) planey isotic fabric
B_{21}	40	silty clay; 5 YR 4/4; loose to friable; weakly developed medium blocky structures; few fine vesicular pores; sharp boundary	vughy isotic fabric with rare sesquioxidic glaebules
B_{22}	50	silty sand; 7.5 YR 4/4; hard; massive; some root channels; few fine tubular pores; sharp boundary	glaebular (sesquioxidic/argillanic), isotic fabric with small areas (20%) argillasepic fabric in lower 30 cm
C	80	clayey silt; 10 YR 5/6; friable; no aggregation; few, fine interstitular pores; diffuse boundary	vughy (isotubules) argillasepic fabric
on	40+	fresh gravels in a sand matrix	not sampled
Komo			
A_1	37	silty clay; 10 YR 3/2; friable well-developed fine blocky structure; many fine interstitular pores; sharp boundary	(*a*)‡ vughy, grainy, argillasepic fabric with sesquans (*b*) vughy, grainy isotic fabric

TABLE 2 (*Continued*)

HORIZON*	THICKNESS (cm)	FIELD DESCRIPTION	MICROMORPHOLOGY†
B_1	35	silty sand with stones; 10 YR 4/3; friable; coarse blocky structure with some prisms; few, medium interstitular pores; sharp boundary	(*a*) vughy, planar, grainy argillasepic fabric (*b*) glaebular (sesquioxidic) vughy argillasepic fabric
on	40+	coarse, fresh gravels in a fine sandy matrix	not sampled
Faiawani			
A_1	17	sandy silt; 10 YR 4/4; very friable; weakly developed medium blocky structure; worm casts; many fine interstitular pores; sharp boundary	vughy argillasepic fabric with rare sesquans
B_1	77	silty sand; 2.5 YR 5/6; friable; structureless; many fine interstitular pores; sharp boundary	vughy argillasepic fabric with common sesquioxide nodules
on	67+	coarse gravels in a sand matrix; some iron staining	not sampled

*Nomenclature after Taylor and Pohlen (1962) in all profile descriptions.

†Brewer (1964) defines the terms "plasma" and "vugh" as follows: *Plasma,* "that part [of a soil material] which is capable of being or has been moved, reorganised and/or concentrated by the processes of soil formation" (p. 12); *Vughs* "are relatively large voids, other than packing voids, usually irregular and not normally interconnected with other voids of comparable size" (p. 189). Other micromorphological terms used in this table and in the text are also taken from Brewer (1964), to whom the reader is referred.

‡(*a*) and (*b*) refer to two separate profiles, indistinguishable in the field, but showing differences in thin section.

sentative profile contain the only buried soil positively identified in the Kokoda Valley. This soil was recognized on the following bases:

1. Root channels and worm casts were found at some depth below the apparent level of present macrobiological activity.
2. Thin sections of the soil confirmed the presence of fossil root channels. In the upper three horizons root channels containing live roots were found, but in the uB horizon those few channels positively identified as root channels contained dead root fragments.
3. In thin section the B_2 horizon exhibited a system of inter- and intra-pedal planes with clay-sized material coating the walls (argillans, Brewer, 1964). All those observed in this horizon contained voids between the argillans. In the uB horizon there were two sets of planes, the first similar to that in horizon B_2, and the second completely filled with clay-sized material. The first system was imposed on the second, suggesting that the two systems represent two separate periods of soil formation.

Komo and Faiawani soils consist of two horizons formed in alluvial sand, silt, and clay, overlying gravels (Table 2). Komo soils show the development of a structural B horizon (Fig. 7), and in thin section they show some pedological alteration. Some profiles studied in thin section exhibited an isotropic plasma, indicating the presence of volcanic ash in the soil, whereas others were birefringent, indicating the absence of volcanic ash. The areal extent of the ash-derived soils was not discovered since the two soils are indistinguishable in the field. Komo soils are thus derived from imperfectly mixed volcanic ash and metamorphic alluvium overlying virtually unweathered gravels.

Faiawani soils are immature alluvial soils with melanization and weakly developed blocky aggregates in the top 15–20 cm (Table 2, Fig. 8).

DISCUSSION

The results of this study indicate that there are differences among the soils on the four surfaces that are not related solely to age, but are also related to the nature of the deposits from which they are formed. Thus Komo and Faiawani soils are alluvial soils with different

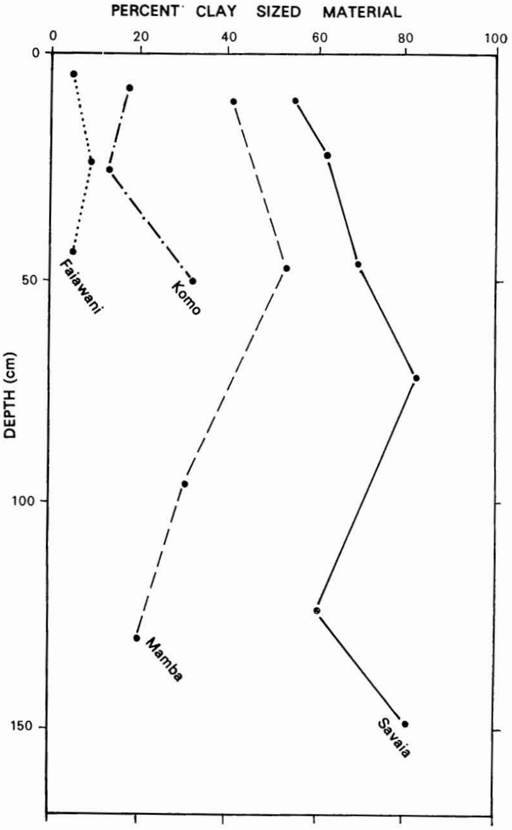

FIG. 4. Percentage clay-sized material with depth for the four soil types.

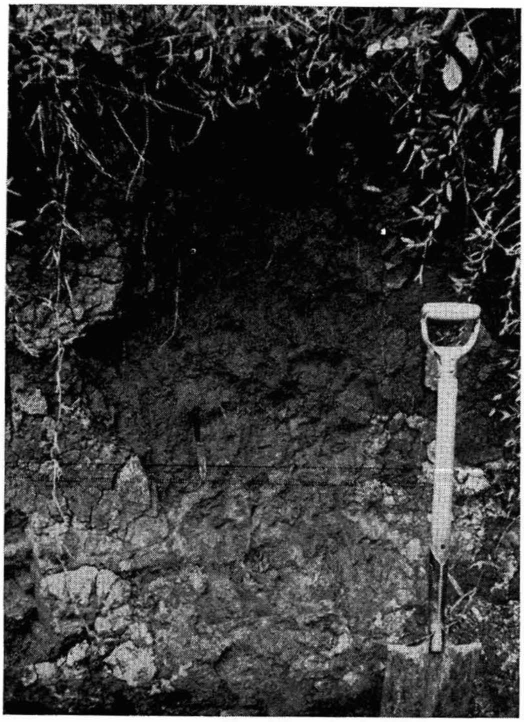

FIG. 5. A Savaia soil profile. The light colors and blocky structure of the A horizons are apparent. The buried soil occurs at the bottom of the knife blade.

degrees of pedological organization which are the result of two factors.

1. The Komo surface is older than the Faiawani surface, since it is higher above the stream than the Faiawani surface, and is not subjected to flooding and present-day deposition, as is the latter. The stronger development of structures in the Komo soil could be related to this difference in age.
2. Micromorphological evidence indicates that some Komo soil profiles contain volcanic ash in varying quantities. Some of the differences between the Faiawani and Komo soils could be the result of this variation in parent material.

FIG. 6. A Mamba soil profile. The A horizon has a dark color and fine subangular blocky structures. The lighter colored B horizons tend to be loose.

FIG. 7. A Komo soil profile. Here a moderately developed alluvial soil lies on rounded boulders, shown at the bottom of the photograph.

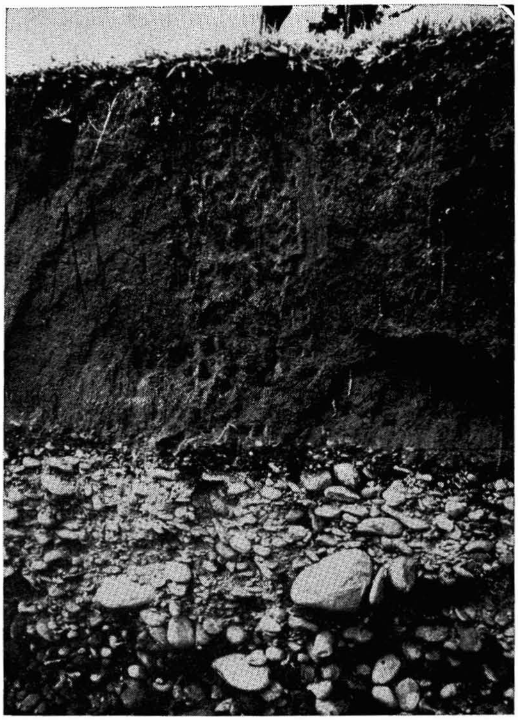

FIG. 8. A Faiawani soil profile. Note the slightly darker A horizon due to melanization of the mineral material, and the structureless B horizon overlying fresh gravels.

Savaia and Mamba soils differ from Komo and Faiawani soils mainly as a result of the differing parent materials, volcanic ash, and alluvium, respectively. However, Savaia and Mamba soils can also be contrasted, particularly in color, structure, and clay mineralogy (see above). These differences are puzzling, since the upper 1 m of both soils must be derived from the same volcanic ash. This ash overlies alluvium on the Mamba surface and older ash with a paleosol on the Savaia surface. The reason probably lies in the resulting differences in drainage conditions of the two soils. The Savaia soil is subject to a great deal of wetting and drying, and the water table is usually more than 5 m below the surface. In contrast to this, the Mamba soil is not subject to severe variations in water content and the presence of an aquifer 2 m below the surface keeps the water table at a constant level high in the soil. These different drainage conditions may be responsible for the soil differences noted, but the factors involved are by no means clear.

Another aspect of the relationship between soils and surficial deposits at Kokoda is the way in which soil data may be used to interpret aspects of the geomorphology of the valley. First, the soil differences noted allow correlation of the fan surfaces with nearby (but not contiguous) terrace, fan, and floodplain surfaces (Fig. 9). Second, the contribution of soil data to Table 1 should be noted.

1. The buried soil in the Savaia profile indicates the presence of a hiatus in the deposition of the volcanic ash (event 3). This buried soil also leads to the conclusion that degradation of the fan to the Mamba alluvial surface (event 4) took place toward the end of the hiatus, shortly before the second period of ash deposition (event 5). The absence of a buried soil in the Mamba profile and the similarity between the thickness of the Mamba profile above the alluvium and the Savaia profile above the buried soil are evidence of this.
2. The recognition of volcanic ash in the Komo profile allows the interpretation that ash

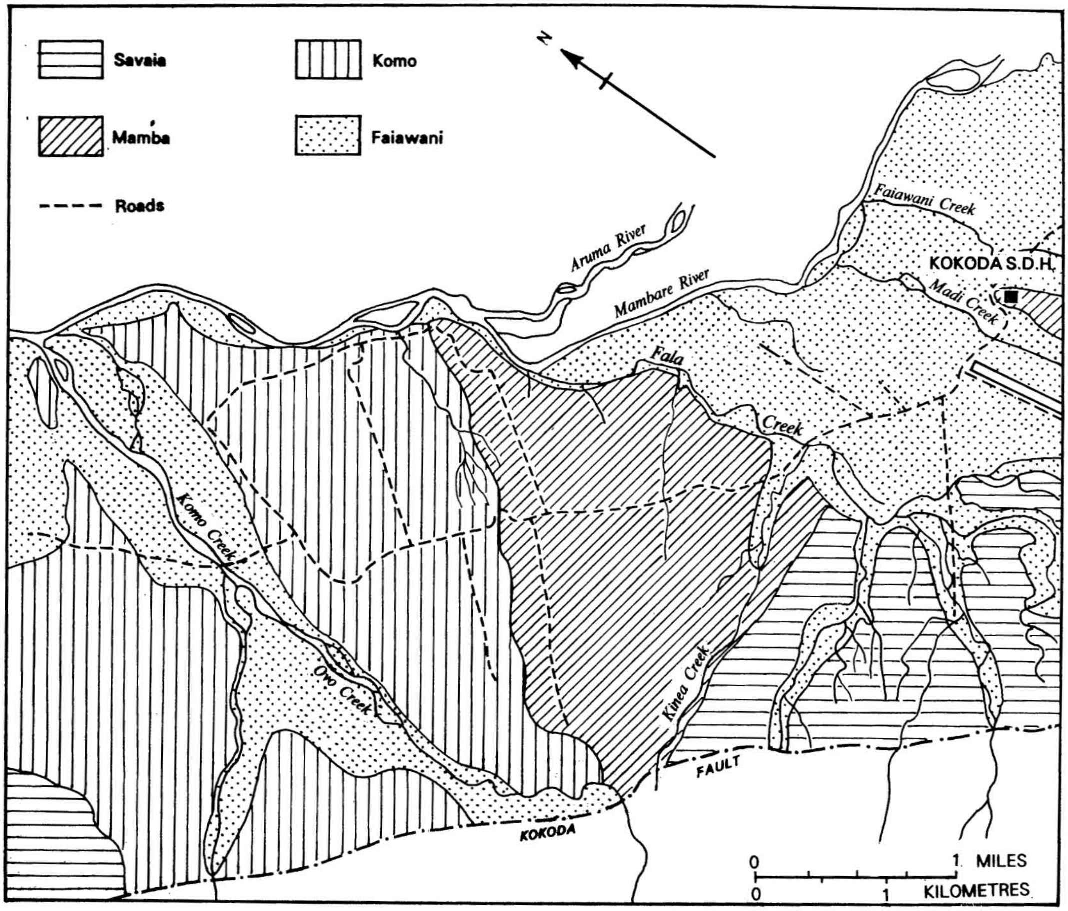

FIG. 9. Areal relationship between the four surfaces in the Kokoda Valley.

was still being deposited during the formation of the Komo surface (event 7). Ash would not only be falling on the fan surface but also in the headwaters of the Ovo Creek, and the ash present in the Komo alluvium is probably rewashed rather than airfall ash. Ash deposition was probably contemporaneous with, but did not go on after, the Komo stage of aggradation

This study indicates that the relationship between soils and surficial deposits in the Kokoda Valley are complex and not easily understood. However, the study has produced useful information, not only on the nature of these relationships, but also on the potential use of soils data to distinguish between different surficial deposits and to contribute to the study of geomorphic events.

ACKNOWLEDGMENTS

The following people assisted with the preparation of this paper: Professor D. P. Drover, University of Papua and New Guinea, carried out the particle size analyses; Dr. R. L. Parfitt, U.P.N.G., carried out clay mineral analyses and gave helpful comments on the soils; Dr. M. J. F. Brown, U.P.N.G., gave assistance and discussion in the field; and Mr. J. N. Jennings and Dr. J. M. Bowler, the Australian National University, gave helpful criticism and advice during the preparation of the manuscript.

Fieldwork was carried out with the assistance of a grant from the University of Papua and New Guinea.

LITERATURE CITED

BREWER, R. 1964. Fabric and mineral analysis of soils. John Wiley and Sons, New York. 470 p.

DALYRYMPLE, J. B. 1957. Preparation of thin sections of soils. J. Soil Sci. **8**:161–165.

HAANTJENS, H. A. 1964. Soils of the Buna-Kokoda area. CSIRO Land Res. Ser. 10:69–88.

HAANTJENS, H. A., J. J. REYNDERS, W. L. P. J. MOUTHAN, and F. A. VAN BAREN. 1967. Major soil groups of New Guinea and their distribution. Dep. Agr. Res., Koninkl. Inst. Voor Tropen, Commun. 55. 87 p., 2 maps.

PAIN, C. F. 1971. Micromorphology of soils developed from volcanic ash and river alluvium in the Kokoda Valley, Northern District, Papua. J. Soil Sci. **22**(2):275–280.

PATERSON, S. J. 1964. Geology of the Buna-Kokoda area. CSIRO Land Res. Ser. 10:54–61.

RUXTON, B. P. 1966. Correlation and stratigraphy of dacitic ash-fall layers in northeastern Papua. J. Geol. Soc. Aust. 13(1):41–67.

SLAYTER, R. O. 1964. Climate of the Buna-Kokoda area. CSIRO Land Res. Ser. 10:45–53.

TAYLOR, B. W. 1964. Vegetation of the Buna-Kokoda area. CSIRO Land Res. Ser. 10:89–98.

TAYLOR, N. H., and I. J. POHLEN. 1962. Soil survey method. Bull. N.Z. Soil Bur. 25. 242 p.