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Article

Geochemical composition of beach sands from Tottori Prefecture, Japan

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Abstract

Fifteen sand samples were collected from ten beaches along the shoreline of Tottori Prefecture to determine their geochemical compositions, using X-ray fluorescence analysis. Two main river systems (Tenjin and Sendai Rivers) supply sediments to the shoreline from the Chūgoku Mountains. Beach parameters, such as the radius of the approximated circle and radian (ℓ/r), were used to describe beach forms: $\ell/R < 1$ describes a short and concave pocket beach. Sands from the eight beaches investigated in the area contained more than 70 wt% SiO_2, and are predominantly composed of quartz and feldspar. This was reflected in their geochemical compositions, with significant SiO_2, Al_2O_3 and Na_2O contents of the beach sand samples further indicating that quartz and feldspar are the main constituents. Detritus was derived from quartz-rich sources, and quartz dilution strongly influences the bulk chemistry of the beach sands. Positive correlation of most elements with Al_2O_3 and negative correlation with SiO_2 suggests quartz dilution is the main control on chemistry. The sediments were derived from relatively felsic source rocks.

Key words: Chūgoku Mountains**,** Tottori Prefecture, beach sand, geochemistry, quartz, feldspar

Introduction

The compositions of coastal sediments are influenced by numerous components and processes, including source composition, sorting, climate, relief, long shore drift, and winnowing by wave action. Among other factors, beaches are also subject to local processes such as wave and tidal regimes, fluvial discharges, and wind transport (Edwards *et al*., 2009). Beach sands are generally composed of quartz, feldspar, other silicates, lithic fragments, and biogenic material such as shells, and are products of weathering, fragmentation and degradation.

The study area in Tottori Prefecture lies on the coast of the Sea of Japan, and is backed by the Chūgoku Mountains. Sediment is produced by the erosion and collapse of mountains slopes and other causes, transported by rivers, and then carried by the motion of waves and currents to form beaches. In the last decade, some studies have been made of major and trace element abundances in size fractions of stream sediments from the Hino River basin (Ortiz and Roser, 2004; 2006), and of beach sand along Yumigahama Peninsula and marine sediments in Miho Bay (Takahashi, 2006). Other studies carried out in the study area include work on sound producing sand in Japan (Igarashi and Shikazano, 2003) and beach erosion of the Tottori coast (Yasumoto *et al*., 2007). However, the geochemical compositions of beach sands along the eastern shoreline of Tottori Prefecture are not well known. The shoreline of Tottori Prefecture is very important for tourism, as it hosts the largest sand dune in Japan. This is a major attraction in the area, and a better knowledge of compositions of beach sans in the area is thus needed.

The purpose of this study is to describe the geochemical compositions of fifteen beach sand samples collected from ten sites along the shoreline of Tottori Prefecture in the area where the Sendai and Tenjin Rivers supply sediments. The aim of this study is to present new data obtained by X-ray fluorescence (XRF) analysis, and to describe the broad relationships between abundances of elements in the beach sands from the shoreline of Tottori Prefecture.

Study area

The study area is located in Tottori Prefecture in the northeastern Chugoku region, which forms part of Honshu, the largest island in the Japanese archipelago. Tottori Prefecture has a 129 km long coastline facing the Japan Sea, and around 60% of the coastline is composed of beach sand sediment. Samples were taken along the shoreline where beach sand is supplied by two of the main river systems running from the Chūgoku Mountains to the Sea of Japan. These are the Sendai River (sites 1-5) and the Tenjin River (sites 6-10) (Fig. 1).

Sendai River basin

The Sendai River flows through the eastern part of Tottori Prefecture. It has the largest watershed in the prefecture, and is the second longest river after the Hino River in the west. The river rises on Mt. Okinoyama in the Chugoku Mountains, then flows to the north and is joined by several tributary rivers, runs across the central part of the Tottori Plain, and finally enters the Sea of Japan. The Tottori sand dunes are located at the coast near the mouth of the Sendai River, and are formed from sediments derived from the nearby Chugoku Mountains and transported by the Sendai

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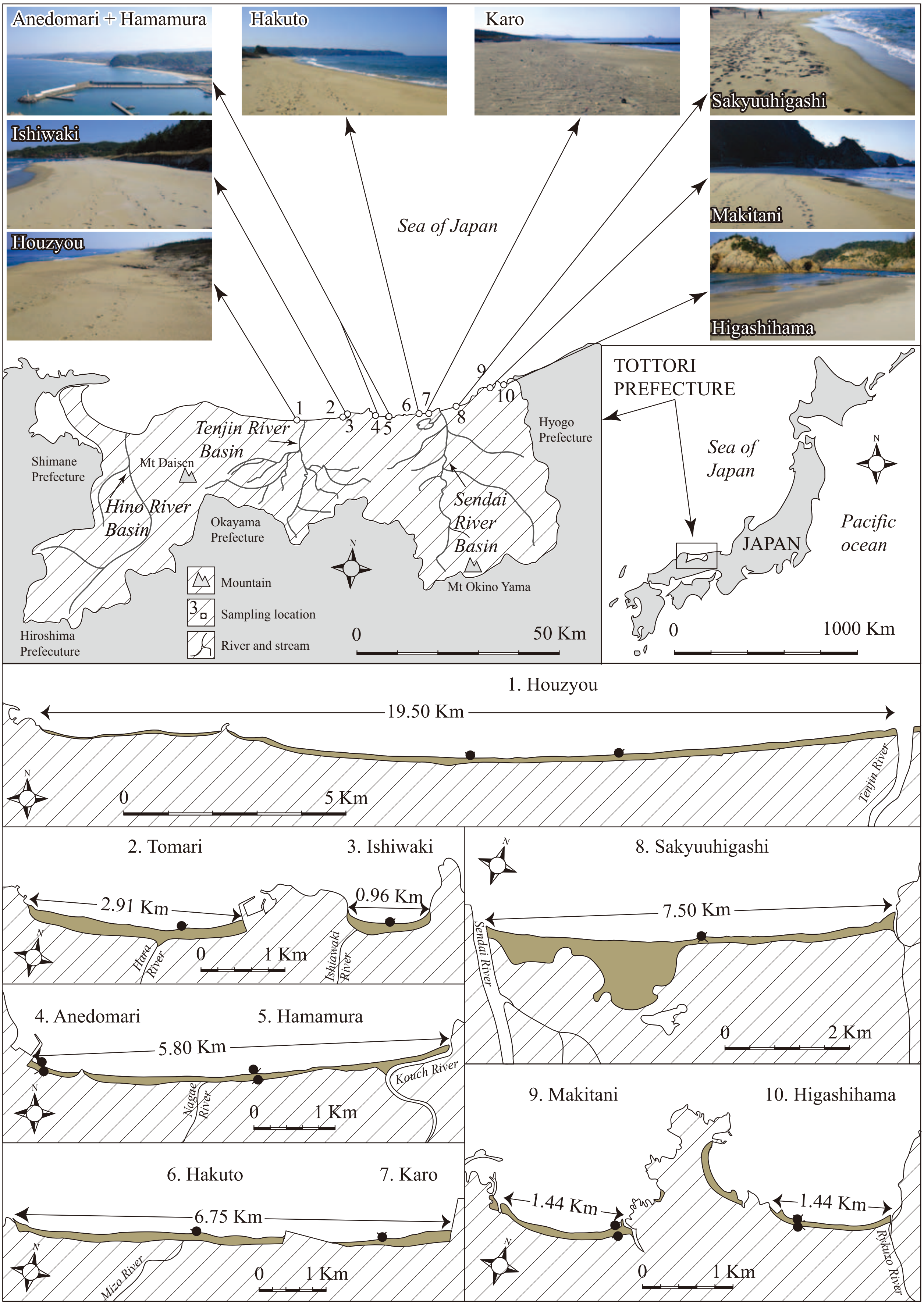

Fig. 1: Map showing the shoreline, sample localities, and outline of the beaches investigated in Tottori Prefecture, Japan.

River to the ocean. The Tottori sand dunes are Japan's largest, covering an area of about 30 km^2. The tallest dunes reach an altitude of about 90 meters above sea level, and slopes reach 40 degrees in some places.

Tenjin River basin

The Tenjin River is located in central Tottori Prefecture, between the Sendai River in the east and Yumigahama Peninsula in the west. The Takeda River, a tributary in the upper part of the Tenjin River, runs through a region of granitic rocks. The Ogamo River, one of the main tributaries of the Tenjin River, flows along a dissected valley on the flanks of the Mt. Daisen volcano.

Types of beach in the study area

The types of beaches present in the area reflect the processes from which the beaches formed, and contain characteristic beach sands. The coastline of Tottori Prefecture is some 129 km in length. The longest of the beaches is that at Houzyou, which stretches some 19.5 km (Fig. 1), whereas the shortest is that at Ishiwaki (0.96 km). The average length of all the beaches investigated is 5.22 km. Among the ten beaches sampled (Fig. 1), four are long (Houzyou, Hakuto, Karo and Sakyuuhigashi); Tomari, Anedomaria, and Hamamura are medium in length, and two (Makitani and Higashihama) are classical pocket beaches. However, Ishiwaki is a very small beach, but cannot be classified as a pocket beach.

Parameters of the beach such as length (L), arc length (ℓ), radius of the approximated circle and radian (ℓ/r) are used to characterize the shape of pocket beaches (Fig. 2). Radian values (arc length of the beach/radius; ℓ/r) of greater than one (> 1) characterize small and concave beaches (Ishiga *et al*., 2010). The beaches at Makitani and Higashihama were found to have radians of > 1, with values equal to 1.11 and 1.08 respectively (Table 1). Other beaches had radian values less than 1, meaning they should be long beaches, although some are less than three kilometers in length. The (ℓ/r) method could not be applied to Houzyou beach because of its extended length (19 km).

Sampling and analytical method

Sampling was conducted on November 6, 2010. Selection of sampling sites was made using 1/25,000 topographic maps (Topographic map of Japan, revised edition, 1979). Three sites were selected on the littoral zone of the Tenjin River, and five around the Sendai River. In addition, two pocket beaches formed between rocky headlands were chosen to complete the study of beaches in the area.

Beach sand samples were collected from the surface of the beaches and packed in plastic bags. Sample location, date of collection, and the type of sand (inshore, foreshore or back shore) were recorded on the labels of the sample bags. A linen tape was used to measure beach lengths, and slopes were measured using an inclinometer. Fifteen samples were collected from the ten beaches. Approximately 350 to 400 g of sample was collected at each site.

About 50 g of each sample were dried in an oven for approximately 24 hours at 110°C. The dried sand samples were then crushed using an automatic agate pestle and mortar. The crushed samples were then used to make pressed pellets and fused glass discs for trace and major element analysis, respectively.

Pressed pellets were made from the powdered samples, using plastic rings (40 mm of diameter) in an automatic pellet press by applying a force of 200 kN in about one minute.

For the preparation of the fused glass discs, about 10 g of crushed sample was stored in glass vials and dried at 110°C for at least 24 hours before determining the loss on ignition (LOI). The LOI determinations were made by transferring about 5 g of dried sample to a previously weighed porcelain crucible, and the overall weight recorded. The samples were then ignited in a muffle furnace for two hours at 1050°C. The power of the furnace was then turned off to allow the crucibles to cool. The crucibles were held in desiccators until they were close to ambient temperature, and then reweighed. Total loss on ignition (total volatile loss, and weight gain by oxidation) was then calculated from the net weight loss.

The ignited materials were then manually disaggregated in an agate pestle and mortar, returned to glass vial, and returned to a 110°C oven for 24 hours. Fused glass discs were prepared using the 2:1 method (Kimura and Yamada, 1996). Fused glass discs were made from a mixture of 1.8 g of the ignited materials and 3.6 g of flux. The mixtures were thoroughly mixed before transfer to platinum crucibles, and then fused in an automatic fusion bead maker with preset fusion parameters.

The XRF analyses were made at Shimane University using an automated RIX 2000 system (Rigaku Denki Co. Ltd.). The ten major elements (SiO_2, TiO_2, Al_2O_3, Fe_2O_3*, MnO, MgO, CaO, Na_2O, K_2O, and P_2O_5) were obtained by analysis of the fused glass discs, and eighteen trace elements (As, Pb, Zn, Cu, Ni, Cr, V, Sr, Y, Nb, Zr, Th, Sc, F, Br, I, Cl, and TS) were obtained by the pressed pellet method (Ogasawara, 1987).

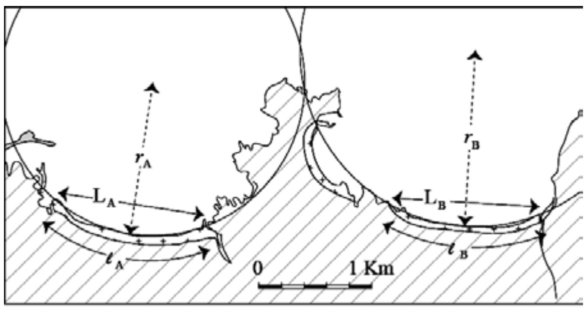

Fig. 2: Shape of the Makitani and Higashihama pocket beaches: (L) beach length, (ℓ) arc length of the beach, and (r) radius of the approximated circle.

Table 1: Shape and characteristics of beach (L = length of the beach, r = radius and ℓ = arc length of the beach).

Sites	L (km)	ℓ (km)	r (km)	ℓ/r
Houzyou-1 + Houzyou-2	19.5	19.6	–	–
Tomari	2.91	2.98	4.72	0.6
Ishiwaki	0.96	0.98	0.99	1
Anedomari+Hamamura	5.8	6.13	8.01	0.8
Hakuto + Karo	6.75	6.8	17.1	0.4
Sakyuuhigashi	7.5	7.58	22.7	0.3
Makitani	1.44	1.48	1.33	1.1
Higashihama	1.44	1.53	1.42	1.1
Mean	5.79	5.88	8.04	0.8

Results

Major elements and LOI

Results of the XRF analysis of the major elements, expressed as weight percent oxide, are presented in Table 2. As expected, SiO_2 is the most abundant, averaging 72.30 wt%, with a range of 66.20-82.23 wt%, followed by Al_2O_3 (average 14.59 wt%, range 10.05-17.35 wt%). Among the remainder CaO (3.89 wt%, range 0.84-7.49 wt%), Na_2O (2.88 wt%, range 1.83-3.50 wt%), K_2O (2.63 wt%, range 1.60-3.77 wt%), Fe_2O_3 (2.47 wt%, range 0.89-3.91 wt%) are the next most abundant on average. MgO (average 1.03 wt%) and TiO_2 (average 0.27 wt%) are present in small amounts, whereas MnO and P_2O_5 (both averaging 0.05 wt%) are present only in trace amounts. In the samples overall, LOI contents are generally less than 2 wt% (Table 2). Three samples with higher LOI values (3.2-5.5 wt%) also have higher CaO contents (5.34-7.49 wt%), suggesting presence of a significant biogenic $CaCO_3$ component in these cases.

Contents of major elements are plotted against SiO_2 contents for all samples in Figure 3. All of the major elements plotted show broad trends of decreasing abundance with increasing silica content. The best correlations are shown by Al_2O_3, Na_2O, and P_2O_5 (Fig. 3). Some scatter to higher values above the general detrital trend is shown by TiO_2, Fe_2O_3, and MgO (Fig. 3). Given the association of elements, these occasional high values are probably caused by sporadic enrichment of heavy minerals such as magnetite or ilmenite, and or ferromagnesian minerals such as biotite or pyroxene. The remaining element, CaO, also shows a well-defined decrease with increasing SiO_2, except for higher values in a small group of samples with low SiO_2 contents (Fig. 3f). These samples also have higher LOI values, and hence are likely to contain a biogenic $CaCO_3$ component such as shell material.

Correlation between Al_2O_3 and the above major elements is shown in Figure 4. As expected from the above, abundances increase with increasing Al_2O_3, suggesting association of most of these elements with the phyllosilicate fraction. However, overall correlations are somewhat poorer than with SiO_2, suggesting that quartz content is the main control of the chemistry of individual samples.

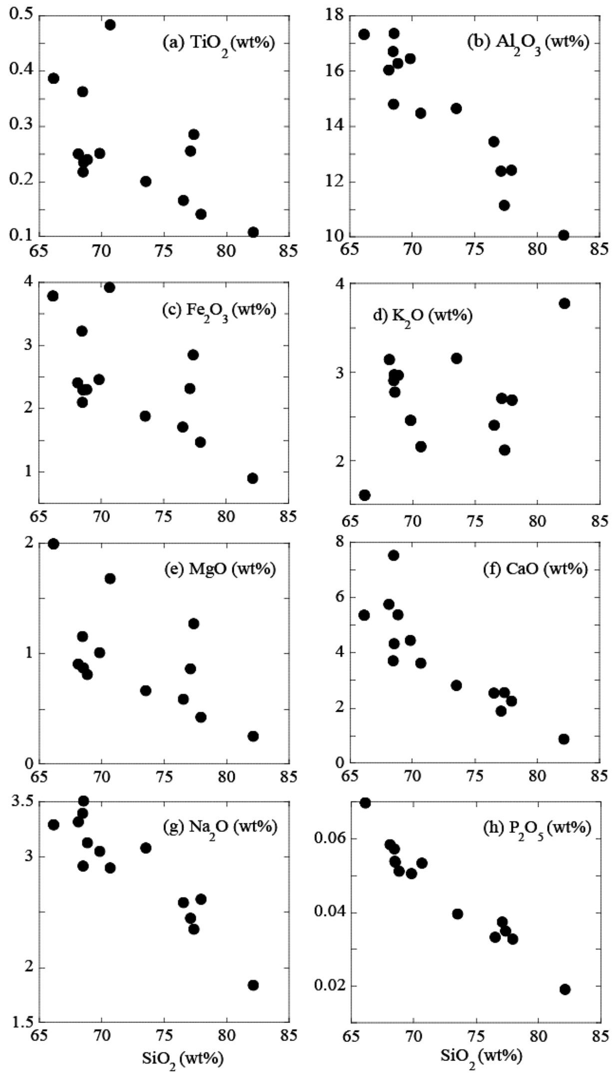

Fig. 3: Major element-SiO_2 variation diagrams for the beach sand samples from Tottori Prefecture, Japan.

Two elements (Na_2O and K_2O) show unusual trends. Na_2O displays strong linear increase with increasing Al_2O_3 (Fig. 4e). This contrasts with the pattern normally seen in quartzofeldspathic sediments, where Na_2O decreases with increasing Al_2O_3 content, due to concentration of albite in the coarser size grades, and depletion in silt and clay fractions (Roser, 2000). The contrasting pattern in the Tottori beach sediments is probably due to higher NaCl content in the finer (less SiO_2-rich) sands. A nonlinear trend is evident for K_2O (Fig. 4g); this probably results from residence of K in two main phases (K-feldspar and phyllosilicates), with the scatter resulting from variable proportions of these two components.

Trace elements

According to the XRF results (Table 3), chlorine in the most abundant trace element, with an average value of 3722 ppm, and a maximum of 7394 ppm. Total sulfur values were

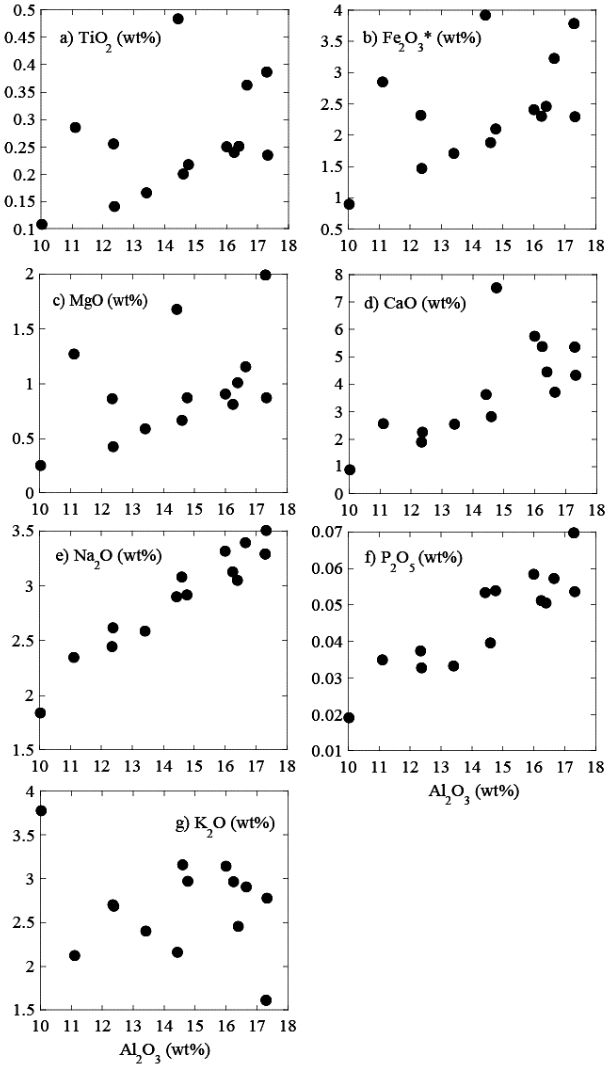

Fig. 4: Major element-Al_2O_3 variation diagrams for the beach sand samples from Tottori Prefecture, Japan.

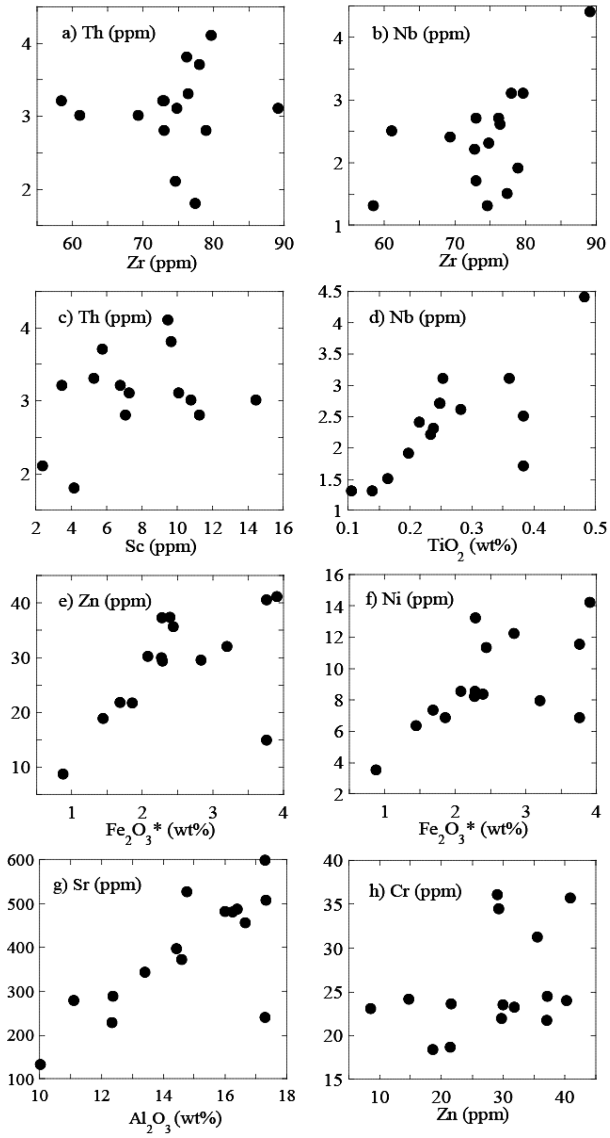

Fig. 5: Selected trace element variation diagrams for the beach sand samples from Tottori Prefecture, Japan.

also significant, ranging from 342 ppm to 1007 ppm, with a mean value of 580 ppm. Strontium was the next most abundant, with a maximum of 598 ppm, minimum of 131 ppm, and average value of 384 ppm.

Among the remaining trace elements, only F, Zr, Zn, Cr, V, and I were present in moderate concentrations. Fluorine values ranged from 37 to 350 ppm (average 158 ppm); Zr from 59 to 89 ppm (average 74 ppm); and Zn from 9 to 41 ppm (average 28 ppm). Chromium (18-36 ppm; average 26), iodine (10-31 ppm, average 22 ppm) and vanadium (3-49 ppm, average 21 ppm) contents were somewhat lower than this group.

Among the remaining trace elements, concentrations of As are relatively high (6-21 ppm), exceeding the value in average upper continental crust. However, Pb (11-15 ppm), Cu (1-6 ppm), Ni (4-14 ppm), Y (12-20 ppm), Nb (1-4 ppm), Th (2-4 ppm), Sc (2-15 ppm) and Br (3-14 ppm) showed very low concentrations normal distributions.

Negative correlations were found between SiO_2 and most of the trace elements (Table 4), whereas those with Al_2O_3 were positive, suggesting association with the phyllosilicate fraction, coupled with dilution by quartz. According to the strong linear correlation between Nb and TiO_2 and between Ni and Fe_2O_3 respectively (Fig. 5d and 5f), these elements are thought to have the same origin.

Discussion

Both major and trace element data provide indications to the composition of the sands due to sedimentation processes and weathering. The major element compositions contain high concentrations of SiO_2, generally more than 70 wt%. The significant SiO_2, Al_2O_3 and Na_2O contents of the beach sand samples indicate that quartz and feldspar are the main

Table 2: Major element abundances (wt%) in beach sand sediments from the shoreline of Tottori Prefecture, Japan. Type of sand: (Blank) = Inshore, (*) = Foreshore and (**) = Backshore.

		Major elements (wt%)										wt%	wt%
Site	Sample	SiO_2	TiO_2	Al_2O_3	$Fe_2O_3^*$	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total	LOI
1	Houzyou	66.20	0.38	17.31	3.77	0.08	1.98	5.32	3.28	1.60	0.07	100.00	0.90
1	Houzyou-2*	82.23	0.11	10.05	0.89	0.02	0.24	0.84	1.83	3.77	0.02	100.00	0.50
2	Tomari	73.57	0.20	14.62	1.87	0.04	0.66	2.78	3.07	3.15	0.04	100.00	0.90
3	Ishiwaki	68.52	0.36	16.69	3.21	0.06	1.15	3.68	3.39	2.89	0.06	100.00	1.20
4	Anedomari	68.61	0.23	17.35	2.28	0.04	0.87	4.30	3.50	2.77	0.05	100.00	1.80
4	Anedomari **	66.20	0.38	17.31	3.77	0.08	1.98	5.32	3.28	1.60	0.07	100.00	0.90
4	Hamamura **	78.03	0.14	12.39	1.46	0.03	0.42	2.22	2.61	2.68	0.03	100.00	1.30
5	Hamamura	76.56	0.16	13.43	1.70	0.03	0.58	2.52	2.58	2.39	0.03	100.00	0.80
6	Hakuto*	77.43	0.28	11.12	2.84	0.06	1.26	2.52	2.34	2.11	0.03	100.00	1.30
7	Karo	70.72	0.48	14.46	3.91	0.08	1.67	3.59	2.90	2.15	0.05	100.00	1.50
8	Sakyuuhigashi *	77.17	0.25	12.36	2.30	0.05	0.86	1.84	2.44	2.69	0.04	100.00	1.40
9	Makitani **	68.58	0.22	14.79	2.09	0.04	0.86	7.49	2.91	2.96	0.05	100.00	5.50
9	Makitani	69.88	0.25	16.43	2.45	0.05	1.00	4.40	3.04	2.45	0.05	100.00	1.90
10	Higashihama	68.16	0.25	16.03	2.40	0.04	0.90	5.71	3.31	3.14	0.06	100.00	4.10
10	Higashihama **	68.89	0.24	16.26	2.29	0.04	0.80	5.34	3.12	2.96	0.05	100.00	3.20
	Mean	72.05	0.26	14.71	2.48	0.05	1.02	3.86	2.91	2.62	0.05	−	1.81
	Min	66.20	0.11	10.05	0.89	0.02	0.24	0.84	1.83	1.60	0.02	−	0.50
	Max	82.23	0.48	17.35	3.91	0.08	1.98	7.49	3.50	3.77	0.07	−	5.50
	STDEV	5.03	0.10	2.37	0.88	0.02	0.52	1.78	0.46	0.59	0.01	−	1.39

Table 3: Trace element abundances (ppm) in beach sand sediments from the shoreline of Tottori Prefecture, Japan. Type of sand: (Blank) = Inshore, (*) = Foreshore and (**) = Backshore.

		Trace elements (ppm)																	
Site	Sample	As	Pb	Zn	Cu	Ni	Cr	V	Sr	Y	Nb	Zr	Th	Sc	F	Br	I	Cl	TS
1	Houzyou	7	15	15	4	7	24	−	239	19	2	73	3	4	198	6	31	293	447
1	Houzyou-2*	6	13	9	1	4	23	−	131	20	1	59	3	−	162	5	25	−	355
2	Tomari	14	13	22	3	7	19	5	371	17	2	79	3	7	62	10	26	4064	621
3	Ishiwaki	14	14	32	5	8	23	32	455	17	3	80	4	10	350	9	22	3404	613
4	Anedomari	16	14	30	4	8	22	9	506	14	2	73	3	7	157	10	20	2753	580
4	Anedomari **	11	11	40	5	12	24	43	598	12	3	61	3	15	115	3	15	−	355
4	Hamamura **	17	13	19	4	6	18	−	287	15	1	75	2	2	156	10	28	4505	679
5	Hamamura	16	12	22	2	7	24	3	342	14	2	78	2	4	131	3	26	−	342
6	Hakuto *	15	11	29	5	12	34	24	277	15	3	77	3	5	200	10	23	3766	598
7	Karo	15	12	41	4	14	36	49	396	16	4	89	3	10	−	9	10	2951	576
8	Sakyuuhigashi *	16	14	29	3	13	36	18	227	17	3	78	4	6	−	10	24	2651	549
9	Makitani **	16	13	30	4	9	23	9	526	17	2	69	3	11	170	12	17	5198	996
9	Makitani	17	13	36	6	11	31	22	486	16	3	73	3	11	102	3	22	−	432
10	Higashihama	21	14	37	6	8	24	17	480	16	3	76	4	10	140	14	18	7394	1007
10	Higashihama **	21	14	37	4	9	22	9	480	16	2	75	3	7	37	4	18	−	517
	Mean	15	13	28	4	9	26	20	387	16	2	74	3	8	152	8	22	3698	578
	Min	6	11	9	1	4	18	3	131	12	1	59	2	2	37	3	10	293	342
	Max	21	15	41	6	14	36	49	598	20	4	89	4	15	350	14	31	7394	1007
	STDEV	4	1	10	1	3	6	15	133	2	1	7	1	3	76	4	6	1854	202

Table 4: Inter-element correlations. Significant correlations (> ± 0.70) are in bold; *n*=15.

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	As	Pb	Zn	Cu	Ni	Cr	V	Sr	Y	Nb	Zr	Th
SiO_2	1.00																					
TiO_2	-0.63	1.00																				
Al_2O_3	**-0.95**	0.51	1.00																			
Fe_2O_3*	-0.68	**0.98**	0.57	1.00																		
MnO	-0.57	**0.95**	0.46	**0.98**	1.00																	
MgO	-0.65	**0.91**	0.54	**0.97**	**0.98**	1.00																
CaO	**-0.87**	0.36	0.74	0.43	0.32	0.44	1.00															
Na_2O	**-0.92**	0.49	0.96	0.55	0.42	0.48	0.70	1.00														
K2O	0.40	-0.66	-0.35	**-0.77**	**-0.81**	**-0.84**	-0.24	-0.29	1.00													
P_2O_5	**-0.95**	0.71	0.90	**0.77**	0.69	**0.76**	**0.76**	**0.85**	-0.49	1.00												
As	-0.17	-0.13	0.17	-0.13	-0.26	-0.28	0.28	0.28	0.18	0.01	1.00											
Pb	-0.28	-0.08	0.36	-0.09	-0.16	-0.14	0.20	0.36	0.32	0.30	0.06	1.00										
Zn	-0.59	0.57	0.51	0.55	0.45	0.43	0.51	0.53	-0.27	0.53	0.61	-0.23	1.00									
Cu	-0.65	0.48	0.58	0.55	0.47	0.48	0.58	0.63	-0.37	0.63	0.45	0.00	0.70	1.00								
Ni	-0.25	0.65	0.12	0.63	0.65	0.57	0.17	0.12	-0.53	0.29	0.27	-0.39	**0.75**	0.45	1.00							
Cr	0.12	0.47	-0.24	0.41	0.46	0.36	-0.18	-0.28	-0.35	-0.04	0.05	-0.28	0.39	0.17	**0.82**	1.00						
V	-0.29	**0.97**	0.13	**0.98**	**0.97**	**0.93**	-0.02	0.10	-0.66	0.50	-0.46	-0.43	**0.72**	0.44	**0.72**	0.51	1.00					
Sr	-0.77	0.31	**0.75**	0.36	0.23	0.30	**0.75**	**0.76**	-0.16	0.63	0.48	-0.12	**0.78**	0.63	0.31	-0.18	0.16	1.00				
Y	0.24	-0.13	-0.28	-0.23	-0.17	-0.21	-0.17	-0.32	0.46	-0.16	-0.43	0.56	-0.56	-0.37	-0.40	0.00	-0.22	-0.60	1.00			
Nb	-0.41	**0.78**	0.30	**0.74**	0.70	0.62	0.22	0.32	-0.44	0.46	0.25	-0.25	**0.79**	0.57	**0.85**	0.74	**0.88**	0.37	-0.28	1.00		
Zr	-0.06	0.37	0.05	0.29	0.23	0.10	-0.10	0.20	-0.14	0.01	0.48	0.09	0.32	0.19	0.37	0.38	0.11	-0.01	-0.06	0.51	1.00	
Th	-0.31	0.36	0.23	0.31	0.26	0.21	0.18	0.27	0.21	0.43	0.09	0.41	0.36	0.35	0.30	0.32	0.26	0.13	0.30	0.52	0.11	1.00

constituents. In general, the compositions of sediments are mainly controlled by the ratio between quartz (SiO_2) and phyllosilicates and clay minerals (Al_2O_3). Strong negative correlation between SiO_2 and Al_2O_3 and positive correlations between Al_2O_3 and most of the other elements indicates that dilution of alumino-silicate minerals with variable amounts of quartz is the dominant control on the chemistry. Overall depletion of CaO and MgO suggests that the carbonate content of the beach sand sediments is generally low, except in a few samples. Most of the trace elements listed in Table 4 show negative correlation with SiO_2. This indicates that the detritus was derived from quartz-rich source rocks. Strontium displays moderate linear increase with increasing Al_2O_3 (Fig. 5g) suggesting that most of the sands are abiogenic, with a few exceptions. There are no significant correlations between Pb and the other elements, suggesting the sands are not contaminated by the former (Table 4).

Conclusions

Major and trace element X-ray fluorescence results indicate that the sandy beach sediments from the shoreline of Tottori Prefecture are composed predominantly of quartz and feldspar. Detritus was derived from quartz-rich sources, and quartz dilution strongly influences the bulk chemistry of the beach sands. Sediment was produced by erosion from the Chūgoku Mountains, and transported by the Sendai and Tenjin Rivers to form the beaches.

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（要　旨）

Bah Mamadou Lamine Malick・佐野絵里香・石賀裕明，2011．鳥取県の海浜砂の地球化学組成の検討．島根大学地球資源環境学研究報告，30，65-72.

鳥取県の 10 箇所の海浜において 50 の砂試料を採取し，蛍光 X 線分析により地球化学組成を検討した．天神川と千代川の構成する河川システムが中国山地から堆積物を海岸に供給している．海浜の形状を示す海浜の半径とラジアンによりポケットビーチの特徴を示す．8 箇所の海浜砂は 70wt% 以上の SiO_2 含有量を持ち，それらは石英と長石からなると言える．このような特徴は SiO_2, Al_2O_3 と Na_2O の含有量にも反映され，海浜砂の構成が石英と長石が主な構成鉱物であることを示す．石英の多く含まれる後背地の起源物質であっても石英粒子による希釈効果が海浜砂の地球化学組成に影響している．ほとんどの元素と Al_2O_3 との正の相関と，SiO_2 に対する負の相関がこのような石英粒子による他の元素の希釈効果を示す．堆積物の起源は珪長質物質である．