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Article

Geochemical approach to evaluate deforest of mangroves

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Abstract

Processes of mangrove deforest related human activities were examined. To evaluate changes of soil feature, multi-elements geochemical compositions of mangrove muds and soils of deforest were analyzed. To describe present situation of the mangrove, Conakry in Guinea, Dar es Salaam in Tanzania, Sundarbans of Bangladesh and Nago in Okinawa of Japan were selected. Soil samples of the forests were evaluated enrichment of biologically concentrated heavy metals such as Zn, Cu and Fe, and TS (total sulfur) and phosphate. Mangrove soils of dominant biome are normally dark colored and enriched in organic matter and element concentrations indicated above compared to those of deforest soils. On the other hand, Ca contents became higher in deforest soils due to inflow of marine carbonate matter by the disappearance of mangrove barrier. Deforest and degradation of soils were related to the land use and agriculture practices; namely development of paddy field and logging in Guinea, salt farm development in Tanzania, red soil inflow and development of constructions in Okinawa. Although the observations were limited in small area, geological and geographical examination can reveal mechanism of the degradation of the forest in relation to environmental change. These observations and geochemical data set would be useful for planning of conservation of mangrove.

Key words: mangrove, tidal zone, conservation, deforest, human activity

Introduction

Mangroves are peculiar salt tolerant biome developed in large coastal areas between latitudes 25° N to 25° S (Giri *et al*., 2011; Sandilyan and Kathiresan, 2012). These areas are thus characterized by the climate of tropical to sub-tropical and by huge variation of tidal level especially at the spring tide. Mangroves has been used for natural resources and these land has served to agriculture, exploitation of fishery and mining operation etc. (FAO, 2007). The global mangrove disappearance would be 35% during the last several decades of the 20th century (Millennium Ecosystem Assessment, 2005), and the rate of extinction of global mangrove has been accelerated (FAO, 2007). Mangrove may stand severe situation of the extinction in relation to the extent land use, thus the society must therefore strike an appropriate balance of the use and conservation of mangrove ecosystems (Farley *et al*., 2010; Sandilyan, 2011). For the sustainable use of coastal zone, the understanding of the ecosystem and the environment of the mangroves is indispensable. This involves the examination of the formation process of the sediments that mangrove funded their lives. We report present situation of the mangroves of Guinea, Tanzania and Okinawa of Japan, even though the observation was limited in small area. Geological and geographical examination, however, provides mechanism of the degradation of the forest in relation to environmental change.

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Study area

Mangrove research has been carried out in Guinea, Tanzania and Okinawa of Japan. Each study area is described below.

Guinea

In Africa both western and eastern sides of the continent are extensive of the mangrove biome (FAO, 2007), of which cover occupies 21% in the world following to those of Asia (39%). The satellite image using Google Earth (Giri *et al*., 2010) disclosed that the coast of the study site can be seen as one of the densely and thickly developed forest in Guinea. Conakry peninsula is composed of Jurassic mafic to ultramafic rocks of Kakoulima laccolith (Deckart *et al*., 1997). The geology of remainders is composed of granitic rocks of Precambrian age. Coastal area can be divided into sand beach and mangroves (Fig. 1).

Dubreka

Dubreka (9° 47′ 00.04″ N, 13° 30′ 59.75″ W) located northern side of Conakry, forming estuary (Fig. 1) of complicated geography by the mangroves and meandering fluvial systems. Satellite image clearly indicates dense mangroves (Fig. 1). The Konkoure River is a major flow from the inland and Dubreka River forms estuaries in the central and eastern parts of the Dubreka area (Fig. 1). The Ministry of Agriculture reported the present situation of mangroves and distribution of farm areas (unpublished). According to this report and satellite image, some parts of the inner side of the mangroves have been changed to farm areas (Fig. 1). The mangroves observed in March, 2014 show

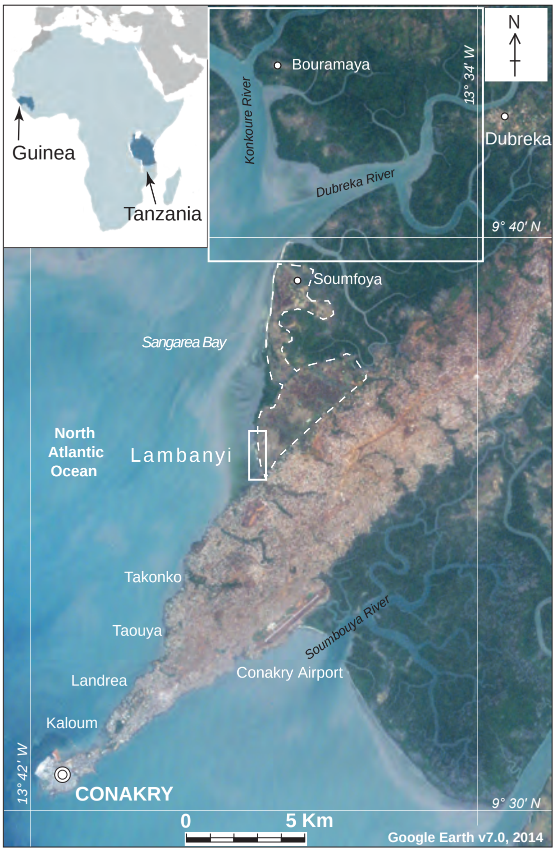

Fig. 1. Map showing index of Guinea and Tanzania in Africa, and Conakry area from Google Earth image. Conakry peninsula is clear for red color houses and mangroves distribution can be distinguished by dark green color. Lambanyi beach (solid line) and paddy field (dotted line) are indicated. Square in norther portion is mangrove study area in Dubreka.

dense communities (Fig. 2 A, B) and mud deposition at the bank of the mangrove which appeared at ebb tide (Fig. 2 B). Sediments are mostly clay and showing light grey color. It is notable of appearance of biomat formed by diatom and algae with yellowish grey color (Fig. 2 B). During the examination, logging along the river coast can been seen (Fig. 2 C), at the small scale dwelling site.

Lambanyi beach

Lambanyi beach (9° 38′ 45.92″ N, 13° 37′ 33.04″ W) located at the northern joint of the Conakry peninsula has the length of 2 km length (Fig. 3). At present narrow white sand beach appeared on the black mud which was supposed to be mangroves (Fig. 1). The northeastern side of this beach occupied by farm area with over 15 km length (Fig. 1). Many mangrove rods remained in the black to dark colored muddy sediments (Fig. 2 D, E). The sketch of 800 m length was drown to describe deforest of mangroves (Fig. 3). The sands are well sorted fine grained character by rich quartz grains (Fig. 2 F). Geochemical analysis was done for the sand samples (no. 1~7 in Fig. 3) showing significant high contents of SiO_2 over 98 wt% (unpublished data).

Tanzania

The eastern side of Tanzania facing to Indian Ocean is characterized by long beach with 1424 km length which is relatively longer coast in Africa following to Mozambique. Close to Dar es Salaam (DSL; -6° 49′ 11.31″ S, 15° 04′ 93″ E), in the Mtoni Relini (river) area, south of DSL and the Kunduchi area, there observed well developed mangroves from satellite image (Fig. 4). In the Kunduchi area, salt farms have been constructed and mangroves have partly disappeared (Fig. 5). The square ponds were constructed to introduce sea water, and then evaporated in the pool. The satellite image shows the process of construction of these salt farms (Fig. 5). Supposing red colored flat plain is the remainder of the salt farm, which now are used for ground of local people (the area indicated in Fig. 5 by an arrow and in Fig. 6 C, D).

The tidal flat occurred during the ebb tide on 10th August, 2015 (Fig. 6A). From our observations, *Sonneratia alba* and *Avicennia marina* are dominated in Mtoni River and Kunduchi areas. Samples for geochemical analysis were collected in Mtoni River and Kunduchi areas in August 2015 (Fig. 6 B and C; Table 1). Msasani coast is characterized by long beachs composed of quartz sands.

Bangladesh

The Sundarbans (UNESCO World Heritage Site) of the Bengal Plain of Bangladesh and West Bengal of India is the largest mangrove in the world. One of the authors (H. I.) had an experiene to visit the mangroves in southern Bangladesh and the margin of the mangroves at Jamtola Beach (21° 50′ 49.29″ N, 89° 49′ 15.49″ E) in 1999 (Fig. 7 A). Mangroves are composed of *Kandelia* and *Rizophora* from the observation at site. This beach is known to be long and wide in Bangladesh and is the site of mangrove tour. The frontal part of the mangrove is covered by sands (Fig. 7 B) and in case they are eroded to appear feature of the roots (Fig. 7 C). Observation of underground roots of the mangrove may be rare, but they were exposed to show complicated structure by the significant erosion (Fig. 7 D).

Japan

Okinawa Islands are composed of many islands located in the southern part of the Japanese Island arc, among these islands the extensive development of the mangroves is famous in Iriomote island (24° 20′ 00.00″ N, 123° 49′ 33.99″ E). The mangrove in the Okinawa Hontou has been believed to be decreased due to intense land use for agriculture practices of sugar cane and pineapples, and constructions of the living site and US army camps. These land use and deforest were considered to be a significant cause of surface soil flows especially related to red soil erosion (Onaga *et al.*, 1999). The accumulation of the red clay transported by fluvial system may affect mangrove habitat and coastal biome, and severely damaging coral reefs of off shore. Our observation in the Nakijin area of Nago City, middle portion

Fig. 2. Photos of mangroves (A and B) and factory of logging and eroded bank (C) at Dubreka. Deforest of mangroves is indicated (D and E) at ebb tide and beach sands on previous mangroves forest (F) in Lambanyi beach (for sketch, see Fig. 3). Black organic muds of previous mangroves are eroded and exposed in the tidal flat (E).

of the Okinawa Hontou (March, 2015) reveals gradual restoration of the mangroves along the coast, comprising of *Rhizophora mucronata*, *Kandelia obovata* and *Bruguiera gymnorhiza*. The Gesashi mangroves (26° 36′ 17.76″ N, 128° 08′ 36.77″ E) is famous for the concentrated biome of the National Heritage of Japan, and the Ohura mangrove (26° 33′ 30.78″ N, 128° 02′ 35.41″ E) designated the Natural Heritage in Nago City (Fig. 8). The Ohura mangroves (Fig. 9A) consist of *Kandelia obovate* and *Bruguiera gymnorhiza*. The former species distributes at the frontal part of the mangroves and marginal part of the forest, while the latter in the central part (Fig. 9B)

Soils of the mangrove shows dark color and is rich in organic matter. L.O.I. values (Table 2) show higher concentrations ranging from 6.89 to 18.34 wt% (average is 12.10 wt%), which is concordant to the observed signature of the soils.

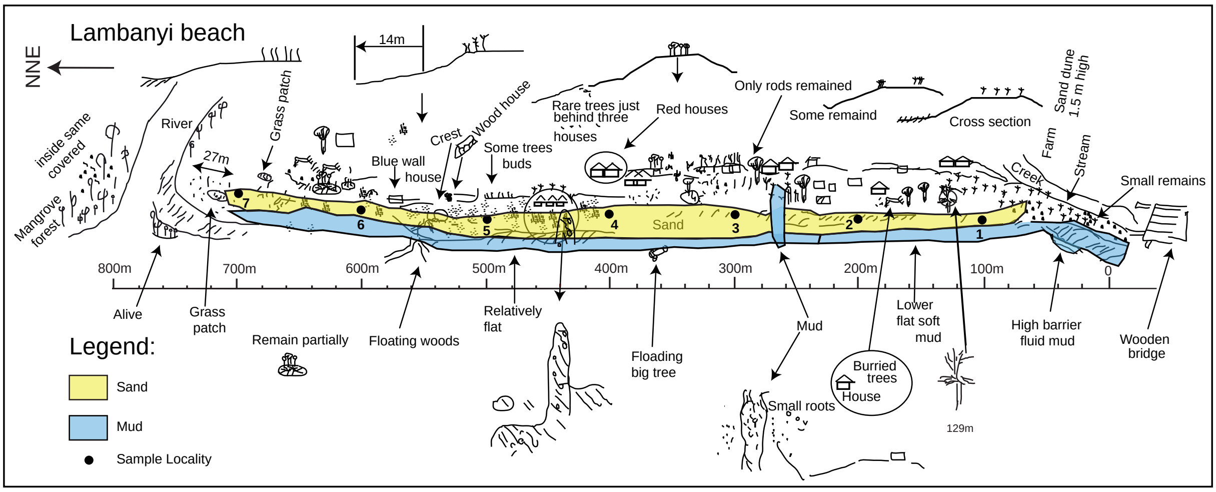

Fig. 3. Sketch of Lambanyi beach in Fig. 1 showing deforest of mangroves related to the development of farm area behind.

Fig. 4. Google Earth image of Dar es Salaam in western Tanzania. Mangroves remain at Mtoni Relini (river) and Kunduchi areas. Long beach developed along the Msasani coast.

Fig. 5. Photo image showing construction of salt farm in mangrove area in Kunduchi (Fig. 4). Square shapes are salt ponds for evaporation of sea water. Arrow indicates the land changed to red soil after deforest of mangroves (see text).

Contrastingly the mangroves of the Gesashi is characterized by variation of species distributions, namely *Rhizophora mucronata* at the part facing to the salt water (Fig. 9 C), and *Kandelia obovate* and *Bruguiera gymnorhiza* at the inner side of the creak (Fig. 9 D, E). Soils of Gesashi is yellow or yellowish grey color (Fig. 9 E) due to the red soil inflow from the surroundings; such as farm and eroded ground (Okinawa Prefecture, 2014; Tsuchiya, 2014). L.O.I. values (Table 2) of the Gesashi mangroves show concentrations ranging from 7.53 to 11.12 wt% (average is 7.54 wt%), relatively lower contents compared to those of Ohura mangrove soil. This is suggestive of less contribution of organic matter for Gesashi mangroves from the mangrove biotope.

Samples for Geochemical analysis

Geochemical analysis of sediments and soils is significant for environmental investigation. To evaluate differences of mangrove mud and other soils which are affected by environmental changes, multi elements geochemical examination was conducted. The Mtoni mangrove muds and Kunduchi salt farm soils from Tanzania are used (Table 1). These samples were imported with permission of Soil Plant Protection, the Ministry of Agriculture, Forestry and Fisheries, Japan in 20^{th} August, 2015. Gesashi and Ohura mangrove muds and Henoko sediments from Okinawa are

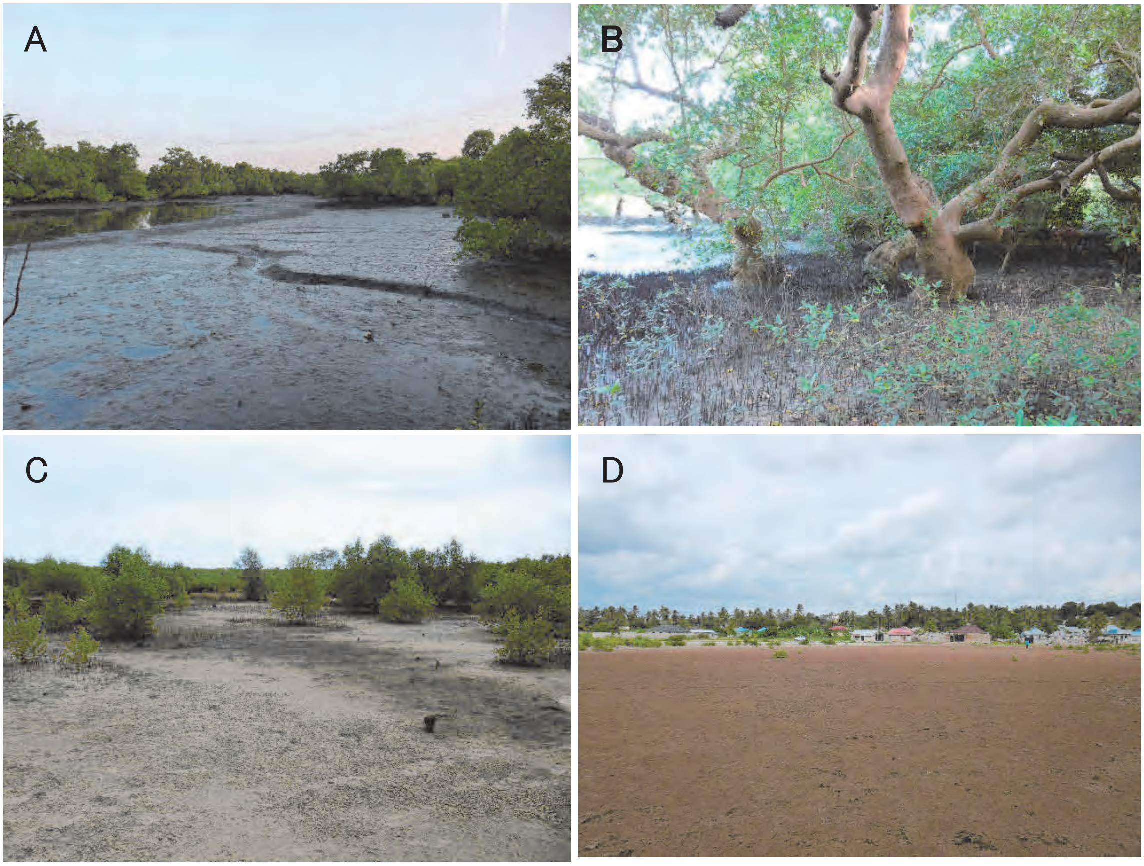

Fig. 6. Photos of mangroves creak (A) and *Avicennia* in mangroves (B) in Mtoni River area. Aerobic roots are fine and flexible representing *Avicennia* characteristics. Feature of deforest (C) and red soil land (D) after deforest are shown.

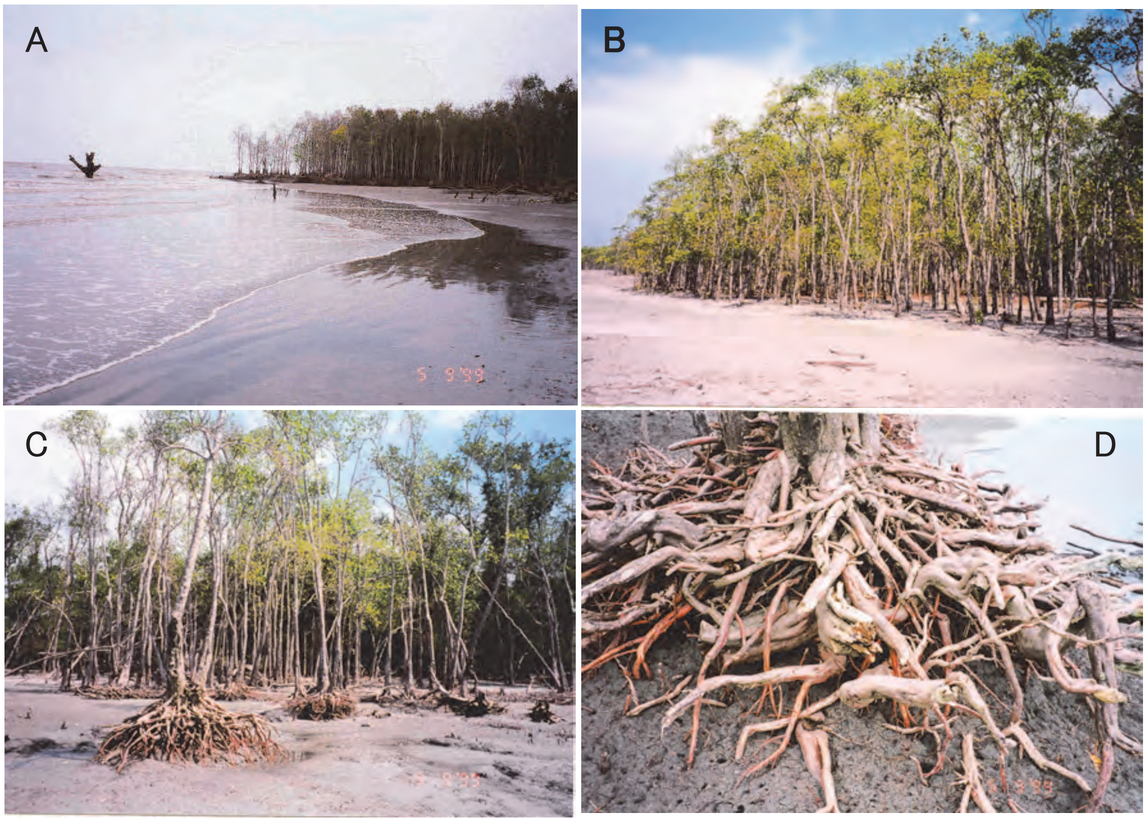

Fig. 7. Deforest of mangroves at Jamtola Beach, Sunderbans, Bangladesh is indicated. Beach coast with tall mangroves (A), mangroves buried by sands (B), eroded mangroves (C) and eroded mangrove root (D) showing complicated structure.

Table 1. Geochemical analysis of mangrove muds from Mtoni and Kunduchi salt farm soils of Tanzania (see Fig. 4).

	Trace elements (ppm)																		Major elements (wt%)				
Sample	As	Pb	Zn	Cu	Ni	Cr	V	Sr	Y	Nb	Zr	Th	Sc	TS	F	Br	I	Cl	TiO_2	Fe_2O_3	MnO	CaO	P_2O_5
Mtoni (M)	mangrove mud																						
1	4	27	84	23	12	86	62	89	8	4	138	2	5	4697		25	49	13754	0.44	2.22	0.02	0.92	0.12
2	8	48	162	49	30	116	146	117	16	11	234	5	11	11574	280	69	25	22561	0.86	6.08	0.02	0.74	0.10
3	7	49	189	61	28	108	144	141	18	12	238	7	11	10153	44	86	16	33525	0.94	6.25	0.03	0.90	0.13
4	7	49	180	56	27	106	137	137	18	12	215	7	9	9839	249	94	27	34500	0.92	6.19	0.02	0.86	0.12
5	8	49	184	58	29	113	144	140	18	12	264	7	11	11237	183	88	22	32466	0.90	6.32	0.02	0.86	0.12
6	8	46	175	59	26	104	138	138	18	11	247	7	9	11257		71	21	26479	0.88	5.97	0.02	0.75	0.10
average	7.0	44.5	162.3	51.0	25.5	105.5	128.4	127.0	16.1	10.3	222.5	5.9	9.5	9792.8	126.0	72.2	26.8	27214	0.82	5.51	0.02	0.84	0.11
Kunduchi (Ku)	salt farm mud																						
1	6	17	52	12	27	110	110	192	15	7	197	5	12	5545	196	35	22	15738	0.69	4.81	0.03	1.63	0.07
2	8	21	61	14	28	92	121	167	17	8	226	6	9	3514		115	27	32610	0.67	5.00	0.02	1.13	0.12
3	8	21	77	12	38	115	143	159	18	9	194	6	10	4718	89	102	31	35132	0.78	5.53	0.02	1.07	0.11
4	9	22	91	15	33	118	134	184	17	8	234	6	12	4580		72	37	34906	0.74	5.60	0.03	2.08	0.13
6	10	32	128	24	34	91	118	198	19	9	164	6	25	3751	133	84	11	43218	0.70	5.78	0.12	6.35	0.16
7	7	20	76	13	21	83	93	189	15	7	246	5	15	4613	74	77	21	46076	0.59	4.02	0.08	3.98	0.11
8	5	17	50	8	20	69	72	213	13	7	238	4	12	1802		28	31	12966	0.55	3.05	0.08	3.29	0.09
9	7	20	79	14	27	101	106	200	17	8	286	6	15	1815	232	32	32	14046	0.74	5.13	0.09	2.91	0.11
average	6.5	18.9	68.1	12.4	25.2	86.5	99.6	166.7	14.62	6.844	198.3	5.0	12	3371	80.4	60.6	23.6	26077	0.61	4.32	0.05	2.49	0.10
M/Ku	1.1	2.4	2.4	4.1	1.0	1.2	1.3	0.8	1.1	1.5	1.1	1.2	0.8	2.9	1.6	1.2	1.1	1.0	1.36	1.27	0.44	0.34	1.12

Table 2. Geochemical analysis of mangrove muds from Gesashi, Ohura and Henoko of Okinawa Hontou (see Fig. 8).

	Trace elements (ppm)																		Major elements (wt%)					(wt%)
Sample	As	Pb	Zn	Cu	Ni	Cr	V	Sr	Y	Nb	Zr	Th	Sc	TS	F	Br	I	Cl	TiO_2	Fe_2O_3	MnO	CaO	P_2O_5	L.O.I.
Gesashi (Ges)																								
1	12	9	35	14	6	51	94	791	12	4	24	6	5	2481	173	18	9	5913	0.55	3.77	0.02	7.55	0.08	11.12
2	17	11	43	17	8	62	126	392	15	8	177	8	7	2526	196	25	16	6588	0.68	5.35	0.05	3.48	0.11	8.20
3	15	13	39	17	11	57	125	63	16	10	294	10	4	2452	89	26	22	5223	0.70	5.35	0.05	0.70	0.09	6.45
4	13	11	37	15	14	54	117	45	17	9	270	9	6	1407	235	13	22	1164	0.63	4.56	0.03	0.51	0.07	6.10
5	15	13	42	18	12	63	131	54	16	9	223	8	7	1688	122	27	18	5650	0.68	5.47	0.07	0.60	0.09	5.82
average	14.5	11.6	39.0	16.1	10.4	57.4	118.5	269.0	15.0	8.1	197.5	8.0	5.6	2110.8	163.0	21.7	17.4	4908	0.65	4.90	0.04	2.57	0.09	7.54
Ohura (Oh)																								
1	9	24	79	26	28	76	148	77	30	14	310	14	7	3516	296	66	13	11031	0.82	4.95	0.02	0.67	0.12	13.80
2	14	14	60	12	12	54	113	618	21	8	208	9	7	1397		15	15	4858	0.61	4.65	0.03	6.35	0.09	9.36
3	13	26	97	32	30	92	177	87	34	16	336	16	10	3361	137	81		11264	0.97	6.66	0.03	0.72	0.16	18.34
4	11	25	92	31	30	88	166	79	33	16	331	16	9	2590	43	59	4	8468	0.92	6.73	0.04	0.66	0.14	14.01
5	11	25	91	33	31	90	166	75	33	16	360	16	8	3061		48	7	7499	0.90	5.84	0.02	0.63	0.14	12.73
6	10	22	81	27	27	92	159	68	32	16	345	15	9	2051	13	39	14	6257	0.91	6.06	0.04	0.58	0.12	9.54
7	9	18	73	19	24	76	154	58	30	15	326	14	6	1375	43	22	12	3346	0.86	5.35	0.03	0.51	0.08	6.89
average	11.1	21.8	82.0	25.9	26.0	80.9	154.7	151.6	30.4	14.2	316.5	14.1	8.1	2478.7	76.0	47.2	9.2	7532	0.86	5.75	0.03	1.45	0.12	12.10
Henoko (Hen)																								
1	19	11	21	5		16	28	661	7	2	112	2	2	1457		13	18	10541	0.14	1.04	0.01	10.51	0.05	9.23
2	18	11	21	5		10	15	725	6	1	65	3	2	1182		11	19	6479	0.08	1.01	0.01	11.61	0.05	10.77
3	19	13	24	6		11	18	728	7	1	63	4	2	1168	115	11	20	5661	0.09	1.15	0.02	11.07	0.05	10.54
average	18.7	11.5	21.8	5.4		12.3	20.4	704.8	6.5	1.2	80.0	2.8	1.6	1269.0	38.3	11.4	18.9	7560	0.10	1.07	0.01	11.06	0.05	10.18
Oh/Ges	0.8	1.9	2.1	1.6	2.5	1.4	1.3	0.6	2.0	1.8	1.6	1.8	1.4	1.2	0.5	2.2	0.5	1.5	1.3	1.2	0.7	0.6	1.4	1.6
Oh/Hen	0.6	1.9	3.8	4.8		6.6	7.6	0.2	4.7	11.8	4.0	5.0	5.0	2.0	2.0	4.2	0.5	1.0	8.3	5.4	2.2	0.1	2.6	1.2

also used for this examination (Table 2)

Detail description of the samples are given in different paper.

Analytical procedures

Abundances of selected major elements (TiO_2, Fe_2O_3* (total iron expressed as Fe_2O_3), MnO, CaO and P_2O_5) and the trace elements As, Pb, Zn, Cu, Ni, Cr, V, Sr, Y, Nb, Zr, Th, Sc, F, Br, I and TS (total sulfur) in the soils were determined by X-ray fluorescence analysis (XRF) in the Department of Geoscience, Shimane University, using a Rigaku RIX-2000 spectrometer.

After removal of roots and any other plant material, approximately 50 g of each sample was dried in an oven at 160˚C for 48 hrs to remove weakly-bound volatiles. The dried samples were then ground for 20 min in an automatic agate pestle and mortar grinder.

The XRF analyses were made on pressed powder briquettes (about 5 g sample by a force of 200 kN for 60s), following the method of Ogasawara (1987). Average errors for all elements are less than ±10% relative. Analytical results for GSJ standard JSl-1 were acceptable compared to the proposed values of Imai *et al*. (1996).

In this paper analytical results of samples from Tanzania and Okinawa are indicated (Table 1 and 2).

Analytical Results

Tanzania samples (Table 1)

Geochemical variations between Mtoni mangrove muds and Kunduchi soils are significant, namely most heavy metals (Pb, Zn, Cu, Cr) of Mtoni samples show higher values than those of the Kunduchi samples. CaO of the Kunduchi samples have higher values than those of Mtoni samples, suggesting inflow of biogenic carbonate from the beach. Element concentrations of geochemically stable for sedimentation and less affected by human activities (Y, Nb, Zr, Th, Sc and Ti) are same level between two areas, suggesting similar source materials.

Okinawa samples (Table 2)

Ohura samples show similar variation to those results of the comparison of mangroves and salt farm samples

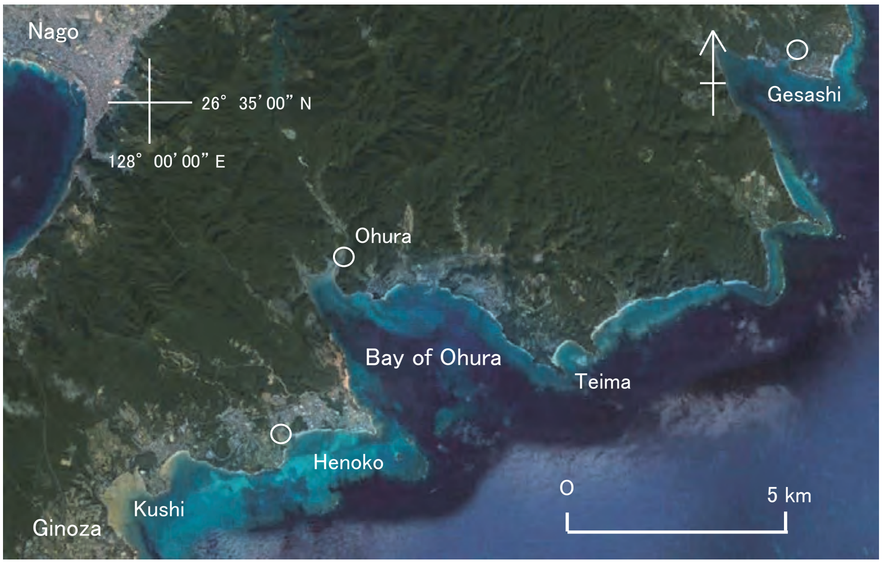

Fig. 8. Map showing location of Gesashi mangroves, Ohura mangroves and Henoko estuary in Okinawa Hontou, Japan.

of Tanzania. Most heavy metals of the Ohura samples show higher than those of the Gesashi samples. Arsenic concentrations of Gesashi samples have relatively higher values of 14.5 ppm in average. CaO and Sr values have higher in Gesashi samples than those of the Ohura samples. Comparing samples of Henoko to Ohura samples, heavy metals of Ohura samples have higher values than those of Henoko samples. Henoko samples are composed of medium and coarse grained sands, thus the trace element concentrations may become lower comparing to mud samples. However, arsenic contents show highest among the three sample groups, which have 18.7 ppm in average. CaO and Sr values are highest in the three sample groups, namely 11.06 wt% and 704.8 ppm, respectively.

Discussion and Conclusion

Mangroves deforest

Conakry a capital town, Guinea has recently developed and intense growing population leads to the expansion in farm areas, especially paddy field. It is reported one million people live in Conakry and such situation can be observed in satellite image of the Conakry peninsula (Fig. 1). As indicated in this figure, norther area of the Lambanyi (marked by dotted line) can be one of the paddy field reclaimed along the coast and inland area. The paddy field development was based on the logging of the mangroves and foundation of the plain land, which in turn has resulted in losing function of windbreak (Sandilyan and Kathiresan, 2012). Wind may accelerate movement of marine waves related to the disappearance of the barrier forests, and sands of shore face may transported up to the beach. This sand can have the potential of erosion of the coast which may damage the mangroves. The feature indicated in Fig. 3 (the sketch map) and Fig. 2 D~F can be strongly suggestive of this process of deforest of mangroves at Lambanyi, Guinea.

Similar situation was observed at Jamtola beach, Sundarbans of Bangladesh (Fig. 7 A~D). At this area sands cover the mangrove forest and deeply eroded roots were apparent (Fig. 7 C, D). In this case the transportation of sands may be related to the human land use, but also global climate change and sea level rise were considered to deforest of mangroves (Sandilyan, 2011; Giril *et al*., 2011). To clarify the issue of mangrove deforest, detailed researches of the Sundarbans are necessary.

Geochemical compositions of mangrove mud

The geochemical analysis clearly revealed the difference of compositions between the mangrove muds and soils of deforest from examples of Tanzania and Okinawa. To test this difference more apparent, mangrove mud compositions were normalized by those of deforest samples. Result of the Tanzania samples (Fig. 10) demonstrates significant enrichment in Pb, Zn, Cu and TS. Zinc and Cu are concentrated in organic rich sediments (Tribovillard *et al*., 1994; Ahmed *et al*., 2010), which have been used for evaluation of environment. TS values are also higher in marine sediments and may be absorbed in organic muds (Ahmed *et al*., 2010). Calcium value of mangrove samples shows depletion from the deforest samples, suggesting influence of biogenic carbonate from marine sediments. As noticed in analytical results, deforest samples yield CaO = 2.50 wt% (average) which would be transported after the weakened windbreak of the mangroves.

Another case of the deforest soils is Okinawa Hontou, which is related to the red soil inflow from the surrounding areas. Samples of Gesashi mangroves (Fig. 8) show relatively lower concentrations of heavy metals, especially Zn content

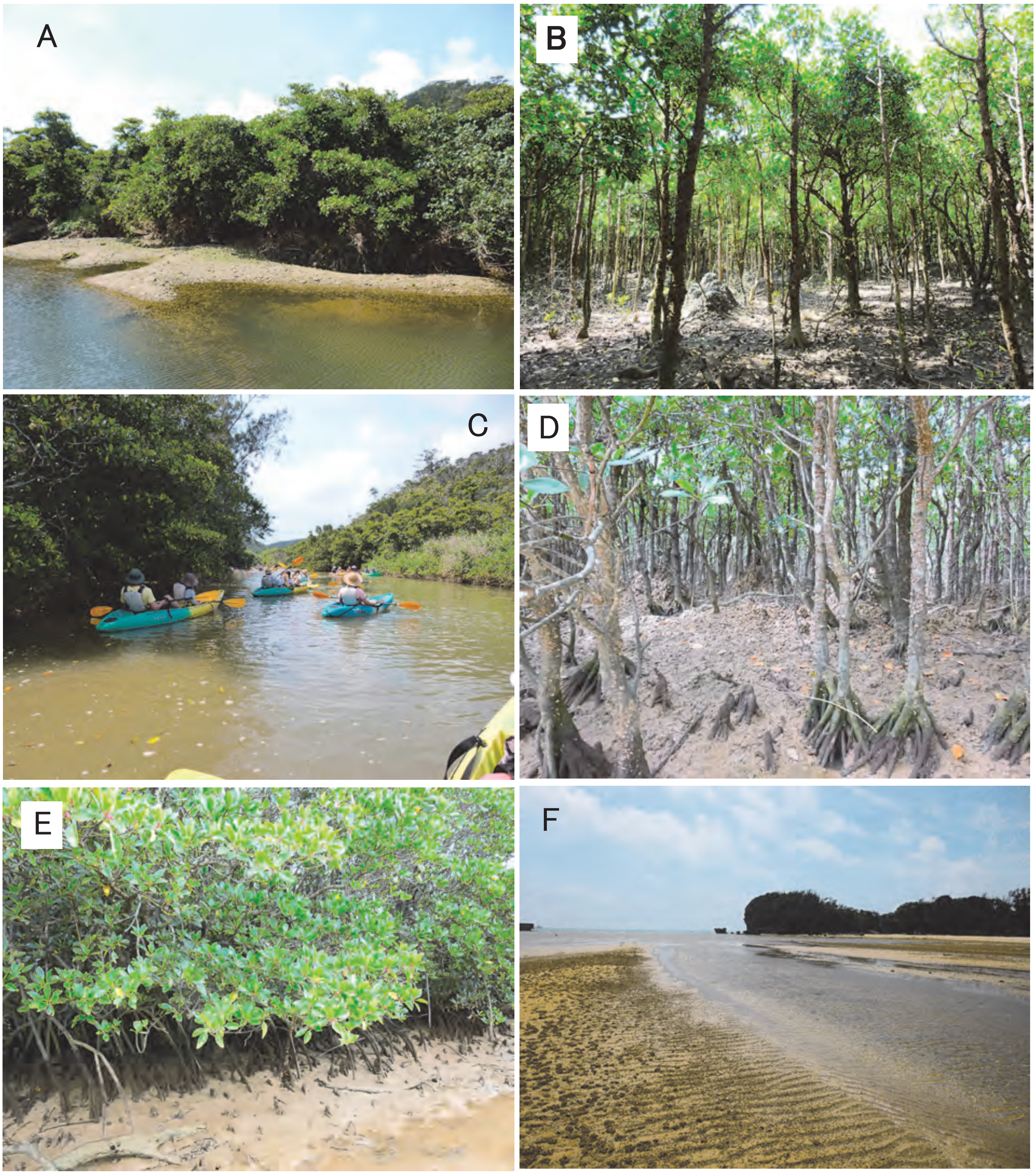

Fig. 9. Mangroves in Ohura area (A) and inside of the forest (B) in Nago, Okinawa (Fig. 8), showing dominance of *Buruguiera* and mounds formed by *Thalassina anomara* can be observed. Gesashi mangrove creak is used for Sea Kayak to understand ecology and environments (C). Water in creak at spring time shows yellowish color due to inflow of particles from red soils. Red soils cover on the mangroves (D and E). *Rizophora* is dominated frontal part of the mangroves (E). Henoko estuary at ebb tide showing red yellowish sands coated by iron oxides (F).

(average) with half level of that of Ohura mangrove muds. Considering lower contents of L.O.I. in Gesashi samples (Table 2), samples covered the mangrove creek (Fig. 9 D, E) can be derived from red soils of the catchment of the Gesashi River. Impact of the red soil inflow and sedimentation in the mangrove area was considered that burial of channel, stagnation of creeks and contamination of water quality related to less circulation of fresh and marine water exchanges (Okinawa Prefecture, 2015). Such changes to inorganic environment also affect the burial of aerial roots and brace roots of the mangroves (Okinawa Prefecture, 2015). Organic matter rich soils are fundamental of the variety of biome (Sandilyan and Kathiresan, 2012), thus the protection of the red soil inflow is urgent and indispensable issue for the

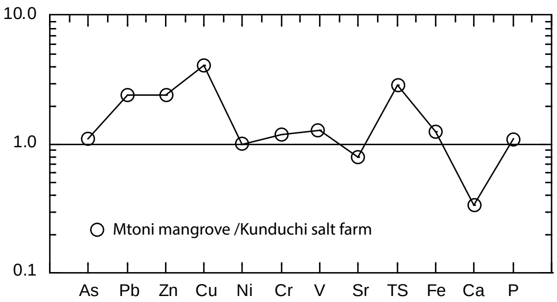

Fig. 10. Plots of normalized geochemical values of Mtoni mangrove by Kunduchi salts farm soils, Tanzania (see text).

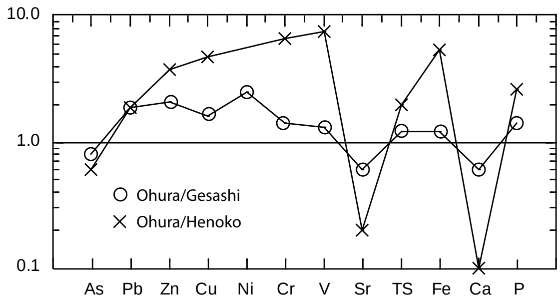

Fig. 11. Plots of normalized geochemical values of Ohura mangrove by Gesashi mangrove muds (red soils) and Henoko estuary sediments (see text).

mangroves conservation.

The Henoko located estuary of the Henoko River (Fig. 8), and the wide diversity of biota in coral reef is well known (NACS-J, 2010). Henoko estuary has been changed to sandy beach (Fig. 9 F) in relation to the development of the town around the Camp Schuwab of US Army from 1956. The sands of the beach show reddish yellow and consist of medium and coarse and angular grains. Reddish yellow color can be related to coatings by iron oxides, so that the color decolorized by diluted acid. Arsenic contents (18.7 ppm in average) show higher than those of Gesashi samples, suggesting of arsenic compound may be adsorbed on the sand grains with iron oxides, even these are coarse grains. Geochemical compositions of the Henoko samples show lower heavy metal concentrations compared to those of the Ohura mangrove samples. Zinc and Cu contents were significantly lowered due to coarse grain size and less amount of finer particles. CaO values, however, show higher contents close to 10 wt% which represents derivation of fragments of biogenic carbonate from coral reefs of Henoko Sea. The Henoko Sea has been argued on the environmental issue of conservation of the coral reefs, thus the present data and others from neighboring areas are important and useful for the future research.

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（要　旨）

石賀裕明・Diallo Ibrahima M’Bemba, Bah Mamadou Lamine Malick, Miguta Faustine Ngulimi, Pascal Justine Magai, Shati Samwel Stanley，2016．マングローブ林の破壊についての地球化学的アプローチ．島根大学地球資源環境学研究報告，34，95-104．

人間活動によるマングローブ林の破壊の過程を検討した．土壌の様相の変化をマングローブ土壌と森林の破壊した土壌の両方の試料の多元素組成分析を行うことにより検討した．マングローブの現状を検討するためにアフリカ，ギニアのコナクリ，タンザニアのダルエスサラーム，バングラデシュのシュンドルボンと沖縄本島の名護を選択した．森林土壌は生物活動に関連する Zn, Cu と Fe，それに TS（全イオウ）と P を用いて評価した．生物相の多様なマングローブ土壌は森林の破壊された土壌と比較して，一般に暗色を呈し有機物を多く含み，また，上に示した元素に富む．一方，Ca は森林破壊の土壌において高くなるが，これはマングローブの障壁が消滅したことによる海成の炭酸塩物質の流入による．森林伐採と土壌劣化の例はギニアにおける農地の開墾や伐採によるもの，タンザニアでの塩田によるもの，沖縄での赤土流入によるものなどがある．今回の調査は小規模なものであるが，地質学的，地理学的検討は環境変化に伴う森林の衰退の機構を明らかにできる．この様な観察と地球化学的資料はマングローブ保全の計画を行う上で有益であるといえる．