MORPHOLOGICAL, PHYSICAL, AND CHEMICAL CHARACTERISTICS OF SOME VOLCANIC SOILS OF MT. GALUNGGUNG

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ABSTRACT

Results of study on morphological, physical, and chemical characteristics of three pedons developed on volcanic materials of Mt. Galunggung, namely BM1, BM2, and BM3, showed that these pedons had a different stage of profile development. Pedon BM1 is classified as undeveloped, BM2 is medium developed, and BM3 is strongly developed. This is mainly caused by differences in relative age of the parent rocks, and elevation. Although classified as undeveloped, the soil represented by pedon BM1, the youngest, has immediately been used by farmers for rice cultivation because of water abundance, and high availability of P, and basic cations derived from weathering of easily weathered amorphous materials and minerals. According to the Soil Taxonomy system of the USDA (Soil Survey Staff, 1996), pedons BM1, BM2, and BM3 are classified as *Typic Udipsamment*, *Taptho Hapludandic Typic Troporthent*, and *Humic Hapludult*, respectively. Whilst, according to FAO/UNESCO system (1988), these pedons are classified as *Eutric Regosol*, *Eutric Regosol* and *Humic Alisol*, respectively.

Keywords: profile development, soil characteristics, volcanic soils.

INTRODUCTION

Soils developed on volcanic materials usually have distinctive properties which in many parts of the world are reflected in extremely high crops productivity, sometimes significantly associated with some of the world's highest human carrying capacity (Leamy, 1984), such as those developed in Java Island (Sutanto, 1988). The most important diagnostic features of volcanic ash derived soils include variation in chemical composition, specific morphologic features and the presence of some specific minerals such as short range order minerals, i.e. allophane, imogolite and some oxides (De Coninck, 1990).

According to FAO/UNESCO (1974), volcanic materials constitute the parent material of many different soils. Volcanic material derived soils have been classified in many countries: as Andosols, Regosols, and Latosols in Indonesia (Pusat Penelitian Tanah, 1976); Allophane soils and Kuroboku soils in Japan; Alluvial or Yellowish Brown Loam in New Zealand; as Andosols by FAO/UNESCO (1974) and Andisol by Soil Survey Staff (1996).

In Indonesia, a group of soils derived from volcanic materials is widely spread over the archipelago, from Sumatera in the west over Java to Lesser Sunda Islands in the east (Tan, 1965), and covers about 20 millions hectares or about 10.4 % of the total land area (Pusat Penelitian Tanah, 1976). Most of food crops production in Indonesia are derived from these soils. Unfortunately, documentation or studies on these very important soils are very rare.

Study on genesis and morphology of volcanic ash derived soils in Indonesia was started by Dudal and Soepraptohardjo (1957). In addition, study on physico-chemical properties was carried out by Tan (1959,1965), Tan and Van Schuylenborgh (1959), and Hardjosoesastro *et al.* (1983). The most recent and comprehensive studies were conducted by Sutanto (1988) and Mulyanto (1990).

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This paper presents results of study on morphological, physical, and chemical properties of different volcanic materials derived soils of Galunggung Volcano in West Java and their classification.

PHYSICAL ENVIRONMENT

Some physical environmental factors strongly determine characteristics of a soil. The most important factors are geology, topography, climate and landuse. The geological factors are related to the properties of parent materials. Topographic position of the soil is related to the water regimes, which influence the weathering processes, and physical and chemical properties. The climate and landuse also determine the weathering processes.

Geology

Mt. Galunggung is located at about 7°15' South Latitude and 108°03' East Longitude which covering an area in part of Garut and Tasikmalaya districts, West Java. The eruption activities of this volcano were reported in 1822, 1894, 1918, and 1982 (Escher, 1920; Bronto, 1982). From these eruptions, young deposits were built on the ruin of old deposits from eruptions before 1822.

Rocks found in surrounding Mt. Galunggung consist of lava, pyroclastic deposits, and thallus which can be divided into 11 rock units as follows: (1) Lahar deposits (QLh1), (2) Galunggung lava (QG1), (3). Beuticanar lava (QB1), (4) Galunggung pyroclastic deposits (QGjp), (5) Volcanic sliding deposits (QGlv), (6) Galunggung stream pyroclastic deposits (QGap), (7) Lahar 2 deposits (Qlh2), (8). Walirang lava (QWl), (9) Lahar 3 deposits (Qlh3), (10) Jadi lava (QJl), and (11) Thallus (Qta) (*Fig. 1*).

Climate

The climate of Java is significantly characterised by a distinct wet and dry seasons. This season type is well pronounced in East and Central Java and less pronounced in West Java (Table 1).

Rainfall almost occurs over the whole year. Minimum rainfall coincides with the monsoon months, that are in June, July and August. The annual rainfall is higher than 3.000 mm. The average annual temperature is generally 24.5°C and the temperature is fairly uniform during the whole year with a variation that never exceeds 2°C. Generally speaking, the mean monthly relative humidity does not vary greatly and is always higher than 80 % due to high rainfall. The highest peak values of potential evapotranspiration is found in March and the lowest one in July.

According to Soil Taxonomy (1996), the investigated soils have udic moisture regime and isohyperthermic temperature regime.

Vegetation and land use

Not much of original vegetation is left in this area. They are mostly found on the top of volcanoes and mountains as protection forest areas. Areas unsuitable for agriculture are used for production forest of *Swietenia macrophylla*, *Pinus merkusii*, and *Albizia falcataria* or used as reforestation and agroforestry areas. The landuse for farming of the study area is mostly irrigated rice field, particularly on the northern and eastern footslope. Since there exist no limitation of water, the cropping pattern varies from continuous rice (3x with short age cultivar or 2x rice of medium age cultivar) to 1x rice and secondary crops or another pattern depending on the market demand. In area where irrigation is not possible, rainfed agriculture is the dominant land use type with a great variety of crops planted in various combinations.

MATERIALS AND METHODS

Material

The three selected pedons are located in locations near Singapama, Sukajadi and Indihiang of the Mt. Galunggung area, Tasikmalaya, West Java (Figure 2). They were selected on the basis of the Soil Map of West Java, at scale of 1:250 000 prepared by Pusat Penelitian Tanah (1976).

Soil samples were taken from every identifiable horizon of the selected pedons. Two kinds of soil samples were collected: bulk samples for routine physico-chemical analysis and undisturbed soil samples for physical analysis.

Methods

The routine physico-chemical analysis was carried out mainly according to the methods described in "Procedure for Soil Survey" (1984) except for granulometric analysis. All data were reported on the basis of the < 2 mm material.

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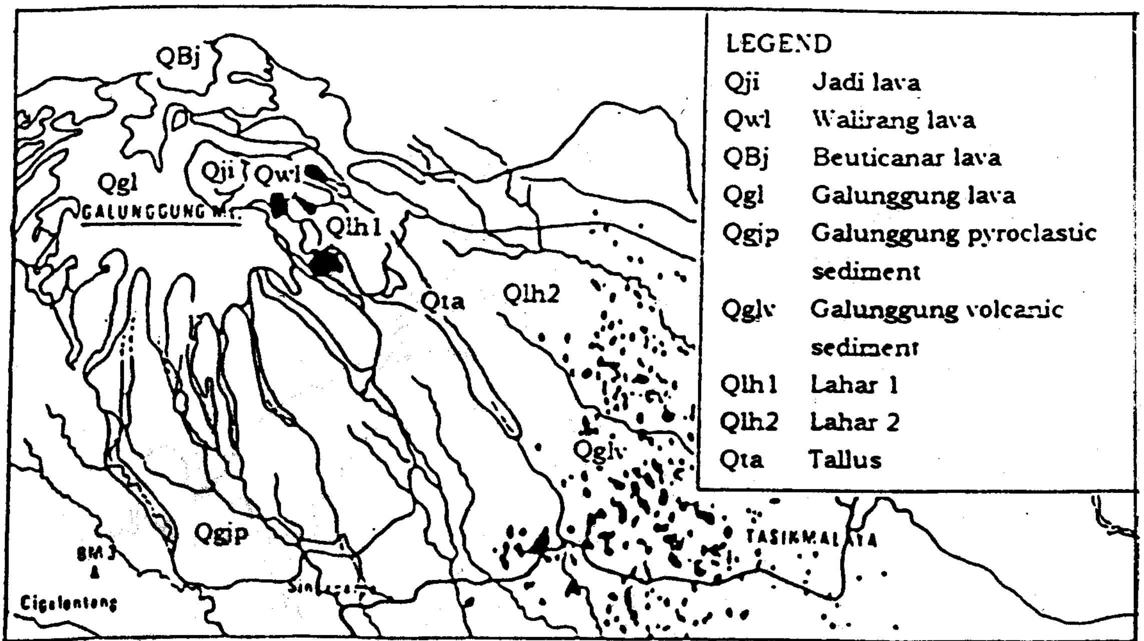

After: Bronto. 1982

Scale 1 : 150 000

Figure 1. Geology of the studied area

Table 1. Climatic Data of Tasikmalaya, West Java

Climatic Factors	Month												Annual
	J	F	M	A	M	J	J	A	S	O	N	D	
Temp. °C	24.6	24.6	24.9	24.8	24.7	23.9	18.7	23.7	23.8	24.5	24.8	24.8	24.0
RH %*	86.0	85.0	86.0	85.0	86.0	85.0	85.0	83.0	84.0	84.0	85.0	85.0	84.9
Rainfall	368.0	386.0	280.0	258.0	315.0	160.0	82.0	103.0	213.0	395.0	337.0	236.0	3237.0
PET*	130.2	122.1	135.5	128.1	111.3	104.1	91.5	119.0	118.8	127.7	127.8	131.1	1447.2

* Relative Hunidity
** Potential Evapo-Transpiration

The granulometric analysis was carried out by sieving and sedimentation. The particle size distribution of fraction <2mm analysis was done with H_2O_2 30 % to remove organic matter by successive sedimentation after treatment. The sand fraction was separated by wet sieving using a 50 μm sieve. Separation of clay and silt was carried out by successive sedimentation. The clay was siphoned and collected after 8 hours and 35 minutes from the suspension from 10 cm depth. The percentage was calculated on the dry weight basis, following the size classes of USDA and textural classes according to International classification (Soil Survey Staff, 1996).

RESULT AND DISCUSSION

All pedons are derived from quaternary deposits have developed on the complex of Galunggung volcanoes: BM1 on the Qta unit, BM2 and BM3 on the QGjp and Qlh2 unit.

Stratigraphically, the Qta unit is the youngest, since it was due to the eruption of 1982. The pedons BM1 and BM2 are situated above 500 m asl, BM3 below 500 m asl. The footslopes of volcanoes have been dissected, giving rise to a gently to rolling landscape at lower altitude, passing over into rolling and hilly at higher altitude.

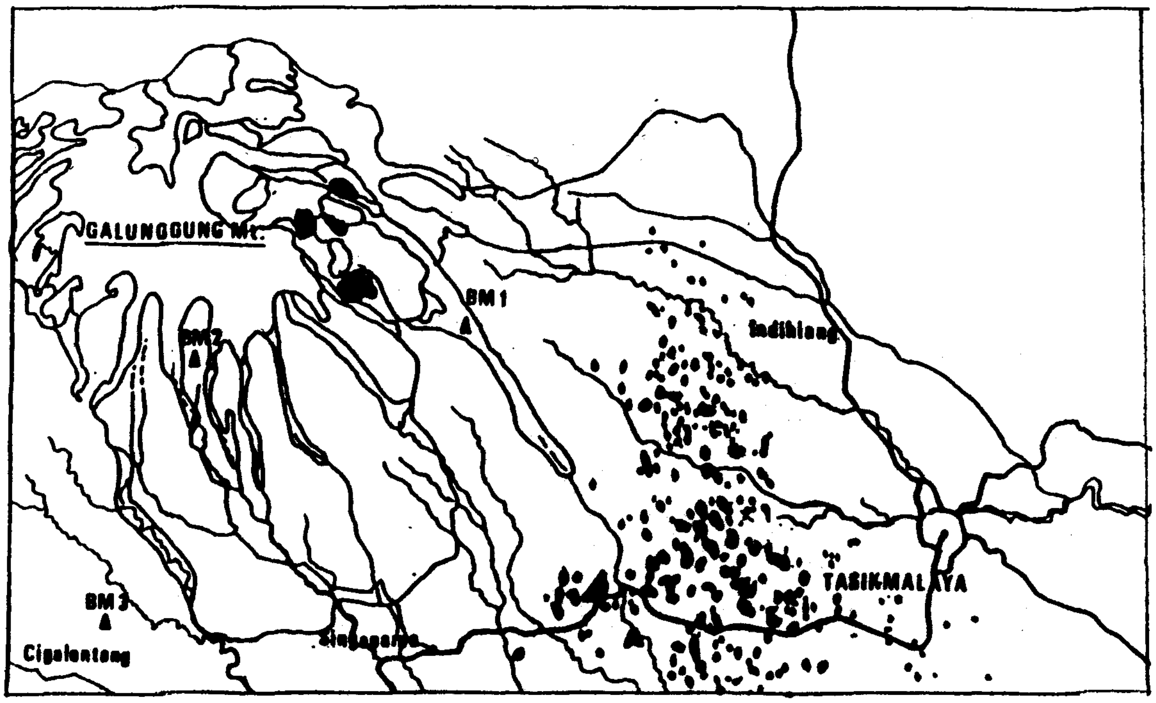

Figure 2. The location of soil profiles

The recent soil on Qta is a Grey Regosol (BM1). On the older deposits situated at higher altitude the soil is Andosol (BM2) while profile BM3 on the oldest deposit and at lower altitude forms a Reddish Brown Latosol. Due to repeated eruptions and sedimentation, the pedons display a composite morphology and several buried soils may be present underneath the present day profiles. Various types of land utilisation are recognised in these areas: gently sloping to level terrain have been transformed into irrigated rice field while the undulating to rolling land is used for dry land agriculture. The hilly to mountainous terrain are mostly for agroforestry.

Morphological properties

Pedon BM1 is located on a recent volcanic alluvial plain at the eastern footslope of Galunggung, about 550 m asl. The terrain is level, without evidence of erosion. The profile has no horizon differentiation, sandy, massive and structurless, firm, and no root development. These sandy soils are mined for building construction and afterwards they are transformed into paddy rice fields.

Pedon BM2, located in Kampung Sukajadi Linggawangi, Leuwisari district, Tasikmalaya is situated in hilly terrain on the southern convex slope of Mt. Galunggung, at about 750 m asl.. The upper layers I to IV are recent and have little or no development. Layer V is an older soil. The soil is mostly sand to sandy loam, alternating massive and loose structureless in the layers I to IV, but layer V is weak, fine subangular blocky, very friable and firm consistence in the range of very dark brown to dark yellowish brown.

This area is dominated by dryland agriculture. Terracing and mixed farming are applied without fertilization.

Pedon BM3, located in Cigalontang village, Tasikmalaya is observed on the middle slope of a hill on the Southern lower footslope of Mt. Galunggung. The evidence of erosion is

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moderate. This soil is relatively deep and well drained.

The colour changes from dark grey brown in the A horizon through reddish brown in the E and Bt1 horizons to strong brown in the Bt2 and the Bt3 horizons. The texture is clay throughout, and very weak patchy cutans are noticed in the Bt2 and Bt3 horizons. The structure is moderate-medium granular in the A horizon, gradually changes into weak medium subangular blocky in the E, Bt1 and Bt2 horizons, and to moderate medium subangular blocky in the Bt3 horizon. The consistence in moist condition is friable in the A, E, and Bt1 horizons and gradually changes to firm and very firm in the Bt2 and Bt3 horizons. The material is plastic to very plastic. Root development is up to 90 cm depth. The land utilisation is mostly agroforestry. Paddy rice field is found only where water is available.

Physical and Chemical Properties

The physical and chemical analysis data are presented in Table 2. and Table 3.

The samples of the young volcanic soil (BM1) disperse in alkali solution. The particle size distribution is dominated by sand fraction. Textural class of the horizons ranges from sand to loamy sand. The bulk density has not been determined. The soil reaction is acid in H_2O and pH KCl is 0.6-1.1 units lower than the pHH_2O. These feature has been assumed to express a net negative charge of the exchange complex throughout the profile (Tan, 1982). The organic carbon content seems very low (0.11-0.88 %) and shows an irregular distribution with depth. The low content of nitrogen is related to the low content of organic matter. The high amount of available P is a result of weathering of volcanic glass and fluoroapatite microcrystals which normally occurs as an accessory mineral or as an inclusion of iron-bearing minerals in all types of eruptive rocks (Prinz *et. al.*, 1978). The CEC of this soil is very low because it has a very small colloidal fraction. Amounts of cations extracted with NH_4OAc are high, giving saturation of 100 % or more, indicating that part of the cations are present as free salts. Since qualitative testing shows the presence of $SO_4^=$, they are probably present as sulphates.

The layers I to IV of profile BM2 show a no clear evolution and the buried soil behave in a different way. The samples of the upper layers disperse with normal dispersing agent whereas the buried one seems to disperse in acid conditions. The texture is dominated by sand: 73.62-95.74 % in the upper layers and 58.94-63.97 % in the buried soil. The bulk density is high in the upper layers but about 0.9 in the buried one. Organic carbon (0.15-2.7 %) and nitrogen (0.02 %) are very low. The available P is medium (0.3-9.2 ppm). The NH_4OAc CEC is low (5.60-11.80 me/100g) and the sum of exchangeable cations ranges from 1.99 to 9.59 me/100g giving a base saturation between 35 and 88 %. The buried soil has different characteristics, with organic carbon between 3.29 and 3.75 % and N ranging from 0.26 to 0.27 %. The available P is not significant. CEC NH_4OAc is relatively high (26.73-32.30 me/100gr) and the sum of extractable cations (1.18-4.73 %) and base saturation are low (4.41-14.64 %). The samples of the old volcanic soil (BM3) disperse with normal dispersing agent and particle size distribution is dominated by the clay fraction ranging between 50.01 to 88.28 %. The clay content increases with depth. Bulk density is higher than 0.9 g/cc.

The pH H_2O is acid, ranging from 5.0 to 5.7. The pH KCl is lower than pH H_2O with a difference in the range of 1.2 to 1.4 units. Organic carbon content decreases with depth and ranges from 0.25 to 2.29 %. The total-N is low (0.4-0.14 %) and the available-P is mostly not significant. The sum of cations is relatively high (7.28-10.36 me/100g) and is dominated by calcium, while the NH_4Oac CEC pH 7 is medium (22.84 to 26.96 me/100g). Therefore, the base saturation is also medium (30.01-45.36 %).

Soil Classification

Pedon BM1 (Grey Regosols). The soil has an ochric epipedon, with <35 % (V) of rock fragments and sand texture. The soil moisture regime is udic and the soil temperature regime is isohyperthermic. Base saturation is 100 %. This soil is classified as *Typic Udipsamment, sandy, isohyperthermic* (Soil survey staff, 1996) or as *Eutric Regosol* (FAO/UNESCO, 1988).

Pedon BM2 (Yellowish Brown Andosols). The soil has an ochric epipedon, < 35 % rock fragments and sand to sandy loam texture. The profile can be divided into two parts, the upper part is a soil without profile development and the buried part is soil with andic properties. The base saturation is higher than 50% in the upper soil but less than 50% in the buried soil. This soil is classified as *Taptho Hapludandic Typic Troporthents, sandy loam, isohyperthermic* (Soil Survey Staff, 1996), or as *Eutric Regosol* (FAO/UNESCO, 1988).

Table 2. Physical Analytical Data

Pedon	Horizon	Depth	Particle Size			Texture	BD
			Sand	Silt	Clay	Classes	(gr/cc)
				........%.....			
BM1	I	0 – 45	91.83	3.93	4.25.	sand	-
	II	45 – 85	88.94	5.43	5.63	sand	-
	III	85 – 120	84.91	12.77	2.42	loamy sand	-
	IV	>120	91.35	4.22	4.43	sand	-
BM2	I	0 - 20	91.35	3.76	4.89	sand	1.10
	II	20 - 28	73.62	20.62	5.76	sandy loam	1.22
	III	28 - 33	95.74	3.23	1.03	sand	-
	IV	33 - 38	79.24	18.01	2.75	sandy loam	-
	VA	38 - 65	63.57	17.92	18.51	sandy loam	0.93
	VAB	65 - 90	63.97	1706	1897	sandy loam	0.93
	VC	90 - 130	58.94	17.43	23.63	sandy loam	0.93
BM3	A	0 - 8	23.15	26.84	50.01	clay	1.08
	E	8 - 26	4.74	38.11	57.15	clay	0.96
	Bt1	26 - 46	3.48	24.61	71.91	clay	0.94
	Bt2	46 - 90	1.14	12.37	86.49	clay	1.01
	Bt3	90 -	1.03	10.69	88.28	clay	1.02

Pedon BM3 (Reddish Brown Latosols). The soil has an umbric epipedon and an argillic subsurface horizon. The NH_4Oac CEC pH7 is >16 me/100g clay or the apparent CEC >12 me/100g clay. The base saturation of the argillic horizon is lower than 35 %. The texture is clay throughout. The clay minerals are dominated by halloysite. This profile is included in *Humic Hapludults, clay, isohyperthermic, halloysitic* (Soil Survey Staff, 1996), and *Humic Alisol* (FAO/UNESCO, 1988).

The morphological, physical and chemical characteristics described above suggest that three pedons of the studied soils have different development. Pedon BM1 is Typic Udipsamment, BM2 is Taptho Hapludandic Typic Troporthent, and BM3 is Humic Hapludult. This different stages of development is mostly caused by different relative ages of the parent materials, besides that the elevation difference also plays a roll. As mentioned earlier, the parent material of pedon BM1 is the youngest and that of BM3 is the oldest; hence pedon BM3 has a stronger development than the others and pedon BM1 has the weakest.

Comparison of pedons BM3 and BM2 shows that below 500 m asl (BM3) no andic properties are present, while above 500m asl (BM2) the andic properties are well developed. This is probably due to the clearly temperature influence at both elevations with causes difference in organic matter accumulation in both profiles.

Pedon BM1 has no profile development but since enough water is available the farmers eagerly to transform this sandy soil into paddy rice field. This seems an appropriate decision, because the chemical analysis showed that the available-P and available basic cations in this soil are high. However, they have to add nitrogen fertiliser because nitrogen content of this soils is very low.

In the older classification system is pedon BM3 classified as Latosol. According to Mohr, *et al.* (1972) Latosols are included in Oxisols without plinthite. Macro and micro morphological analyses show that this pedon seems to be an Oxisol, but mineralogical and chemical analyses show that the weatherable minerals and also the CEC NH_4OAc pH7 of clay are still too high for the oxic horizon requirement. Hence, pedon BM3 is classified as Ultisol (Humic Hapludult).

CONCLUSIONS

The morphological, physical and chemical characteristics of three pedons developed on the volcanic materials of Mt. Galunggung show that these three pedons have different profile developments. The pedon BM1, BM2 and BM3 have no development, medium development and strong development respectively. This different stages of development is mostly caused by different relative ages of the parent materials, and the elevation difference.

According to the Soil Taxonomy (Soil Survey Staff, 1996) pedon BM1, BM2 and BM3 are classified as Typic Udipsamment, Taptho Hapludandic Typic Troporthent, and Humic

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Hapludult; and according to FAO/UNESCO (1988) these pedons are classified as Eutric Regosols, Eutric Regosol, and Humic Alisol respectively.

High available-P of the BM1 which developed on the most recent extrusive volcanic materials are a result of weathering of volcanic glass which probably contains abundant microcrystals of apatite.

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Table 3. Chemical Analytical Data

Ped	Hor	Depth	pH		Org.	N	C/N	Av-P	Exch	Exchangeable Cations					CEC		Base
			H2O	KCl	Total	Total			acid	Ca	Mg	K	Na	sum	NH4 OAc	sum	Sat.
					%	%				...me/100gr...							%
BM1	I	0 - 45	4.20	3.60	0.11	0.02	5.50	5.20	0.95	11.83	3.92	0.25	1.05	17.05	5.30	18.00	100
	II	45-85	4.80	4.10	0.08	0.02	4.00	5.00	0.38	13.56	3.75	0.36	1.00	18.67	6.80	19.05	100
	III	85-120	5.60	4.80	0.15	0.02	7.50	6.30	0.07	11.88	3.49	0.33	0.88	16.58	6.50	16.65	100
	IV	120-	7.10	6.00	0.88	0.03	29.33	9.20	0.07	12.12	3.49	0.33	0.85	16.79	7.50	16.86	100
BM2	I	0 - 20	6.50	5.20	0.27	0.02	13.50	1.10	0.07	4.13	1.09	0.13	0.12	5.47	6.20	5.54	88.23
	II	20-28	5.80	4.50	0.19	0.02	9.50	0.30	0.53	7.02	1.70	0.30	0.24	9.26	11.80	9.79	78.47
	III	28-33	6.20	4.20	0.15	0.02	7.50	9.20	0.23	1.73	0.17	0.04	0.05	1.99	5.60	2.22	35.54
	IV	33-38	5.30	4.00	0.23	0.02	11.50	0.40	2.91	7.74	1.31	0.30	0.23	9.58	15.20	12.49	63.03
	VA	38-65	5.50	4.60	3.52	0.26	13.54	ns	0.68	0.80	0.15	0.11	0.12	1.18	26.73	1.86	4.41
	VAB	65-90	6.00	4.70	3.29	0.27	12.19	ns	0.35	1.11	0.15	0.12	0.12	1.50	30.93	1.85	4.85
	VA	90-130	5.90	4.90	3.75	0.27	13.89	ns	0.15	4.26	0.20	0.07	0.20	4.73	32.30	4.88	14.64
BM3	A	0 - 8	5.70	4.40	2.29	0.14	16.36	ns	0.38	7.35	2.27	0.27	0.47	10.36	22.84	10.74	45.36
	E	8 -26	5.20	3.90	1.36	0.11	12.36	0.20	0.98	5.44	2.15	0.16	0.34	8.09	26.96	9.07	30.01
	Bt1	26-46	5.00	3.80	1.53	0.12	12.75	0.20	1.14	4.75	2.08	0.12	0.34	7.28	25.84	8.42	28.17
	Bt2	46-90	5.00	3.70	0.48	0.05	9.60	ns	1.29	5.04	2.11	0.07	1.12	8.34	24.15	9.64	34.54
	Bt3	90 -	5.30	3.90	0.25	0.04	6.25	ns	0.84	5.42	3.40	0.06	1.16	10.04	24.43	11.27	41.10