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Particle size distribution, minerals and chemical composition of red soils from silicate rock area of Central Okinawa

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Abstract

The study was conducted to determine the characteristic of Kunigami mahji from central part of Okinawa Island. The samples were collected from Gushikawa recreation center (GRC) and nearby Royalgolf (RG). Particle size distribution, mineralogy of clay, silt and fine sand and chemical composition experiments were carried out. The influence of soil erosion to amend distribution of particles and soluble cations was observed in surface sample from GRC. Pure, intergrade and irregular mixed layer minerals were found. In RG sample even in fine sand clay minerals were observed. We assumed that weathering have proceeded more in GRC than in RG sample. This is also supported by the difference of their chemical compositions. The ratios of oxides of soluble cations (alkalis and alkaline earth) to that of insoluble (Al, Fe and Si) were very higher for RG (0.042) than for GRC (0.011). Chlorite widely appeared in RG sample and only once as vermiculite-chlorite intergrade mineral in GRC, hence suggests that samples were formed from different parent materials.

Introduction

Okinawa Island comprises four types of soil, Kunigami, Shimajiri, Jahgaru and Chuseki soil (Alluvial soil). Kunigami soil (reddish to yellow) occupies about 53.4 % of total land. Okinawa geographical location is subtropical humid with strong wind and rainfall of about 2400–2600 mm/yr, an average of 3 mm/10 min rainfall occurs 50 times in a year which is about 3 to 4 times higher than Japan Honshu (Onaga, 1969). Okinawa also has higher erosion rate estimated to 400 tons/km² /yr (Yamamoto, 1976) hence large amount of base cations have been removed which make soil dominated with aluminum and iron. This area covered by red soil almost was formed by silicate rocks. The particle size distribution is most stable soil characteristic being little modified by cultivation or other practices. The particle size distribution is mostly used as basis of soil textural classification and also is valuable research

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method in problems dealing with weathering, segregation of soil particles by leaching, soil structure and sediments transport by water and wind.

Total elemental analysis normally is not useful for characterizing soil as media for plant growth to the sense of available nutrients or toxicity because the large portion presents as insoluble forms in crystal structure of particle (Black et al., 1965) but is useful as basis for characterizing a soil with respect to type of parent material weathering etc. Also may be used with analysis of other components of clay to compute value an indicative of type of clay mineral present (Marshall, 1949). Tokashiki and Nakamura (1980) already reported particle size distribution, physical and chemical properties and mineralogy of clay and silt fractions of soils from Gushikawa city, where is near to Ishikawa city. But they did not survey mineralogy of fine sand and total chemical composition. The study was done to analyze the particle size distribution, minerals and total chemical composition in order to understand the effect of erosion and type of parent material in a central part of Okinawa as a base for further study in their acidification effect to natural waters.

Materials and Methods

Two samples from central part of Okinawa Island (Ishikawa city), Gushikawa recreation center (GRC) and nearby the Royalgolf (RG) were collected for study. Soil sampling points are shown in Fig. 1. The altitude of GRC is 50 m and RG is 100 m. In GRC, sample was taken at the surface while RG at depth of 1 m. The sample were air dried and crushed to pass through 2 mm sieve. The particle size distribution was done by sedimentation method. Ten grams of each sample were first treated to remove organic matter by 6 % H_2O_2 and coarse sand was fractionated by 0.2 mm sieve. The solution was sonified for 15 min, mechanical shook for 1 hr to disperse particles prior to collection of clay and silt particles. The suspension was mixed thoroughly and allowed to stand in vibration free room at temperature of 20°C. The clay particles were collected after 12 hrs at 15 cm depth until supernatant was clear and silt particles after 4 min 48 sec. After the solution was clear the sediment was calculated as fine sand.

The minerals were determined by X-ray diffractometry method for clay, silt and fine sand particles. Every treated clay sample suspended in water was mounted on a glass slide, dried and analyzed by X-ray diffractometer from 2 to 30° 2θ using Cu $K\alpha$ radiation at 30 kV, 10 mA and 1000 count range. The XRD analysis was done on parallel oriented clay after Mg^{2+} and K^+ saturation. Mg^{2+} saturated sample was analyzed after air dried and glycerol solvation, K^+ saturated was X-rayed after air dried and progressive heating at 105, 300 and 550°C. Fine sand and silt particles were grinded by agate mortar and packed in aluminum holder before X-rayed from 2 to 60° 2θ in random orientation. The conversion from degree to basal space d was calculated from conversion table in appendix of Brindley et al., 1980.

The chemical composition was determined after digestion with HF and $HClO_4$ mixture. Na and K were measured by flame emission spectrophotometer and Ca, Mg, Fe and Al were determined by atomic absorption spectrophotometry using acetylene-nitrous oxide flame for Al and air-acetylene for the rest of cations. Lanthanum was added to the standards and to the samples for Ca and Mg (Lanyon and Heald, 1982) and 2% KCl and 3 M HCl for Al and Fe respectively. Silicon dioxide (SiO_2) was measured by gravitation method (Jackson, 1965) after alkaline fusion and ignition loss was determined as the weight loss from 105 to 1000°C.

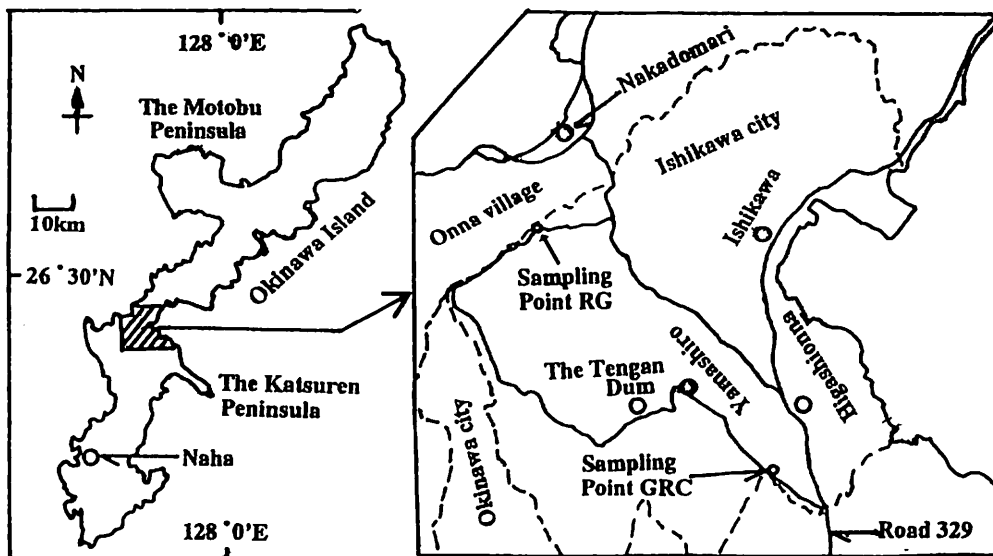


Fig 1. Map showing the sampling points, GRC and RG.

Results and Discussion

Particle size distribution

The particle size distribution and their corresponding texture are shown in Table 1. In GRC sample the quantity of fine sand was higher followed by silt, coarse sand and least clay while in RG silt was higher followed by fine sand, clay and final coarse sand. Also the clay particles were higher in RG than GRC. This difference shows the effect of erosion because clay and silt particles are small and lighter so it is easily weathered since the later sample was taken at the surface while the former at 1m deep. Tokashiki and Nakamura (1980) presented particle size distribution for the sample from Gushikawa city. Comparing with their surface sample, coarse sand and clay were lower, and fine sand and silt were higher. This might be caused by the difference in parent materials or/and weathering processes. Both samples fall under loam textural class according to ISSA standard (JSSSP, 1990).

Table 1. Particle size distribution (%), texture and color.

Particle size	GRC	RG
Coarse sand (2-0.2mm)	13.88	6.78
Fine sand (0.2-0.02mm)	42.07	37.94
Silt (0.02-0.002mm)	36.07	45.22
Clay (< 0.002mm)	7.81	10.06
Soil texture	Loam	Loam
Color	10YR 8/8 Yellow orange	10YR 7/4 Dull yellow orange

Mineralogy

The X-ray diffraction patterns are shown in Fig.2 to 4. For clay fraction both samples show the presence of kaolinite, and goethite minerals. Kaolinite was shown by the appearance of strong peak at 7.15\AA which disappeared after being heated at 550°C , and goethite was represented by peak at 4.15 in all treatments (Lewis, 1993). In GRC sample the peak at basal space $d = 13.81$ in Mg^{2+} saturated air dried and glycerol solvated which contracted gradually during progressive heating to 10.7\AA in K^+ saturation indicates presence of vermiculite-chlorite intergrade mineral. The weak peak at 12.2\AA in both saturations can be assigned to vermiculite/illite irregular mixed layer. RG clay showed strong peak at 10\AA regardless treatment and moisture content, confirms the presence of illite. Also strong peak was found at 14.25\AA in all treatment until after heat treatment at 550°C shifted to 12.11 , this indicates the presence of irregular mixed-layer mineral of vermiculite/ chlorite (Kodama and Brydon, 1968). Tokashiki et al., 1980 reported kaoline, illite, vermiculite-chlorite intergrade, and vermiculite/illite irregular mixed layer from Gushikawa for surface sample of Kunigami mahji, the results are almost same as ours, except absence of illite in this study.

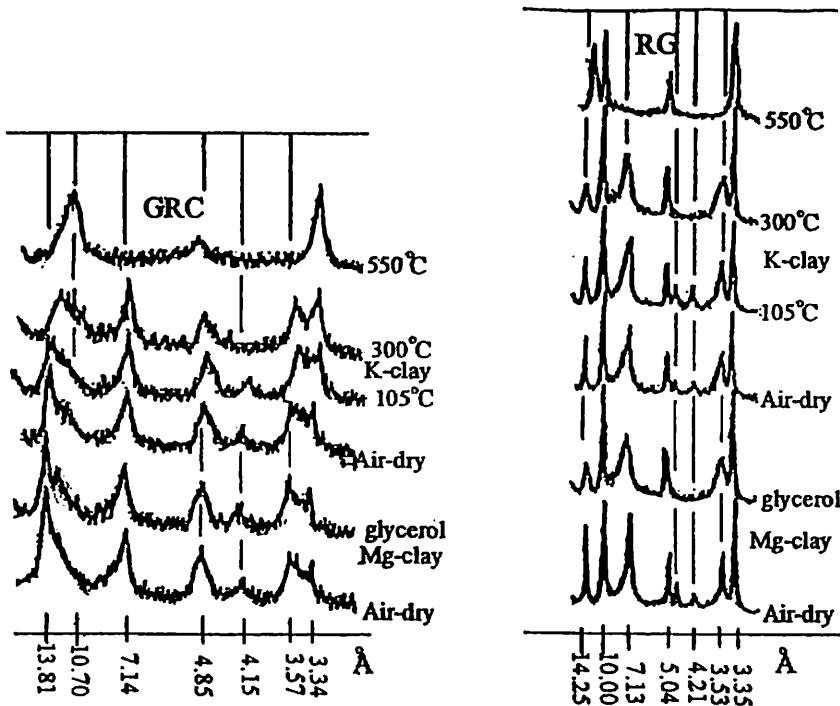


Fig 2. Oriented X-ray diffractograms of GRC and RG clay fractions.

Silt particles of GRC sample contained quartz, muscovite, feldspar, goethite, vermiculite and kaolinite, while fine sand contained quartz only. RG silt and fine sand particles both contained quartz, muscovite, chlorite, feldspar, and kaolinite, as shown in Table 2. In comparing the mineralogy of the two samples we can understand that fine sand of GRC sample did not contain clay mineral while that of RG contained, this indicates that all clay particles were separated from fine sand but not for RG. This may be clay particles are occluded in the crystal of sand particles, hence the results indicate the GRC sample accepted

heavily weathering process than RG. Also chlorite widely appeared in RG sample and only once as vermiculite-chlorite intergrade in GRC, hence suggests that samples were formed from different parent materials. Silt fraction of the surface sample by Tokashiki and Nakamura (1980) consisted only primary minerals Quartz and feldspar like fine sand particles of this study. This difference may show different weathering conditions.

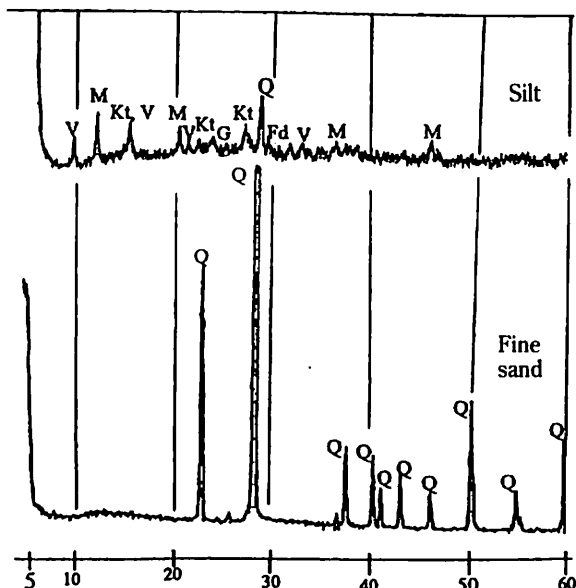


Fig 3. X-ray diffraction patterns of GRC silt and fine sand fractions (random orientation).
 *Abbreviation: Fd = feldspar, G = goethite, Kt = kaolinite, Kt, V = kaolinite and vermiculite, M = muscovite, Q = quartz, V = vermiculite.

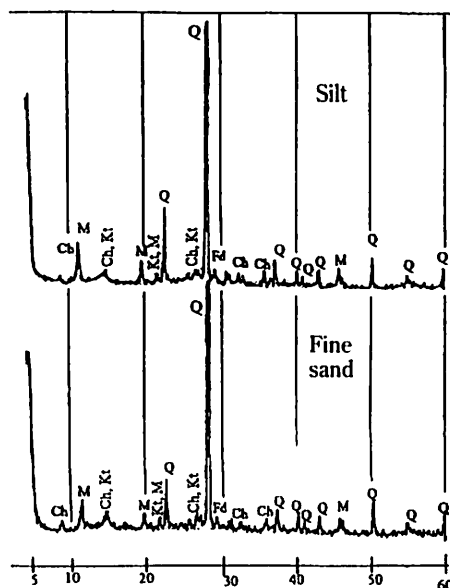


Fig 4. X-ray diffraction patterns of RG silt and fine sand fractions (Random orientation).
 *Abbreviation: Ch = chlorite, Fd = feldspar, Ch, Kt = chlorite and kaolinite, Kt, M = kaolinite and muscovite, M = muscovite, Q = quartz.

Table 2. Mineralogy composition of clay, silt and fine sand of GRC and RG samples.

Particle size	GRC		RG	
	Major	Minor	Major	Minor
Clay	Vt-Ch, Kt	Vt/It, Gt	Vt/Ch, It, Kt	Gt
Silt	Qz, M	Fd, Gt, Vt, Kt	Qz, M	Ch, Kt, Fd
Fine sand	Qz		Qz, M	Ch, Fd, Kt

*Abbreviation: Ch = chlorite, Fd = feldspar, Gt = goethite, It = illite, Kt = kaolinite, M = muscovite, Qz = quartz, Vt = vermiculite, Vt/Ch = vermiculite/chlorite irregular mixed layer mineral, Vt-Ch = vermiculite-chlorite intergrade mineral, and Vt/It = vermiculite/illite irregular mixed layer mineral.

Total chemical composition

The results are presented in Table 3. For GRC sample, oxides of alkali and alkaline earth metals accounted to 1.05 while Fe and Al are 13.43 and SiO₂ is 79%. RG sample was 3.89, 25.38 and 65.67% for alkali and alkaline earth metals, Fe and Al and SiO₂ respectively. In both

samples for alkali and alkaline earth metals, K was the highest value followed by Mg, Na and Ca, this trend is the same as those presented by Naruse et al. (1990) for the soil from northern area of Okinawa, and also only concentration of Ca was higher in GRC than RG. The oxides of alkalis and alkaline earth were more than three times higher for RG than in GRC while oxides of Al and Fe were 2 times. The ratios of oxides of soluble cations (alkalis and alkaline earth) to that of insoluble (Al, Fe and Si) were very high for RG (0.042) than for GRC (0.011). This shows the effect of soil erosion in eroding soluble cations in GRC. Kaneshima et al. (1973) and Kobayashi and Shinagawa (1966) analyzed chemical composition of reddish soil from some areas of Okinawa and Na-clay of Kunigami mahji respectively. Their results showed Al was higher than Fe and Mg was higher than Ca. This trend was the same as of this study.

Table 3. Chemical composition (%).

	GRC	RG
Na ₂ O	0.05	0.13
K ₂ O	0.77	3.11
CaO	0.03	0.01
MgO	0.20	0.64
Fe ₂ O ₃	3.85	5.36
Al ₂ O ₃	9.58	20.02
SiO ₂	79.00	65.67
Ignition loss	4.40	5.60
Total	98.03	100.54

Conclusion

Both smaller and lighter particles (silt and Clay) and soluble cations were few in GRC sample than in RG. So, we concluded that this was due to the effect of higher soil erosion rate in Okinawa Island. Also due to differences in mineralogical and chemical compositions we concluded that GRC and RG samples were formed from different parent materials.

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