

Quaternary volcanic ash deposits in the Padang Terap District, Kedah, Peninsular Malaysia

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Abstract: Rhyolitic ash deposits, observed locally in north-west Malaysia, are studied with regard to their nature, origin and age.

Volcanic ash layers are found scattered along the axis of the Padang Terap river, in its most upstream section. The ash was deposited there, following its widespread deposition, subsequent erosion and transport to the contemporary drainage axis of the basin. The ash does not cover the young alluvium.

The pyroclastic materials contained in the deposits are composed of glass shards of different habits, pumice fragments and distorted phenocrysts (i.e. quartz, biotite, plagioclase, sanidine and hornblende).

The chemical analyses of the glass shards show their average composition corresponds to hydrous, slight peraluminous melts of rhyolitic composition, belonging to the high-K calc-alkaline rock series.

Based on its microscopical and chemical composition, the ash is thought to originate from the Toba area, north Sumatra, and can be correlated with either a 75,000 year old or a 30,000 year old eruption. A K-Ar dating of the glass shards is in progress.

The geomorphic position of the ashes and their approximate age suggest that older important landforms in the area have formed under drier Late Pleistocene conditions.

The stage of weathering of the soils developed on rhyolitic ash, characterised by an argillic horizon, is intermediate between the weathering stage of soils on young and on old alluvium. Differences in drainage conditions are thought responsible for differences in intensity of weathering of the material.

The present study deals with the geomorphological position of the ash deposits in the Padang Terap District and the description of their microscopical and chemical properties. The characteristics of the soils developed on the ash deposits are examined and compared to those of soils developed on similar on parent material in other localities. An absolute dating with the K-Ar method is in progress. The results will be communicated in a forthcoming paper.

INTRODUCTION

The occurrence of Quaternary rhyolitic ash deposits on the Malay Peninsula has often been reported. The deposits were observed in Perak (Scrivenor, 1930; Wilbourn, 1938; Stauffer, 1970), West Pahang (Richardson, 1939; Alexander, 1968) and Selangor (Stauffer, 1971, 1973; Stauffer and Batchelor, 1978). It was postulated that these

pyroclastic rocks originated from the Toba volcano in north Sumatra and were mingled with local detrital material prior to final deposition.

Soils developed on volcano ash deposits were first described in Malaysia by Leamy and Pantan (1966) and were later mapped by Soo (1968) and Law (1968) in Perak and Pahang respectively. The detailed analysis of a soil profile developed on volcanic ash in Perak was given by Paramanathan (1977).

During the soil and geomorphological survey carried out in the Padang Terap District (De Dapper, 1981; Debaveye *et al.*, 1983) the presence of volcanic ash deposits was established in Kedah. They were found extended over 238 ha. This is so far the most northerly position of the ashes observed on the peninsula.

GEOMORPHOLOGICAL SETTING

The rhyolitic ash deposits in Kedah occur scattered on both sides of the Padang Terap river lying between latitudes $6^{\circ} 17'N$ and $6^{\circ} 21'N$ (Fig. 1). The observed thickness of the pyroclastic material is 1.2 m to more than 2 m.

The bedrock in the area consists of Mesozoic sedimentary rocks of the Middle to Upper Triassic Semanggol Formation. The later includes interbedded shales and sandstones and locally contains interbeds and lenses of conglomerate and chert.

The plain of the Padang Terap river has an elevation which ranges from 15 to 50 m above sea-level. It is divided by a great number of parallel ridges, emerging from the surrounding upland and running almost perpendicular to the main drainage axes. Hence, the plain is compartmentalized and the main rivers break through the ridges by narrow watergaps which form local temporary base levels.

A set of two river terraces (T_1 and T_2) occurs along the main river channels. T_1 is mostly cut-and-filled in T_2 -deposits. A short distance upstream the watergaps, due to the bunding effect of the latter, the younger T_1 -deposits can locally overlap the T_2 -deposits. The T_2 -terrace level belongs to a geomorphic surface that also comprises important pediments (P_2) which developed at the feet of the ridges and isolated low hills in between the ridges (Fig. 2). This geomorphic surface has been formed during drier climatic conditions than the ones prevailing at the present day (De Dapper and Debaveye, 1984).

The volcanic ashes occur on flat terrain (0–1%), on top of the T_2 -terrace and the toeslope of the P_2 -pediments. They never cover the T_1 -deposits. In the most upstream section of the Padang Terap river valley the pyroclastic material occurs at an elevation of 35 m a.s.l. and takes a position in between imperfectly to well drained old alluvial soils (T_2) and well drained young alluvial soils (T_1). In the lower section of the river valley the ashes are found at 28 m a.s.l. and are covered by poorly drained young alluvial soils (T_1) (Kg. Pisang). In the latter no soil profile development was observed. For more details on the geomorphology of the Padang Terap District one is referred to De Dapper and Debaveye (1986).

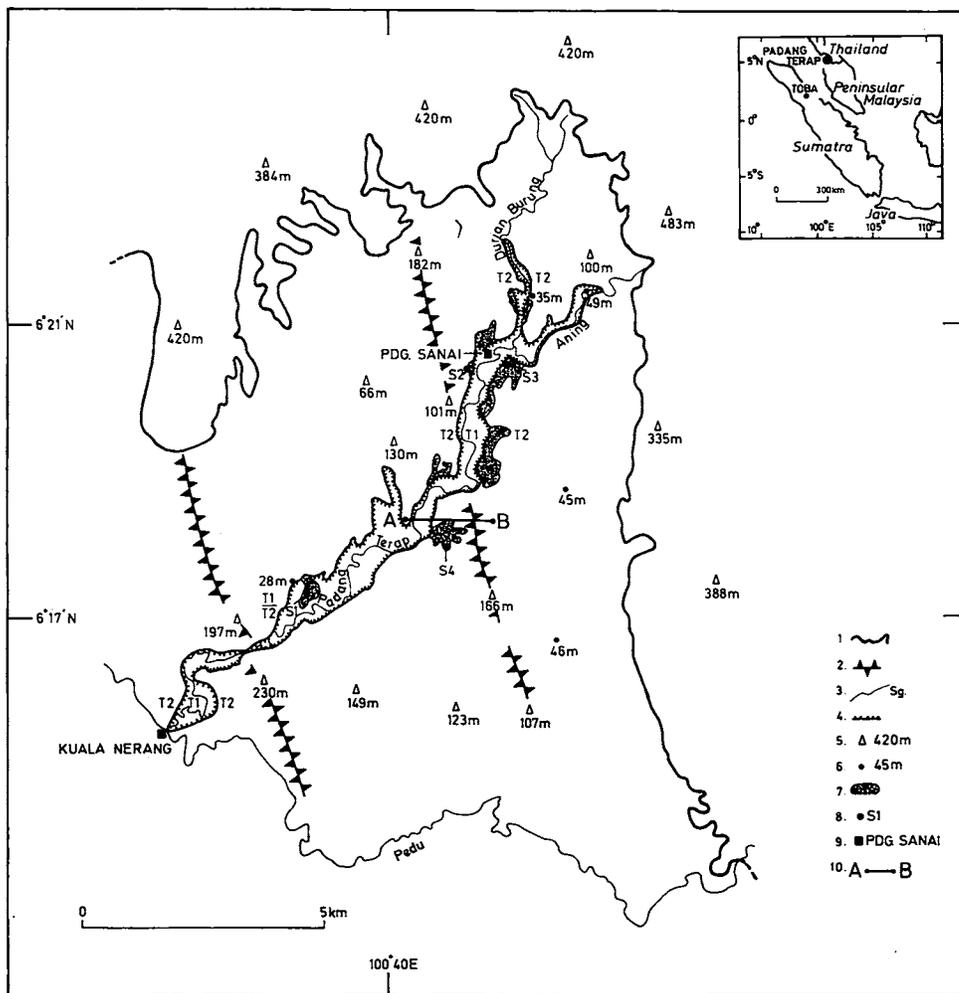


Fig. 1. Location of the Quaternary volcanic ash deposits in the Padang Terap District.
 Legend: 1. upland boundary; 2. important ridge;
 3. river; 4. rim of the T₂-terrace;
 5. hilltop; 6. elevation (m); 7. rhyolitic ash; 8. sampling location; 9. town;
 10. cross-section represented on Fig. 2.

MICROSCOPICAL AND CHEMICAL PROPERTIES

Samples coming from four localities (S1, S2, S3, S4) in the Padang Terap District (Fig. 1) were analysed with respect to the nature and the origin of the pyroclastic material they contain. As the physical and chemical properties of the latter were found not to change from one sampling locality to another it is likely that the examined rocks have a common source. For that reason only general descriptions are given below. No

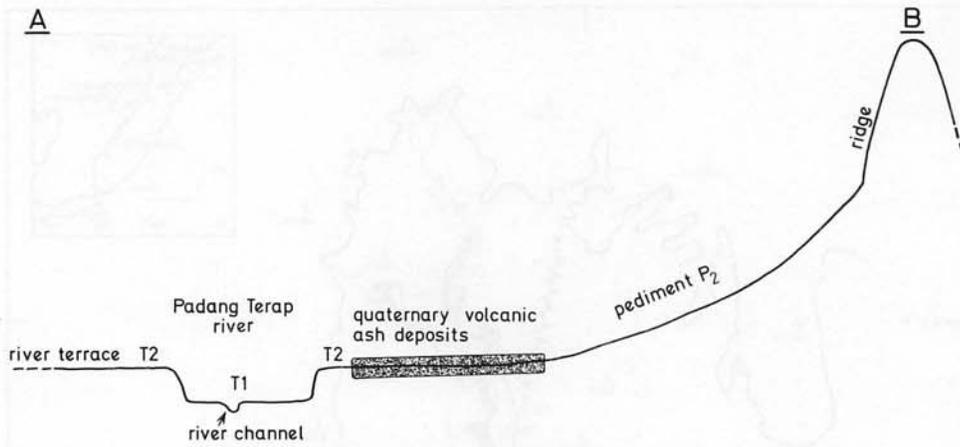


Fig. 2. Geomorphic position of the Quaternary volcanic ash deposits in the Padang Terap District. The cross-section is situated on Fig. 1.

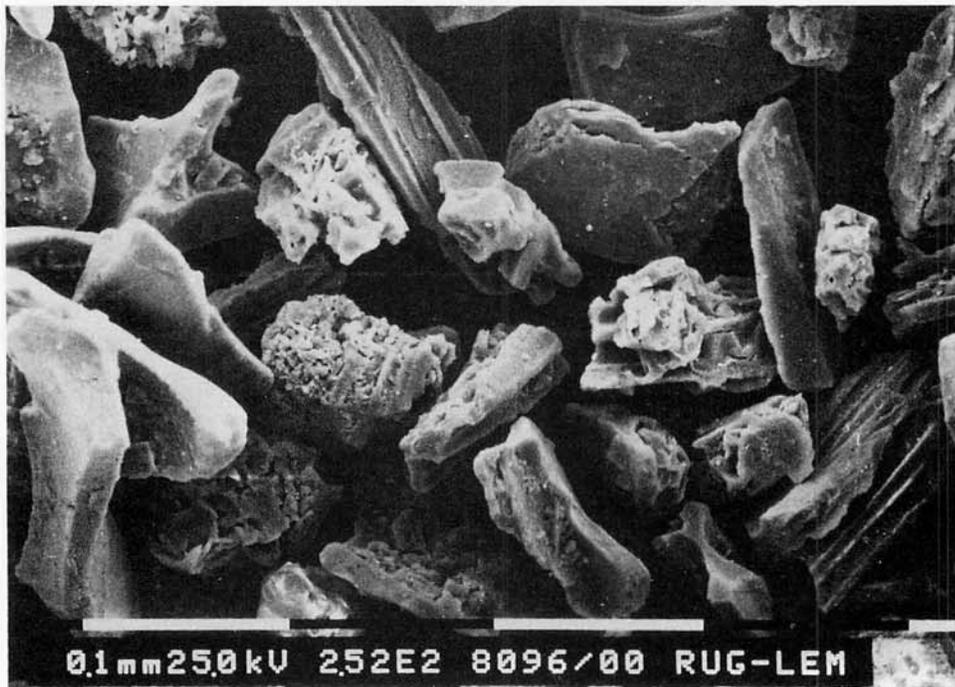


Plate 1. Scanning electron microscope photo of different types of glass shards and pumice from an ash bed at locality S4. The bars are 0.1 mm. For the location of the ash bed, see Fig. 1.

attention is paid either to the grain size distribution or the sorting of the pyroclastic deposits as reworking may have taken place before final deposition.

The pyroclastic materials are mostly of medium sand to silt in size. They are composed of glass shards, pumice fragments and broken chips of crystals. The maximum size of the shards and the crystals is approximately 1.2 mm whereas the diameter of the pumice fragments may exceed 2.0 mm.

The glass shards are by far the most common and exhibit three main habits (Plate 1). The greater part of the glass shards originated from the explosive disruption of vesiculated glass carrying numerous globular bubbles. As a result they usually consist of arcuate fragments of bubble walls. U-shaped and Y-shaped ejecta occur most, as well as tricuspidate fragments bounded by arcs of circles. As the original glass contained vesicles of different size, shape and thickness of bubble walls, there are many variations to the forms described above. Another type of shard is made up of flat, although commonly slightly curved plates. A third type is rather fibrous due to the presence of innumerable tube-like vesicles. With the exception of some pale brown fragments it appears that most glass shards are colourless in thin section. Their refractive indices range from 1.498 to 1.502.

The pumice fragments are characterized either by fine or thick cellular glassy walls. In plane-polarized light they are always colourless. The refractive indices of the glass of the pumice do not differ substantially from those recorded in the glass shards they are associated with. Both the glass shards and the pumice fragments are unaltered and occasionally include automorphic small crystals whose composition is comparable to that of the loose mineral grains.

As stated above the pyroclastic material also comprises a variable but always only a small quantity of broken or distorted microphenocrysts. In order of decreasing abundance they are composed of quartz, biotite, plagioclase, sanidine and hornblende. Biotite is by far the most common mafic mineral. It generally occurs as reddish brown tabular crystals which display a strong pelochroism suggesting a rather high TiO_2 content. Some biotite flakes contain minute prisms of zircon; others are strongly bent or frayed. The plagioclases are often twinned according to the albite law and some crystals show a well-developed normal or complex oscillatory zoning. An andesine composition is likely for at least some of them. Hornblende was only rarely observed. In thin section it is yellow to dark brown. Among the loose crystals only biotite is affected by weathering.

Chemical analyses of 22 glass shards and glassy coarse cellular pumices coming from two localities (S3, S4) were carried out on an electronprobe X-ray microanalyzer Joel Superprobe 733 at the Department of Chemistry of the University of Antwerp. Nine major elements were determined. The average chemical composition of the glasses coming from each locality as well as the corresponding CIPW norms are listed in Table 1. The oxide deficits of the analyses are considered to be close estimates of the water content. The norms were calculated with total iron expressed as FeO.

The average compositions given in Table 1 correspond obviously with those of

TABLE 1
CHEMICAL COMPOSITION AND CIPW NORMS OF GLASS SHARDS AND
PUMICES FROM THE PADANG TERAP DISTRICT

	1	2		1A	2A
SiO ₂	75.32%	75.18%	Q	36.06%	35.91%
TiO ₂	0.05	0.07	Or	28.84	29.13
Al ₂ O ₃	12.20	12.23	Ab	26.48	26.31
FeO	0.89	0.87	An	3.62	3.57
MnO	0.08	0.03	C	0.44	0.47
MgO	0.03	0.05	Hy	1.77	1.66
CaO	0.73	0.72	Il	0.09	0.13
Na ₂ O	3.13	3.11			
K ₂ O	4.88	4.93	DI	91	91
Total	97.31	97.19			

1, 1A Average of 11 fragments from locality S3-12

2, 2A Average of 11 fragments from locality S4-16

hydrous, slight peraluminous melts of rhyolitic composition. When plot on a K₂O-SiO₂ diagram, using Hutchison's (1982) boundaries between tholeiitic, calc-alkaline, high-K calc-alkaline and shoshonitic series, the glasses of the Padang Terap District fall into the high-K calc-alkaline rock field (Fig. 3). The extremely low MgO contents and the differentiation indices are moreover characteristic for highly fractionated melts.

ORIGIN OF THE ASHES

In the north-eastern part of the Indian Ocean (Malaysia, Indonesia, Thailand, etc.) important sources of extensive rhyolitic tephra of Quaternary age are rather few. One source is undoubtedly the area neighbouring the Toba caldera in northern Sumatra (Aldiss and Ghazali, 1984). Here, according to Ninkovich *et al.* (1978a) Ninkovich *et al.* (1978b) and Ninkovich (1979), a most spectacular eruption took place some 75,000 years ago and resulted in the formation of the so-called 'Toba Tuffs'. These rhyolitic ignimbrites and ashes have an estimated volume of at least 2,000 to 3,000 km³ and cover an area of over 20,000 km². According to these authors the deposits of the eruption of some 75,000 years ago are exposed not only in the north-westernmost part of Sumatra but they are also found in piston cores from the Bay of Bengal and on the Malay Peninsula. Stauffer *et al.* (1980) disagree with the hypothesis that the eruption of Toba, about 75,000 years ago, was a solitary event and present radiometric dating evidence for four or five great eruptions in the last 1.9 million years. They suggest an age of about 30,000 years for the most catastrophic eruption and show that the Malayan ash deposits may have formed at that time. Very recently, Aldiss and Ghazali (1984) gave geological evidence that the 30,000-year-old airfall tuff erupted from a centre just north of the Toba depression and called it the Sibuatan Tuff.

A second source is located near the Straits of Sunda (Ninkovich *et al.*, 1978b; Ninkovich, 1979) in southeast Sumatra. The Sunda Strait rhyolitic ash-falls are

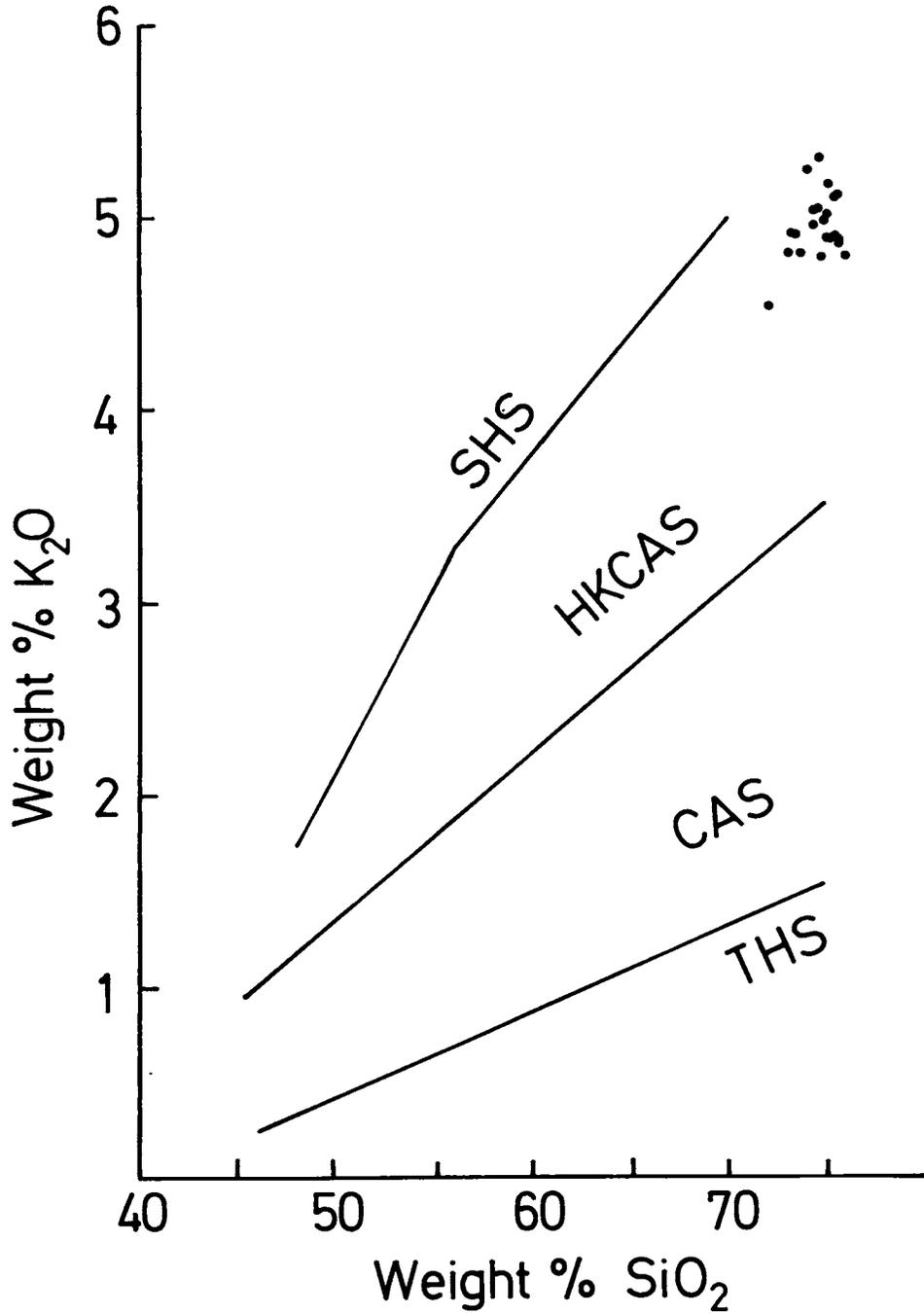


Fig. 3. Position of glasses from Padang Terap on a K₂O-SiO₂ diagram, showing the boundaries between tholeiitic (THS), calc-alkaline (CAS), high K calc-alkaline (HKCAS) and shoshonitic (SHS) series (after Hutchison, 1982).

exposed at Lampong, Pasomah and Pardang and were also recognized in deep-sea sediments dredged in the area west and southwest of Sumatra (Ninkovich, 1979). The Bantam tuffs on the western coast of Java also originate in the same area. According to Van Bemmelen (1949) the Sunda Strait tuffs and ignimbrites erupted during the Late Miocene to the Pleistocene time.

The glass shards from the Toba and Sunda Strait tephra are always colourless in thin section and have refractive indices which range from 1.496 to 1.500 (Ninkovich, 1979). Compared to the Toba ash falls the Sunda Strait tephra are richer in plagioclase phenocrysts but contain less quartz. Chemical analyses of rocks belonging to both tephra layers are given in Table 2. From these analyses Ninkovich concluded that the 75,000-year B.P. Toba glass is notably lower in SiO_2 and higher in Al_2O_3 , FeO, MgO, and CaO and $\text{K}_2\text{O}/\text{Na}_2\text{O}$ than the glass separated from the Sunda Strait ash falls. Quite recently some microprobe analyses of glass shards and minerals separated from Lake Toba-ignimbrites have been published (Kusnaeny, 1977; Beddoe-Stephens *et al.*, 1983). Some of these results are presented in Table 3. They show clearly that the individual glass shards are more siliceous than the whole rock. This is certainly not unexpected as whole-rock samples of the 'Toba Tuffs' often contain a considerable amount of minerals (plagioclase, sanidine, quartz, biotite and hornblende) which have a SiO_2 content, much lower than that of the glass. Other striking differences between the chemical composition of the glass shards and the bulk of the ignimbrites concern the TiO_2 , total iron, MgO, CaO and Na_2O contents. The pure glass analyses yielded lower TiO_2 , total iron, MgO, CaO, Na_2O and Al_2O_3 concentrations but on the other hand it appears that the glass contains much more water.

TABLE 2
WHOLE-ROCK COMPOSITION OF QUATERNARY IGNIMBRITES
AND ASHES FROM SUMATRA

	1	2	3	4
SiO_2	70.0 %	71.11 %	74.09 %	75.48 %
TiO_2	0.37	0.28	0.29	0.09
Al_2O_3	13.9	12.68	13.30	13.63
Fe_2O_3	2.0	1.01	0.78	0.63
FeO	0.9	1.86	0.50	0.24
MnO	0.06	0.07		0.03
MgO	0.8	0.41	0.32	0.13
CaO	1.8	2.88	1.85	0.54
Na_2O	3.4	3.72	4.39	3.21
K_2O	5.2	4.36	3.86	3.87
P_2O_5	0.06	0.09	0.06	0.02
H_2O	1.4	1.46	0.05	2.24
Total	99.89	99.93	99.49	100.11

1. Toba welded tuff, Si Gura Gura (Ninkovich *et al.*, 1978a)
2. Toba ignimbrites, Sangkal (average of 6 samples) (Kusnaeny, 1977)
3. Pasomah ignimbrite (Westerveld, 1952)
4. Lampong tuff (Westerveld, 1952)

TABLE 3
CHEMICAL COMPOSITION AND CIPW NORMS OF GLASSES
SEPARATED FROM TOBA IGNIMBRITES

	1	2		1A	2A
SiO ₂	74.17%	77.64%	Q	36.68%	49.27%
TiO ₂	0.05	0.06	Or	29.55	26.00
Al ₂ O ₃	12.19	12.67	Ab	23.52	12.86
FeO	0.88	1.17	An	3.17	3.77
MnO	0.07		C	1.04	4.03
MgO	0.04	0.09	Hy	1.76	2.27
CaO	0.64	0.76	Il	0.09	0.11
Na ₂ O	2.78	1.52			
K ₂ O	5.00	4.40	DI	90	88
Total	95.82	98.31			

1, 1A Glass from Toba ignimbrite samples exposed N and NW of Lake Toba (average) (Beddoe-Stephens *et al.*, 1983)

2, 2A Glass from Toba ignimbrite samples coming from Sangkal (average) (Kusnaeny, 1977)

The similarity between the chemical properties of the glass shards investigated from the Padang Terap District and those analyzed by Beddoe-Stephens *et al.* (1983) from the Toba area is surprisingly good. It is concluded therefore that the ash-fall tuffs and ashes as well as the pyroclastic ejecta included in the tuffaceous sediments of the Padang Terap District originate from the Toba area in northern Sumatra.

SOILS

The soils in Padang Terap, developed on rhyolitic ash, are mostly cultivated with rice or are covered with grasses and a secondary succession of shrubs. They have the following important field characteristics.

The texture of the subsoil (25–50 cm) varies from fine sandy loam over fine sandy clay loam to clay loam. The topsoil texture (0–25 cm) is loamy fine sand. At 50 cm depth the soil colour may vary in the range: gray (N6/), light gray (N7/) to pinkish gray (7.5YR6/2). The diagnostic subsurface horizon is argillic; the profile is poorly to imperfectly drained. The textural B horizon starts at around 25 cm depth and is often separated from the underlying C horizon by a thin (< 5 cm) layer of manganese nodules. The C horizon begins at around 50 cm and displays a discernible horizontal and subhorizontal layering of beds with various components and variable physical properties (hardness, density, porosity, colour) giving proof of the varied nature of the ashes and the load of different wash deposits. Often, the C horizon is massive and hardly permits any root penetration. Upon drying it becomes extremely hard. In places the C horizon may form a pan, impenetrable to spading, and a perched water table may form during the humid season. According to Paramanathan (1977) the pan meets the requirements of a duripan. It is suggested that the cementation of particles is due to amorphous silica. The morphology of a soil profile formed on rhyolitic ash is illustrated in Plate 2. The detailed description of a soil on the ash deposits is given



Plate 2. Profile morphology of a soil developed on rhyolitic ash at Padang Terap.
Legend: 1. a layer of weathered biotite crystals;
2. a layer of manganese nodules.

TABLE 4
PHYSICO-CHEMICAL CHARACTERISATION OF A
SOIL DEVELOPED ON RHYOLITIC ASH

Depth (cm)	Horizon	Granulometric composition (%)				
		Clay	Silt	Fine sand	Coarse sand	Gravel
0-7	Ap	5.5	10.9	60.4	23.2	—
7-26	AB	4.9	11.6	60.0	23.5	0.1
26-35	Bt ₁	16.8	20.1	44.8	18.3	0.56
35-45	Bt ₂	29.5	23.7	34.2	12.6	4.0
45-75+	C	65.9	21.0	10.2	2.8	0.4

Depth (cm)	Horizon	(1 N NH ₄ Ac at pH 7 (meq./100 g soil))					Base Satur- ation (%)	ACEC (meq./100g clay)
		CEC	Exchangeable Cations					
			Ca	Mg	K	Na		
0-7	Ap	3.30	2.35 (86)*	0.18 (7)	0.19 (7)	0.16	87	—
7-26	AB	3.20	1.22 (77)	0.18 (11)	0.19 (12)	0.04	51	—
26-35	Bt ₁	5.70	1.29 (83)	0.12 (8)	0.14 (9)	1.16	48	31
35-45	Bt ₂	8.40	1.84 (80)	0.21 (9)	0.24 (11)	2.38	56	27
45-75+	C	18.50	5.30 (76)	0.94 (14)	0.72 (10)	3.16	55	27

Depth (cm)	Horizon	C (%)	N (%)	C/N ratio	pH H ₂ O	pH KCl	Free Iron (%)	Exch. Al (meq. 100g)
0-7	Ap	0.43	0.05	8.6	7.0	6.1	2.57	Traces
7-26	AB	0.24	0.04	6.0	6.5	5.0	4.82	Traces
26-35	Bt ₁	0.21	0.04	5.3	5.9	3.8	6.07	0.6
35-45	Bt ₂	0.24	0.04	6.0	5.8	4.1	0.57	0.6
45-75+	C	0.30	0.05	6.0	5.9	4.1	0.36	0.2

*The values between brackets indicate the mutual ratio (percent) between the cations Ca, Mg and K.

below, followed by its physico-chemical characterisation (Table 4). The profile is situated at 31 m elevation, on the concave lower slope of a ridge pediment next to old alluvia.

Profile description

Ap—0-7 cm: Brown (7.5YR 5/2) with common very fine faint clear strong brown

(7.5YR 4/6) root mottles, loamy fine sand; weak coarse subangular blocky; non sticky, non plastic; friable; no cutans; frequent fine and medium, and few coarse roots; clear, smooth boundary.

AB—7–26 cm: Pink (7.5YR 7/4) with many fine faint clear strong brown (7.5YR 5/8) root mottles, loamy fine sand; weak coarse sub-angular blocky; non sticky, non plastic; friable; clay coatings on the root channels; common fine and medium, and few coarse roots; clear smooth boundary.

Bt₁—26–35 cm: Very pale brown (10YR 7/4) with few fine faint clear pinkish gray (7.5YR 7/2), common medium distinct diffuse strong brown (7.5YR 5/8) mottles and many distinct sharp yellowish red (5YR 5/8) mottles along the root channels, fine sandy loam; moderate coarse subangular blocky; slightly sticky, non plastic; firm; fine patchy cutans; few to common fine roots; clear, smooth boundary.

Bt₂—35–45 cm: White (10YR 8/1) with common coarse distinct diffuse strong brown (7.5YR 5/8) mottles, fine sandy clay loam to clay loam; few (5% v/v) small (ϕ 1 cm) manganese gravel; moderate coarse subangular to angular blocky; slightly sticky, slightly plastic; firm; thick broken cutans on peds; few to common fine roots; abrupt, smooth boundary.

C—45–75 + cm: Pinkish gray (7.5YR 6/2), heavy clay; strong, very coarse angular blocky; sticky, plastic; firm; thick continuous cutans; common fine roots.

From the analytical data (Table 4) the granulometric composition of the horizons shows an increase of the clay content with depth. The increase of clay in the upper horizons is gradual, but abrupt in the C horizon. This textural discontinuity may be explained by an important admixture of local detrital material, or by the discontinuity of the ash deposit itself, as mentioned earlier. The soil reaction in the upper horizon is near neutral (pH 6.5–7) and slightly acid (pH 5.9) in the lower horizons. These relatively high pH values may explain the presence of the layer of manganese nodules mentioned above. Throughout the profile little KCl exchangeable aluminium is present.

The cation exchange capacity of 100 g of clay averages 28 meq. in B and C horizons, indicating the presence of both 1:1 and 2:1 clay minerals. The base saturation varies around 50%. The amount of exchangeable Ca²⁺ is moderately high; the exchangeable Mg²⁺ content is low. Both the amounts of exchangeable K⁺ and Na⁺ are high. The high potassium content may be explained by the release of interlayer K⁺ from the mica present in the soil. The high Na⁺ saturation is related to the volcanic present in the soil. The high Na⁺ saturation is related to the volcanic origin of the ashes. The Ca:Mg:K ratio averages 80:10:10 throughout the profile. The amount of organic matter in the profile is very low but of good quality (C/N < 10).

The lower horizons in the profile have a low free Fe content (0.36–0.57%) reflecting the Fe poor nature of the ash and a permanently reduced environment. In the upper horizons, the higher amounts of free Fe are probably due to lateral transport of iron with ground water from the adjacent hill slopes and redistribution in the profile with fluctuations of the ground water table.

Micro-elements occur in moderately high quantities in the topsoil. The amounts of Cu, Zn, Mn and Fe extracted by 0.5 N HNO₃ are 5.0 ppm Cu, 4.4 ppm Zn, 133.4 ppm. Mn, and 236 ppm Fe.

The X-ray diffraction of the clay fraction of the Bt₂ horizon shows the presence of kaolinite and mixed layer clay minerals of the vermiculite group (Fig. 4). The latter are thought to be a transformation product of biotite. Gibbsite, quartz, geothite and mica are present in only minimal quantities. The silt fraction is composed only of quartz.

Soils developed in volcanic ash deposits are named Halu Series in the Malaysian Classification Tables (Paramanathan, 1978). Halu Series is classified as Ferric Luvisol according to the FAO-UNESCO Legend (1974) and loamy, mixed, isohyperthermic Aquic Tropudalf according to Soil Taxonomy (Soil Survey Staff, 1975). For soils which have a duripan, Paramanathan (1977) suggests the term Duriudalf.

In comparison with the soil developed on rhyolitic ash described by Paramanathan (1977) the latter soil has a similar profile morphology, but differs in the following aspects: (a) the soil is better drained; (b) manganese nodules are absent; (c) the clay distribution is more homogeneous throughout the profile and reaches a maximum of 35% clay in the Bt₂ horizon; (d) geothite, gibbsite and mixed layer clay

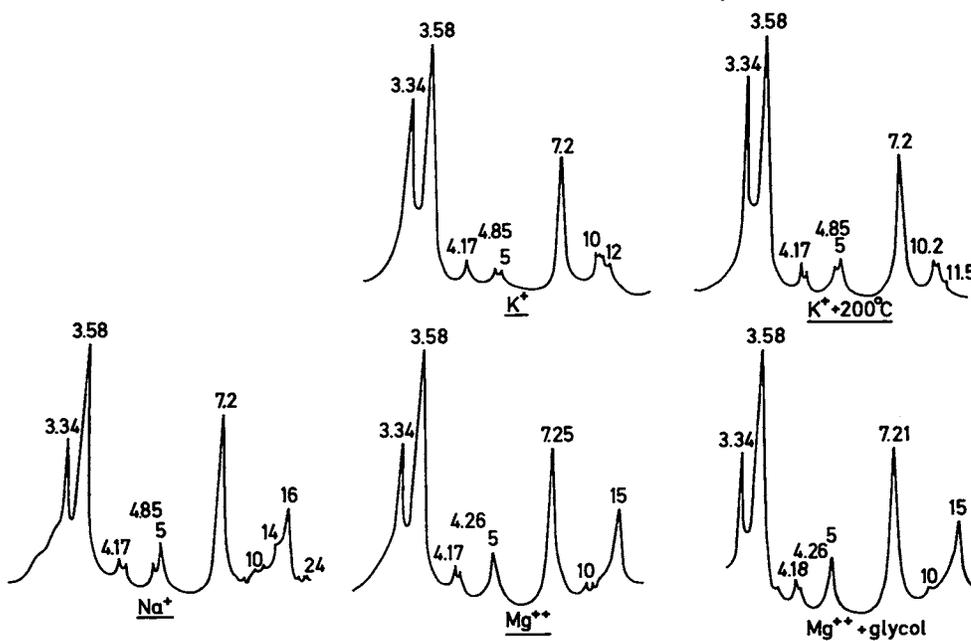


Fig. 4. X-ray diffractograms of the clay ($< 2\mu$) fraction of the Bt₂ horizon of the soil developed on volcanic ash. The clay fraction contains geothite (4.17 Å), quartz (3.34 Å and 4.26 Å), gibbsite (4.30 Å and 4.85 Å), kaolinite (7.2 Å and 3.58 Å), mica (10 Å and 5 Å), mixed layer mica-vermiculite and chlorite-vermiculite.

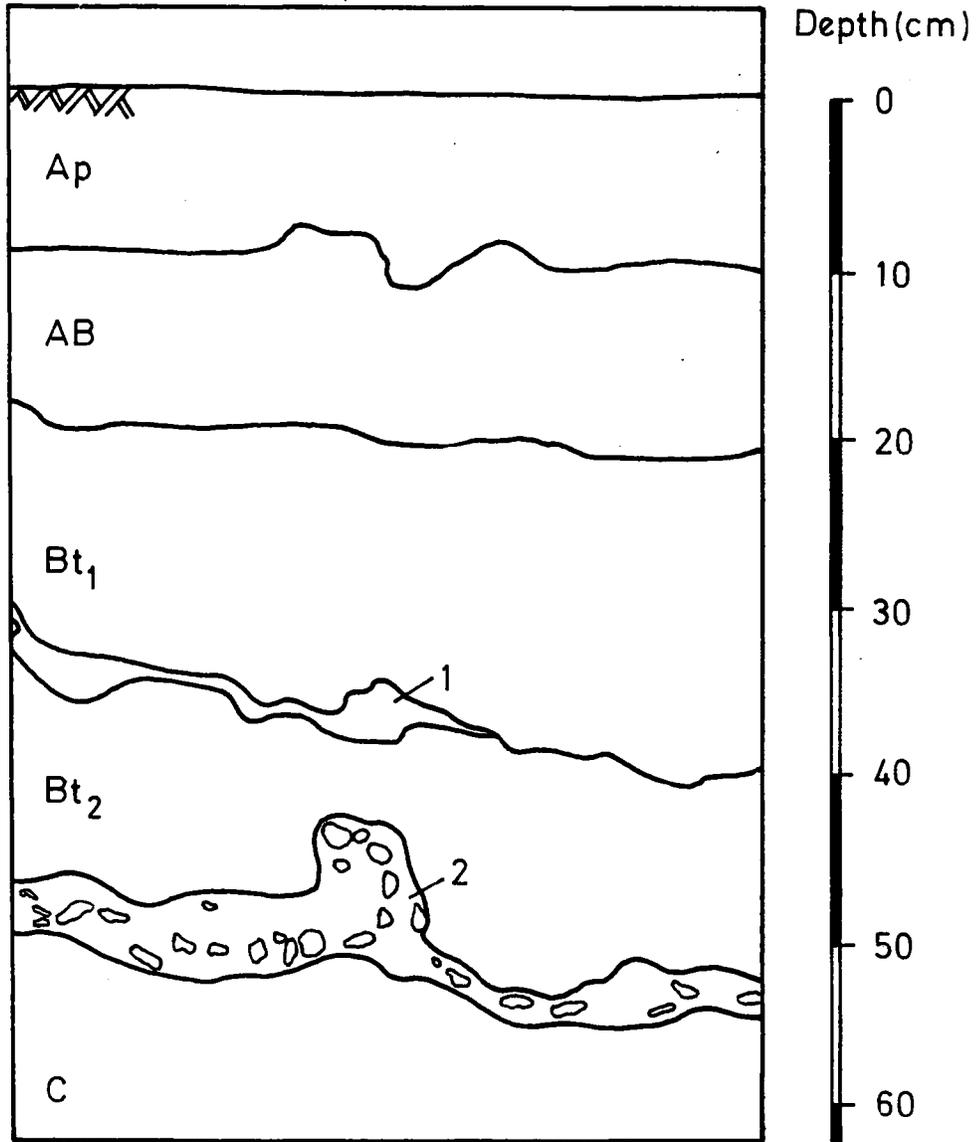


Fig. 5.

minerals were not observed in the clay fraction; the C.E.C. scores lower values; (e) the B_{t2} and the C₁ horizons contain more KCl exchangeable Al³⁺ (2.09 and 1.74 meq. per 100 g soil respectively) and the content of exchangeable Ca²⁺ is low (0.79 meq. per 100 g of soil) resulting in lower values for the base saturation and the pH; (f) the free iron content is low throughout.

Although both soils have reached an intermediate stage of weathering, characterised by the development of an argillic horizon, the above differences in soil properties indicate that the soil described by Paramanathan (1977) is slightly more developed. This is shown particularly by the stronger decationisation and the increased role of Al³⁺ on the exchange complex. The difference in the intensity of weathering is attributed to the difference in drainage of both soils.

The stage of weathering of the soils developed on the rhyolitic ash is intermediate between the near ultimate weathering stage of the soils formed on old alluvium (Ultisols and Oxisols) and the initial weathering stage of the soils on young alluvium (Inticceptisols). Although the latter developed on different parent materials, this finding lends support to the dating data discussed earlier.

CONCLUSION

Rhyolitic ashes in the Padang Terap District are only found along the main river axis, in the most upstream section of the river profile. So far they have not been observed in any other district in Kedah.

The limited occurrence of the ashes can be attributed to erosion, which removed most of the loose ash and concentrated it in the drainage axis of the basin, where it was deposited. The ridge near Kuala Nerang may have played an important role in the preservation of the ash deposits.

The chemical composition of the glass shards found in Padang Terap proves beyond any doubt that the ash originated from the Toba volcano. At the present stage of our research it is however not possible to establish with certainty whether the ash originated from the 75,000 year old Toba eruption or from the 30,000 year old Sibuatan eruption. According to Stauffer *et al.* (1980) the tephra from both eruptions are chemically identical. Until the results of the K-Ar dating of the Padang Terap samples are known, no evidence on the precise date can be given.

The geomorphic position and approximate age of the ash permits to situate the development of important landforms in the area, e.g. pediments, in a drier Late Pleistocene environment.

The soils developed on rhyolitic ash have reached a weathering stage intermediate between those of the young and old alluvia. They are characterized by an argillic horizon. Differences in drainage conditions result in minor variations in the degree of weathering of the material.

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