

МІНЕРАЛОГІЯ, ГЕОХІМІЯ ТА ПЕТРОГРАФІЯ

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GEOCHEMISTRY OF BEACH SANDS FROM ABU DHABI, UNITED ARAB EMIRATES (UAE)

(Рекомендовано членом редакційної колегії д-ром геол. наук, доц. С. Є. Шнюковим)

Fifty-seven beach sediment samples were collected along the beaches of Abu Dhabi, United Arab Emirates to determine their geochemical composition using X-ray fluorescence and ICP analysis. Two dominant sediment groups i.e. marine biogenic carbonate and terrigenous sediments were identified through major elements scatterplots and ternary diagram of the dominant major elements. CaO has shown negative correlation with all major and most of the trace elements with exception Sr, As and U. The scatter plots for both Al_2O_3 and SiO_2 show positive correlation with all major elements with the exception of CaO and LOI and all the trace elements with exception of Sr, As and U. Therefore, strontium, uranium and arsenic are considered to have marine origin.

Keywords: beach, sands, geochemical composition

1. Introduction. The compositions of coastal sediments are influenced by numerous factors, including source composition, sorting, climate, relief, long shore drift, and wave action. Among other factors, beaches are also subject to local processes such as tidal regimes, fluvial discharges, and wind transport [4]. 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.

Previous research on the origin and genesis of the mineral phases, especially carbonate, in coastal systems have focused mainly on examples from the Bahamas, the Caribbean sea, and a few other areas of the world [2, 3]. In the study area, Evans, Kendal, and Skip with [7] and Kendell and Skipwith [9] made preliminary studies of the sedimentary facies and diagenetic minerals. Evans et al.

[8] explained the mode of formation of the Abu Dhabi, United Arab Emirates (UAE). Alsharhan and Kendell [5] described the carbonate and evaporites of Abu Dhabi. El-Sammak [13] investigated sediment characteristics and metallic element concentrations in the water of Dubai creek. However, until now, studies investigating the geochemistry of beach sands of UAE in general and Abu Dhabi in particular have been few.

The purpose of this study is to describe the geochemical compositions of fifty seven beach sand samples collected along the shoreline of Abu Dhabi. The study presents new data obtained by X-ray fluorescence (XRF) (Table 1) and Inductively Coupled Plasma–Mass Spectrometry (ICP–MS) analyses (Table 2), and will be used to describe the broad relationships between abundances of elements in the beach sands, composition and their possible provenances.

XRF analysis of the major elements, expressed as weight percent oxide

Table 1

Sample	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	SiO_2	TiO_2	L.OI
1	2.41	29.37	1.13	0.55	3.30	0.01	0.95	0.04	31.84	0.11	27.13
2	1.11	48.63	0.38	0.20	2.07	0.00	0.91	0.06	9.01	0.06	36.83
3	2.13	36.82	0.67	0.44	1.94	0.01	3.73	0.05	16.81	0.12	38.25
4	2.91	31.71	1.02	0.55	2.49	0.02	1.27	0.05	26.49	0.14	28.22
5	2.72	37.37	0.99	0.45	1.92	0.02	1.25	0.06	22.61	0.20	33.33
6	1.25	37.79	0.45	0.32	2.79	0.00	4.90	0.04	8.01	0.08	44.80
7	3.28	31.72	1.15	0.63	2.23	0.03	1.13	0.05	31.86	0.18	27.71
8	1.77	41.34	0.58	0.34	1.79	0.01	2.24	0.04	14.03	0.10	38.30
9	3.75	31.20	1.10	0.65	2.33	0.03	1.75	0.06	30.96	0.20	28.40
10	2.43	23.09	0.82	0.73	2.01	0.01	1.24	0.04	48.36	0.11	21.44
11	0.47	48.89	0.28	0.10	1.05	0.00	0.76	0.04	3.89	0.04	42.29
12	2.25	38.64	0.82	0.40	2.64	0.01	1.56	0.05	18.12	0.15	35.22
13	1.61	38.14	1.47	0.24	4.83	0.02	1.25	0.03	17.82	0.09	34.47
14	3.44	32.19	1.02	0.60	1.94	0.02	1.57	0.06	30.81	0.18	28.42
15	3.82	28.39	1.03	0.76	2.27	0.03	2.08	0.05	38.64	0.15	22.70
16	3.14	32.82	0.89	0.60	1.73	0.02	1.58	0.06	30.55	0.15	28.99
17	2.54	36.08	0.73	0.45	3.87	0.02	1.43	0.03	20.03	0.13	34.34
18	3.39	30.87	1.37	0.58	2.93	0.03	1.08	0.05	32.25	0.18	27.06
19	4.42	26.11	1.19	0.81	2.25	0.03	2.11	0.06	38.71	0.21	24.92
20	1.72	36.79	0.67	0.40	2.56	0.01	3.92	0.05	13.74	0.11	37.55
21	2.67	37.04	0.69	0.46	1.81	0.02	1.83	0.04	21.41	0.14	34.05
22	3.17	34.30	0.92	0.55	2.46	0.02	1.50	0.05	25.15	0.18	31.39

End table 1

Sample	Al ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	MgO	MnO	Na ₂ O	P ₂ O ₅	SiO ₂	TiO ₂	L.OI
23	0.94	48.52	0.43	0.15	1.70	0.00	0.32	0.03	6.68	0.09	40.07
24	0.49	48.71	0.22	0.12	0.85	0.00	1.45	0.04	3.58	0.04	43.59
25	2.35	32.70	1.31	0.48	3.97	0.02	0.96	0.05	28.68	0.11	29.23
26	1.39	42.71	0.55	0.28	1.80	0.01	1.20	0.09	12.40	0.08	39.02
27	2.84	30.45	1.42	0.50	5.33	0.03	1.05	0.04	26.48	0.16	28.86
28	3.39	30.45	1.24	0.65	2.81	0.03	1.35	0.06	31.94	0.19	27.69
29	2.70	31.51	1.56	0.46	5.41	0.03	0.91	0.05	26.07	0.16	28.97
30	3.48	22.81	1.56	0.63	6.04	0.03	1.50	0.06	28.64	0.20	23.66
31	2.93	33.73	1.03	0.52	3.00	0.02	1.30	0.06	23.84	0.20	30.57
32	0.62	49.65	0.29	0.11	1.22	0.00	0.67	0.05	4.56	0.05	41.96
33	0.85	42.49	0.48	0.24	3.32	0.01	4.03	0.03	4.07	0.05	44.14
34	4.31	23.84	1.16	0.93	2.90	0.03	1.86	0.05	42.29	0.19	22.58
35	1.02	43.13	0.80	0.21	3.00	0.01	1.13	0.05	11.51	0.07	38.78
36	0.85	47.58	0.33	0.17	1.30	0.00	0.84	0.06	7.25	0.06	40.92
37	1.20	37.28	1.06	0.30	4.28	0.01	0.84	0.04	21.29	0.07	40.00
38	0.70	48.23	0.32	0.13	1.40	0.00	0.65	0.05	6.52	0.05	42.02
39	1.35	45.53	0.44	0.24	1.60	0.01	0.97	0.05	10.53	0.10	38.90
40	0.73	48.65	0.24	0.13	1.01	0.00	0.76	0.05	6.24	0.05	41.26
41	1.28	41.19	0.72	0.29	2.09	0.01	0.93	0.05	17.28	0.10	35.65
42	3.76	33.42	1.27	0.48	3.54	0.03	1.48	0.05	25.44	0.18	30.00
43	2.12	34.18	0.84	0.56	2.28	0.01	1.05	0.04	28.82	0.10	30.19
44	2.10	34.62	1.77	0.38	5.58	0.02	0.95	0.05	23.01	0.14	31.37
45	2.22	38.50	0.81	0.40	2.30	0.02	0.99	0.06	19.27	0.14	33.83
46	2.48	38.33	0.90	0.47	2.66	0.02	1.64	0.05	18.01	0.15	35.17
47	1.90	42.33	0.81	0.37	2.25	0.01	1.25	0.05	13.68	0.11	37.71
48	1.49	40.53	0.55	0.38	1.47	0.01	0.93	0.05	18.62	0.11	35.41
49	2.39	35.02	2.15	0.25	6.92	0.03	0.81	0.05	20.89	0.13	30.33
50	2.78	27.72	0.98	0.65	1.81	0.02	0.83	0.05	40.68	0.21	23.93
51	2.99	34.32	1.11	0.54	2.01	0.02	1.14	0.06	27.61	0.23	29.63
52	1.81	40.77	0.74	0.35	1.78	0.01	0.86	0.06	18.22	0.12	34.77
53	3.41	31.79	1.10	0.61	2.48	0.03	2.19	0.06	29.12	0.27	29.85
54	1.25	43.70	0.48	0.25	2.22	0.01	0.94	0.08	11.95	0.12	38.38
55	4.33	26.53	1.10	0.78	2.73	0.03	2.34	0.06	37.21	0.23	25.53
56	1.72	36.28	1.08	0.41	3.30	0.01	0.78	0.04	24.17	0.12	31.70
57	0.36	50.97	0.23	0.09	0.80	0.00	0.82	0.05	2.66	0.03	43.35

1.1. The study area is located in Abu Dhabi emirate (state) which is the capital and the largest city in the United Arab Emirates. Abu Dhabi, accounts for 87 percent of the UAE's total area (67,340 square kilometers), with an estimated population of 896,751 in 2009. Abu Dhabi generated 56.7% of the GDP of the United Arab Emirates in 2008. UAE is situated in southwest Asia, boarding on the Gulf of Oman and the Arabian Gulf, between Oman and Saudi Arabia. It is located along the northern part, approaching the strait of Hormuz which is a central transit point for world crude oil. the UAE lies between 22°50' and 26°00' north and between 51°00' and 56°25' east. The climate in the UAE is hot and humid in the summer time, moderate with slight raining in the winter. the average temperature in the coastal site of Abu Dhabi emirates is 43°C between May and September, and 14°C between October and April.

The United Arab Emirates coast is mainly Holocene sediments accumulated on Neogene sedimentary rocks (Fig. 1). The Miocene substrate consists of a sequence of marls, sandstone, limestone, and the evaporation occurred

with a southward gentle dip [10]. Along the coast these rocks crop out northeast – southwest escarpment with height more than 35 m, paralleling the United Arab Emirates escarpment called by valleys that trend northwest – southeast. The valleys and ridges orientation is similar to that of many of local islands and lagoons, suggesting a combinable structural control and dominant wind blowing from the northwest. Distinguishing between these structural and wind controls is difficult. Banked up against the Neogene rocks and covering them are Quaternary Carbonate known locally as Miliolite [11, 12]. During the last major glacial eustatic change the sedimentary rocks were deposited in the Arabian Gulf. These largely aeolian sands line the inner margins of the present – day salt flats or sabkhas and sometimes their festoon cross beds are exposed as wind-deflated surfaces [14]. They underlie much of the Holocene carbonate evaporate complex and form the core barrier island and headlands. Walkenden and Williams [6], however, argue that since The Arabian Gulf, where the study area is located, has been above sea level for over

much of the past 2.5 Ma, and since it is in tectonic, eustatic and depositional disequilibrium it should not be considered a ramp. Despite this controversy, the Holocene sedimen-

tary fill of the current Gulf has been and will continue to be used as a model for a carbonate ramp [15].

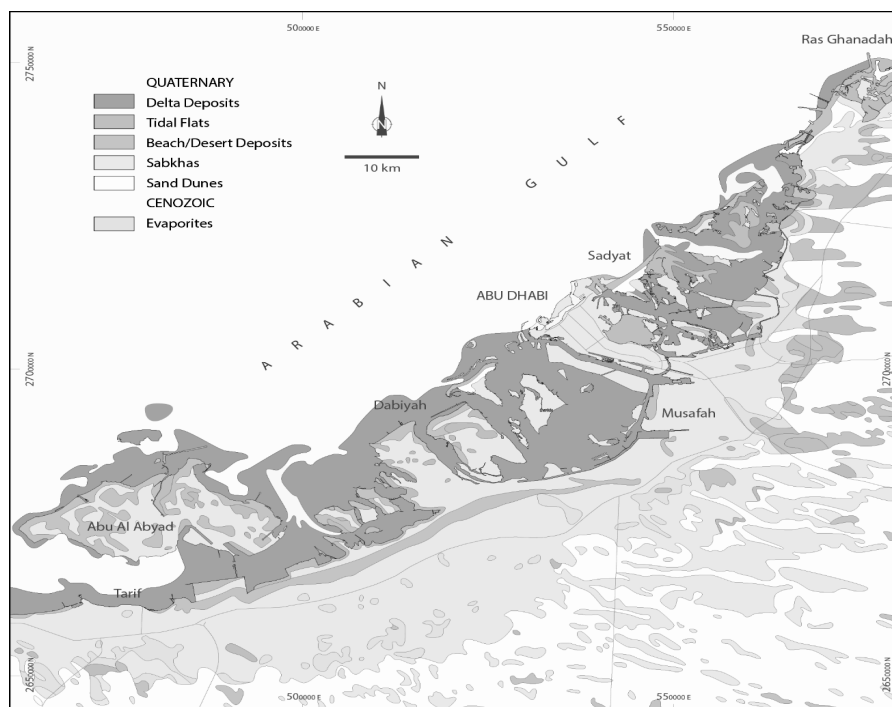


Fig. 1. Geological map of the study area (Simplified from EAD, 2012)

2. Material and Methods

2.1. Sampling. 57 beach sediment were collected from the study area (Fig. 2). Sampling was manually conducted from the coastal sites under the condition of 10–15 cm in length and 5.5 cm in diameter. handling the soil samples followed the 1981 EPA/CE-81-1 protocol [1] the collected

samples were taken in polyethylene bags and transported in sample container 3–4 hours after collection for various analyses. Sample analyses were run out by the Acme labs, Canada, and central analytical facilities, Stellenbosch university, South Africa.

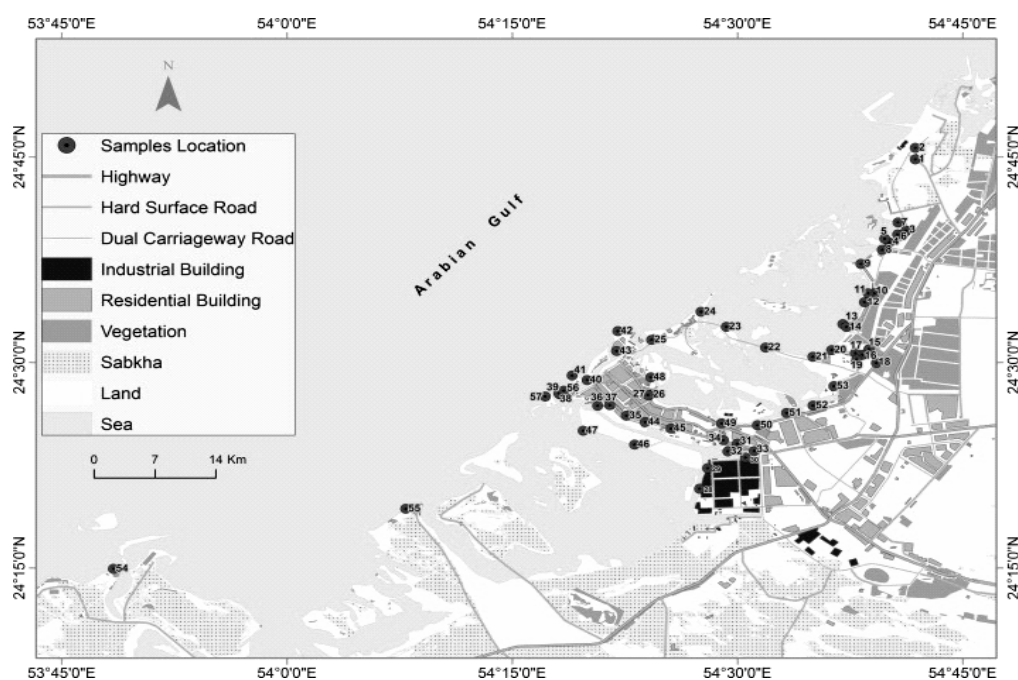


Fig. 2. Abu Dhabi map with blue dots positioning the 57 sampling locations

2.2. Sample analyses were run out with a help of X-ray fluorescence (XRF) (Table 1) and Inductively Coupled Plasma–Mass Spectrometry (ICP–MS) analyses (Table 2)

by the Acme Labs, Canada, and Central analytical Facilities, Stellenbosch University, South Africa.

Table 2

Sampling name and the trace elements concentration, which has been done by Inductively Coupled Plasma (ICP) Analyses

	Analyte	Ba	Be	Co	Cs	Ga	Hf	Nb	Rb	Sn	Sr	Ta	Th	U	V	W	Zr	Y	La
	Unit	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM
Sample	Type																		
1	Soil	201	<1	6.4	0.4	3.1	2.1	3.9	20.0	<1	1702.5	0.3	1.4	1.7	39	<0.5	76.7	7.4	6.7
2	Soil	68	<1	2.6	0.2	1.7	0.8	2.5	8.7	<1	4163.2	0.2	0.9	3.0	26	<0.5	29.1	3.8	4.9
3	Soil	134	<1	4.1	0.4	2.5	1.7	3.8	15.1	<1	2027.5	0.2	1.6	3.2	38	<0.5	65.7	7.4	6.9
4	Soil	157	<1	4.7	0.5	3.6	2.1	3.7	17.3	<1	1430.3	0.2	1.7	1.6	42	0.5	72.2	7.4	9.2
5	Soil	136	<1	5.5	0.5	3.3	4.6	4.9	16.4	<1	1079.6	0.3	2.3	1.9	47	<0.5	166.1	10.0	11.3
6	Soil	90	<1	2.8	0.4	0.9	0.8	1.5	9.6	<1	3653.2	0.1	0.8	2.9	24	<0.5	42.2	3.4	3.8
7	Soil	185	<1	5.2	0.6	2.9	2.2	2.9	20.4	<1	1273.0	0.3	1.8	1.6	36	<0.5	88.9	8.0	9.9
8	Soil	92	<1	2.5	0.2	1.6	1.0	2.0	11.3	3	1647.1	0.2	0.9	2.5	25	<0.5	50.0	5.0	5.9
9	Soil	159	<1	5.3	0.9	3.7	2.1	4.1	21.4	<1	560.9	0.3	2.0	1.4	43	0.5	74.7	8.7	9.9
10	Soil	190	<1	3.2	0.6	2.8	1.9	2.1	21.5	3	870.8	0.1	1.2	1.4	20	<0.5	78.3	5.5	6.0
11	Soil	74	<1	5.0	0.2	1.3	1.1	0.9	7.6	2	3916.1	<0.1	1.8	2.5	22	<0.5	59.4	4.5	6.9
12	Soil	109	<1	2.9	0.4	2.5	2.8	2.0	12.3	1	3389.7	0.2	1.4	3.1	24	<0.5	86.3	7.4	7.2
13	Soil	125	<1	3.9	0.4	2.1	4.3	3.5	12.7	<1	3521.9	0.2	0.8	3.0	24	<0.5	161.9	6.6	3.6
14	Soil	156	<1	4.6	0.5	3.3	2.1	4.0	19.1	<1	880.8	0.3	1.8	1.3	36	<0.5	68.9	8.8	8.7
15	Soil	179	<1	4.6	0.5	2.9	1.5	3.4	19.4	<1	915.3	0.2	1.4	1.5	31	<0.5	56.5	6.8	8.3
16	Soil	197	<1	4.1	0.6	2.9	1.3	2.8	21.1	<1	908.8	0.2	1.4	1.4	44	<0.5	58.3	7.1	7.0
17	Soil	124	<1	3.2	0.3	2.2	1.3	2.7	16.9	<1	2131.9	0.2	1.3	4.6	28	0.6	61.0	6.2	7.8
18	Soil	161	<1	5.0	0.5	3.3	1.6	3.3	19.2	<1	1446.5	0.3	1.6	1.7	32	<0.5	60.7	7.1	7.4
19	Soil	168	1	4.7	0.6	4.0	1.7	4.0	21.9	<1	875.1	0.2	1.8	1.9	33	0.5	58.4	8.2	8.3
20	Soil	115	<1	3.1	0.3	1.6	1.5	2.2	11.9	<1	2330.9	<0.1	1.3	2.6	24	<0.5	60.4	5.9	6.5
21	Soil	131	2	3.7	0.5	2.9	2.3	3.4	17.2	<1	3189.4	0.3	1.6	2.9	40	0.5	107.5	7.1	8.5
22	Soil	123	<1	3.7	0.5	2.7	1.5	4.0	17.1	<1	2328.1	0.3	1.7	3.2	29	<0.5	66.9	8.3	8.7
23	Soil	89	<1	3.5	0.3	1.3	2.6	2.6	10.8	<1	1987.1	0.2	1.2	1.8	26	<0.5	112.5	5.3	5.5
24	Soil	46	<1	1.4	<0.1	<0.5	0.6	1.4	3.7	<1	7243.6	0.1	0.6	3.6	16	<0.5	37.0	2.1	3.4
25	Soil	70	<1	1.3	0.1	<0.5	1.0	1.1	4.9	<1	4643.7	<0.1	0.7	4.0	17	<0.5	41.7	3.2	3.8
26	Soil	99	<1	2.2	0.3	1.1	0.9	1.3	10.7	<1	4444.1	<0.1	0.7	3.1	16	<0.5	36.0	3.8	4.2
27	Soil	176	<1	12.9	0.7	2.6	1.9	3.0	17.3	<1	2188.0	0.2	1.4	2.0	36	<0.5	74.7	6.9	7.3
28	Soil	179	1	4.4	0.7	3.0	3.9	3.2	18.6	<1	923.3	0.2	1.8	1.9	39	<0.5	147.4	8.6	7.5
29	Soil	161	<1	5.6	0.4	3.2	2.6	3.0	18.1	<1	1254.8	0.2	1.6	1.7	33	<0.5	92.7	8.3	8.8
30	Soil	227	<1	9.7	0.9	4.0	3.7	4.6	24.2	<1	1789.3	0.3	2.4	2.2	47	1.1	150.9	9.1	10.2
31	Soil	141	<1	5.1	0.5	2.8	2.9	3.0	17.4	<1	1966.0	0.3	1.5	3.0	36	<0.5	113.7	7.8	8.2

End table 2

	Analyte	Ba	Be	Co	Cs	Ga	Hf	Nb	Rb	Sn	Sr	Ta	Th	U	V	W	Zr	Y	La
	Unit	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM
Sample	Type																		
32	Soil	184	<1	6.7	0.5	2.8	2.0	2.6	18.1	<1	2019.8	0.2	1.5	1.9	34	<0.5	80.7	6.7	9.2
33	Soil	35	<1	1.9	0.2	<0.5	0.4	0.7	4.9	<1	6851.6	<0.1	0.4	4.0	14	<0.5	18.6	1.8	2.4
34	Soil	199	<1	4.1	0.5	3.6	2.5	3.7	23.1	<1	682.3	0.2	2.0	1.4	40	0.6	102.1	8.9	9.6
35	Soil	136	<1	4.5	0.3	1.6	3.0	3.0	13.8	<1	3199.7	0.2	1.2	2.7	31	<0.5	130.4	5.7	5.9
36	Soil	62	<1	1.9	0.2	0.7	0.9	1.1	7.1	<1	4148.8	<0.1	0.7	3.6	15	<0.5	34.2	3.3	3.1
37	Soil	122	<1	5.3	0.3	2.5	1.7	2.5	12.3	1	3208.5	0.1	0.9	1.6	25	<0.5	71.7	4.3	6.8
38	Soil	68	<1	3.2	0.1	1.4	1.0	1.6	7.1	<1	4277.3	<0.1	0.6	2.5	16	<0.5	35.5	3.3	4.2
39	Soil	68	<1	1.1	<0.1	1.6	1.2	1.9	8.0	<1	2033.4	<0.1	0.8	4.6	24	<0.5	45.4	4.0	6.0
40	Soil	28	<1	0.4	<0.1	<0.5	0.1	0.7	3.0	<1	6855.0	<0.1	0.2	2.4	9	<0.5	11.6	1.6	2.0
41	Soil	139	<1	4.6	0.2	2.1	2.7	2.4	11.7	<1	3091.4	0.1	1.0	1.7	25	<0.5	119.1	5.8	6.1
42	Soil	183	<1	4.0	0.5	3.3	1.6	3.2	16.2	<1	1781.3	0.2	1.5	2.8	27	<0.5	61.0	6.6	10.2
43	Soil	180	<1	4.7	0.5	2.8	2.1	2.4	17.9	<1	1852.8	0.2	1.4	1.5	18	<0.5	69.2	4.9	8.8
44	Soil	166	2	6.5	0.5	3.3	2.2	4.1	15.9	<1	1884.3	0.3	1.6	2.2	30	<0.5	91.9	8.0	9.6
45	Soil	210	<1	3.9	0.5	3.3	2.1	3.7	16.1	<1	3148.5	0.3	1.6	1.8	29	<0.5	91.5	7.6	10.6
46	Soil	128	<1	3.2	0.5	2.7	1.3	2.9	13.7	<1	2330.8	0.2	1.5	2.3	21	<0.5	55.3	6.0	7.7
47	Soil	120	1	2.8	0.5	2.8	2.1	3.5	16.3	<1	1098.9	0.2	1.3	2.0	27	<0.5	87.5	6.0	8.7
48	Soil	139	<1	4.0	0.2	2.0	1.7	2.4	13.6	<1	3363.8	0.2	1.0	1.9	17	<0.5	63.2	4.4	5.9
49	Soil	150	1	7.0	0.4	3.2	2.3	3.9	15.9	<1	1829.4	0.2	1.5	2.0	30	<0.5	95.1	7.0	10.2
50	Soil	190	<1	4.8	0.3	3.5	6.7	4.6	20.2	<1	974.3	0.3	1.6	1.3	35	<0.5	262.5	8.3	10.7
51	Soil	149	<1	5.6	0.6	3.7	4.7	6.0	17.5	<1	993.7	0.4	2.0	1.7	41	<0.5	208.1	10.6	13.3
52	Soil	165	<1	4.2	0.6	3.1	2.0	2.8	17.7	<1	1207.6	0.2	1.5	1.5	26	<0.5	82.9	7.4	9.5
53	Soil	141	2	6.6	0.4	3.6	7.1	6.1	14.7	<1	1168.7	0.5	2.5	2.3	46	<0.5	300.1	10.5	12.7
54	Soil	117	<1	5.0	0.3	2.5	7.5	4.4	12.4	<1	3678.5	0.3	1.9	3.4	34	<0.5	288.0	8.2	8.9
55	Soil	396	1	3.9	0.5	3.5	2.5	3.6	19.6	<1	1231.0	0.2	1.6	1.8	27	<0.5	84.2	8.0	10.0
56	Soil	173	<1	7.2	0.4	2.5	4.8	4.0	17.8	<1	1250.9	0.3	1.2	1.7	33	<0.5	210.7	6.4	7.3
57	Soil	77	<1	1.8	0.2	1.2	1.0	1.8	9.7	<1	3914.1	<0.1	0.5	2.6	9	<0.5	37.5	4.0	3.5

To understand the composition, distribution and the source of the beach sediment. Univariate and bivariate analyses were carried out, distribution of the dominant major elements and scatter plots of CaO, Al_2O_3 and SiO_2 , against major and trace elements were studied. Ternary diagram of the three major components, i.e., CaO, SiO_2 and Al_2O_3 was plotted to discover the dominant sediments type.

Results and Discussion. Major and trace element analyses of Abu Dhabi beach sands are listed in Table 1 and 2. The beach sands have moderate to high contents CaO, with abundances ranging 22.81 to 50.97 in wt.% (Table 1), and average of 36.97 in wt.% well above the 4.24 wt.% present in the average. Upper continental crust (UCC) reported by Wedepohl (1995) [15]. The higher values in the beach sands reflects their biogenic carbonate content. The next most abundant element is SiO_2 ranging between 2.66 to 48.35 in wt.% (Table 1), averaging 21.23 wt.%, less than in UCC (66.62 wt.%). Among the remainder LOI (33.42 wt.%, range 21.44–44.80 wt.%), Al_2O_3 (2.23 wt.%, range 0.36–4.42 wt.%), MgO (2.64 wt.%, range 0.80–6.92), Na_2O (1.43 wt.%, range 0.32–4.90 wt.%) are the most abundant on average. Fe_2O_3 (average 0.89 wt.%), K_2O (average 0.43 wt.%), TiO_2 (average 0.13 wt.%) are present in small amount, whereas MnO and

P_2O_5 both averaging 0.02 and 0.05 wt.%, respectively are present only in trace amounts (Table 1). In all samples the CaO and LOI contents are above 20 wt.%, suggesting that marine biogenic CaCO_3 component is dominant in Abu Dhabi beach sediments.

Table 2 also shows the concentration of trace elements in the beach sand of Abu Dhabi. Strontium (Sr) has the highest concentration, averaging 2434.02 ppm ranging from 560.90 to 7243.60 ppm, followed by Chromium (Cr), averaging 272.48 ppm and ranging from 0.001 to 752.62 ppm. Barium contents are significant varying from 28 to 396 ppm, whereas Zirconium varies from 11.60 ppm to 300.10 ppm, Nickel varies 3.50 to 118.20 ppm. Uranium content varies from 1.30 to 4.60 ppm, while Thorium varies from 0.20 to 2.50 ppm. Arsenic contents varies between 1.40 to 5.10 ppm. Concentration of other trace elements are very low.

The mean, standard deviation, minimum, maximum, values generated from the analyses of the 57 beach sand samples are presented in Table 3. The standard deviation of the beach sands chemical composition showed that the sands in the beach area is not uniform. The variation could be attributed to difference in their sources.

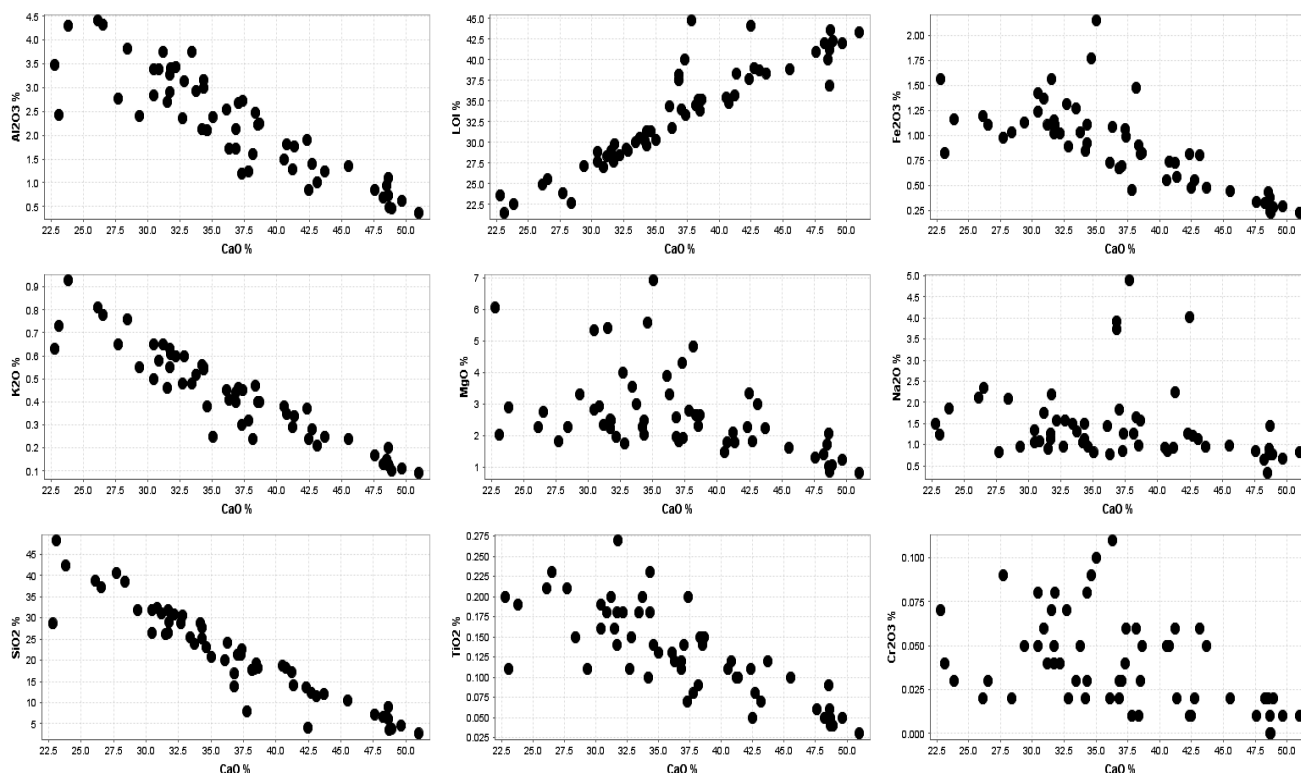


Fig. 3. Major elements – CaO variation in beach sand samples from Abu Dhabi, United Arab Emirates

Correlation involving CaO may be attributed to marine biogenic carbonates. The strong positive correlation between Sr – CaO and Sr – LOI (Table 3, Fig. 3) suggests that strontium is associated with CaO in marine biogenic carbonate material. Similarly the correlation between U–CaO and U–LOI propose the association of uranium with CaO in marine biogenic carbonate, in contrast to Th that has positive correlation with SiO_2 and Al_2O_3 suggesting that thorium has terrigenous sources possible from felsic rocks. As is negatively correlated with most of the major element with exception of CaO, Na_2O and LOI.

Significant correlation was found among trace elements (Table 3, Fig. 4), especially Ni–Co ($r_2=0.76$), Co–Th ($r_2=0.61$), Pb–Zn ($r_2=0.52$), Cu–Zn ($r_2=0.65$), Ni–Zn ($r_2=0.66$), Th–V ($r_2=0.84$), Nb–V ($r_2=0.81$). Cr_2O_3 is mostly positively correlated with Fe_2O_3 , MgO, Co, Nb, V, and Zr, indicating possible heavy mineral minerals and weathering of chromitite rich rocks.

CaO is positively correlated with LOI, Sr, U and As, while is negatively correlated with almost all the major, minor and trace elements, thus suggesting that strontium, uranium and arsenic has marine origin and not from the continent.

Table 3

Correlation coefficient matrix of different geochemical variables for the beach sands of Abu Dhabi

	Al ₂ O ₃	CaO	Cr ₂ O ₃	Fe ₂ O ₃	K ₂ O	MgO	MnO	Na ₂ O	P ₂ O ₅	SiO ₂	TiO ₂	LOI	As	Ba	Co	Cu	Nb	Ni	Pb	Rb	Sr	Th	U	V	Zn	Zr
Al ₂ O ₃	1																									
CaO	-0.88	1																								
Cr ₂ O ₃	0.31*	-0.46	1																							
Fe ₂ O ₃	0.67	-0.74	0.72	1																						
K ₂ O	0.93	-0.93	0.26	0.56	1																					
MgO	0.30*	-0.47	0.59	0.82	0.19	1																				
MnO	0.90	-0.81	0.48	0.82	0.78	0.54	1																			
Na ₂ O	0.16	-0.20	-0.27*	-0.09	0.22	0.01	0.07	1																		
P ₂ O ₅	0.23	-0.07	0.07	0.03	0.16	-0.17	0.19	-0.12	1																	
SiO ₂	0.87	-0.94	0.44	0.66	0.94	0.28*	0.76	-0.01	0.12	1																
TiO ₂	0.90	-0.78	0.48	0.63	0.82	0.26	0.84	0.10	0.33*	0.76	1															
LOI	-0.88	0.92	-0.50	-0.72	-0.90	-0.36	-0.81	0.10	-0.16	-0.96	-0.78	1														
As	-0.05	0.10	-0.23	-0.14	-0.08	-0.07	-0.09	0.27*	-0.30*	-0.19	-0.03	0.23	1													
Ba	0.69	-0.71	0.35	0.70	0.70	0.28*	0.62	-0.02	0.19	0.71	0.63	-0.72	-0.27*	1												
Co	0.37	-0.46	0.65	0.31*	0.54	0.28*	0.55	-0.17	0.02	0.38	0.44	-0.46	-0.22	0.52	1											
Cu	0.27	-0.38	0.21	0.26	0.26	0.36	0.24	-0.12	-0.02	0.31*	0.17	-0.35	-0.09	0.29*	0.42	1										
Nb	0.63	-0.55	0.58	0.54	0.54	0.28*	0.61	-0.05	0.27*	0.55	0.78	-0.59	-0.09	0.56	0.58	0.23	1									
Ni	0.03	-0.26	0.39	0.06	0.06	0.50	0.11	-0.22	-0.26	0.17	-0.04	-0.21	-0.18	0.28*	0.76	0.58	0.10	1								
Pb	-0.09	-0.03	0.41	-0.06	-0.06	0.24	-0.03	-0.24	0.03	0.02	-0.08	-0.07	-0.18	0.12	0.33*	0.29*	0.06	0.42	1							
Rb	0.78	-0.78	0.38	0.80	0.80	0.28*	0.69	-0.04	0.16	0.80	0.71	-0.81	-0.19	0.82	0.59	0.37*	0.69	0.29*	0.10	1						
Sr	-0.71	0.66	-0.39	-0.70	-0.70	-0.19	0.60	0.05	-0.14	-0.71	-0.71	0.71	0.20	-0.68	-0.49	-0.28*	-0.68	-0.18	-0.11	-0.86	1					
Th	0.70	-0.59	0.43	0.62	0.62	0.20	0.65	0.003	0.31*	0.57	0.80	-0.61	-0.01	0.59	0.61	0.32*	0.81	0.17	0.10	0.74	-0.72	1				
U	-0.39	0.44	-0.30*	-0.46	-0.46	-0.02	-0.31*	0.22	-0.09	-0.54	-0.37	0.53	0.36*	-0.59	-0.47	-0.27*	-0.42	-0.30*	-0.20	-0.64	0.60	-0.44	1			
V	0.65	-0.58	0.47	0.54	0.57	0.26	0.61	0.06	0.23	0.54	0.72	-0.58	0.01	0.53	0.64	0.31*	0.81	0.23	0.02	0.73	-0.70	0.84	-0.40	1		
Zn	0.16	-0.32*	0.22	0.19	0.19	0.41	0.19	-0.20	-0.03	0.26	0.08	0.08	-0.17	0.31*	0.47	0.65	0.17	0.66	0.52**	0.31*	-0.22	0.29*	-0.35*	0.23	1	
Zr	0.22	-0.26	0.65	0.22	0.22	0.14	0.28*	-0.16	0.22	0.28*	0.50	0.50	-0.12	0.29*	0.44	0.04	0.72	0.03	0.21	0.34*	-0.36*	0.57	-0.22	0.55	0.10	1

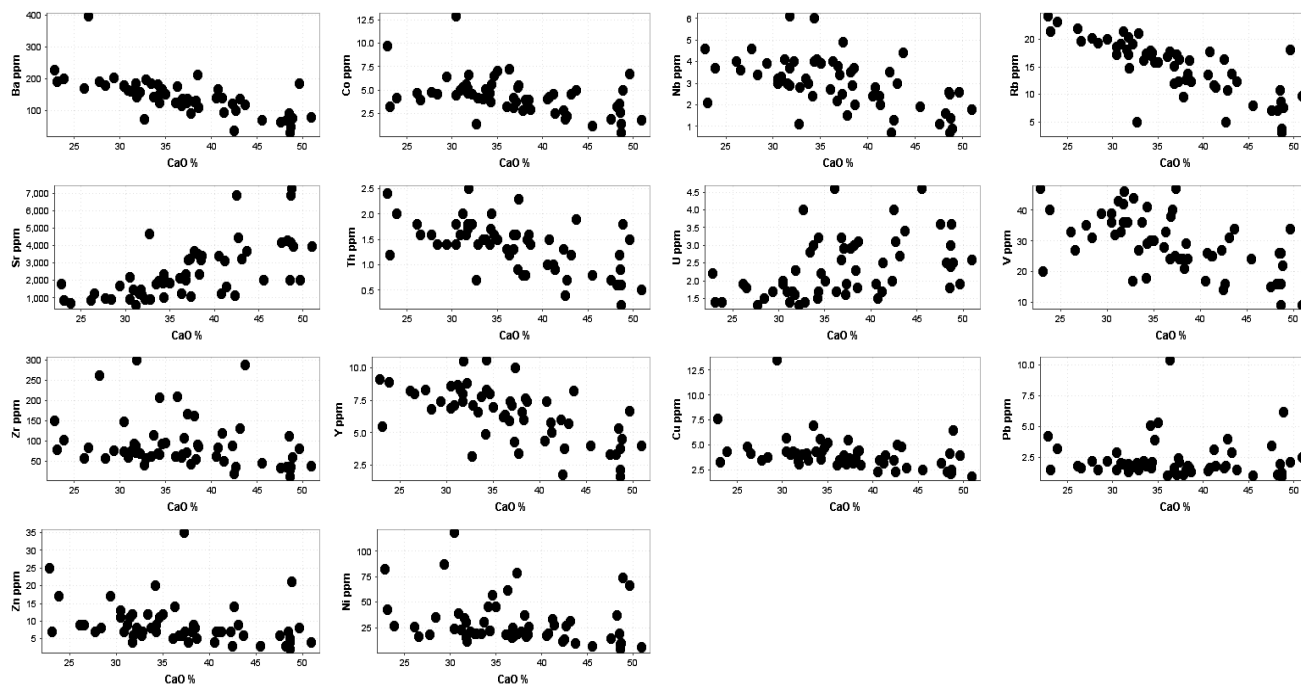


Fig. 4. Minor and trace elements – CaO variation in beach sand samples from Abu Dhabi, United Arab Emirates

The relationship between the three primary components i.e., CaO for biogenic carbonate, SiO_2 and Al_2O_3 in the beach sand sediments of Abu Dhabi samples are shown in

ternary diagram of Fig. 5. The data from the beach sand sediments of Abu Dhabi plot mostly in CaO corner, thus pointing at marine biogenic carbonate materials.

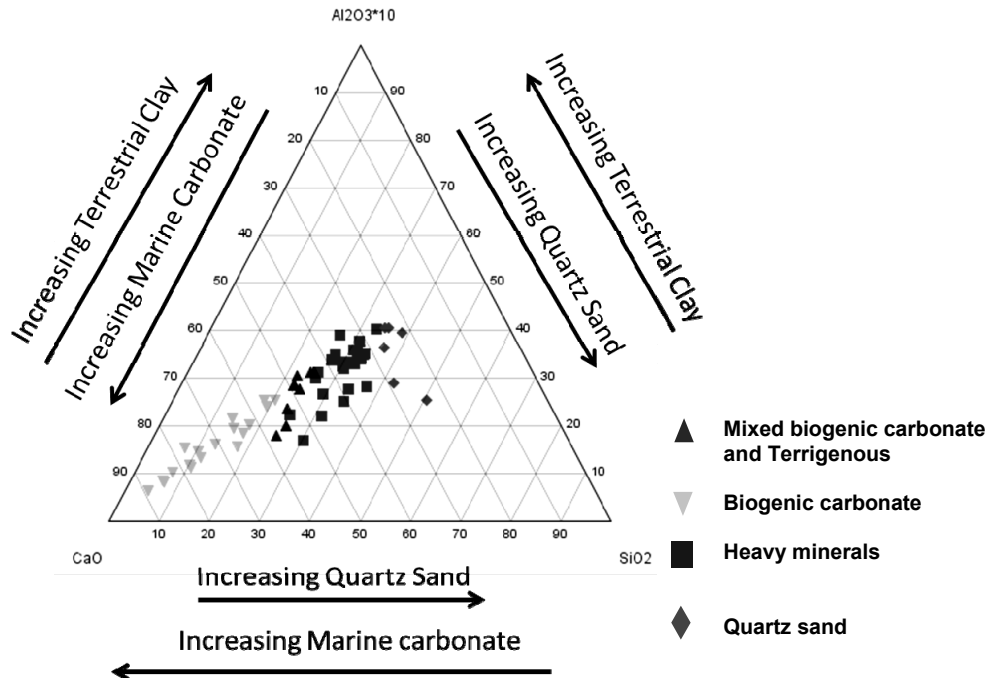


Fig. 5 Ternary plot for CaO , SiO_2 and Al_2O_3 for the beach sand sediments of Abu Dhabi, United Arab Emirates (UAE)

Conclusion. Major and trace X-ray fluorescence and ICP results indicate that the beach sand sediments of Abu Dhabi, United Arab Emirates are composed predominantly of marine biogenic carbonates and terrigenous sediments. The marine biogenic part of the beach sediment is enriched with CaO, LOI, U, As and Sr, while the terrigenous component is derived from intermediate and mafic rocks rich in

chromite (MgO , Fe_2O_3 , Cr_2O_3 and MnO) possibly from Semailophiolites of the Hajar Mountains of Oman and the United Arab Emirates rich in copper and chromite ore bodies. The ternary diagram of the three major components (CaO , SiO_2 , Al_2O_3) suggests the dominance of the marine biogenic carbonate sediments of the Abu Dhabi sand rather than quartz.

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ГЕОХІМІЯ ПЛЯЖОВИХ ПІСКІВ АБУ-ДАБІ, ОБ'ЄДНАНІ АРАБСЬКІ ЕМІРАТИ (ОАЕ)

На пляжах Абу-Дабі, Об'єднані Арабські Емірати, було відібрано п'ятдесят сім зразків пляжових пісків для визначення геохімічного складу за допомогою рентгенофлуоресцентного та мас-спектрометричного ІСР аналізу. На основі діаграм розсіювання головних елементів та розподілу головних домінуючих компонентів було визначено дві домінуючі групи осади, а саме, морські біогенні карбонати та терригенні осади. СаО показав від'ємну кореляцію з усіма головними компонентами та більшістю розсіяних елементів, за винятком Sr, As і U. Діаграми розсіювання, як для Al₂O₃, так і SiO₂, показали додатну кореляцію з усіма головними компонентами, за винятком СаО і LOI, та з усіма розсіяними елементами, за винятком Sr, As і U, що свідчить про морське джерело походження останніх.

Ключові слова: пляж, піски, геохімічний склад

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ГЕОХИМИЯ ПЛЯЖЕВЫХ ПЕСКОВ АБУ-ДАБИ, ОБЪЕДИНЕННЫЕ АРАБСКИЕ ЭМИРАТЫ (ОАЭ)

На пляжах Абу-Дабі, Объединенные Арабские Эмираты, были отобраны пятьдесят семь образцов пляжевых песков для определения геохимического состава с помощью рентгенофлуоресцентного и масс-спектрометрического ИСР анализов. На основе диаграмм рассеяния главных элементов и распределения главных доминирующих компонентов удалось определить две доминирующие группы осадков, а именно, морские биогенные карбонаты и терригенные осадки. СаО показал отрицательную корреляцию со всеми главными компонентами и большинством рассеянных элементов, за исключением Sr, As и U. Диаграммы рассеяния, как для Al₂O₃, так и SiO₂, показали положительную корреляцию со всеми главными компонентами, за исключением СаО и LOI, и со всеми рассеянными элементами, за исключением Sr, As и U, что свидетельствует о морском источнике происхождения последних.

Ключевые слова: пляж, пески, геохимический состав.