Analysis of Beachrock Samples Along Southern and Western Coasts of Sri Lanka by Spectroscopic Methods

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Abstract

Beachrocks are sedimentary structures commonly observed where there is warm sea water in tropical and subtropical regions as a result of cementation by $CaCO_3$ of coastal sediments in the tidal zone. Comprehensive studies have been carried out to determine the formation mechanisms of beachrocks specially Japan to improve an alternative countermeasure against erosion by man-made rocks. When focusing on formation mechanism of beachrocks elemental and mineralogical composition is vital. Considering this important application, we used spectroscopic techniques to understand composition of beachrocks in southern coastal region between Ahangama to Kaikawala and Uswetakeiyawa in the western coastal region of Sri Lanka. The presence of minerals in beach rock samples in southern coast were identified by FT-IR spectroscopic technique. The constituents of minerals present in the beach rocks are further confirmed by XRD technique. Elemental concentrations of beach rock samples have been analyzed using technique of WDXRF spectrometry. Uswetakeiyawa beachrock was mainly analyzed by using EDX in SEM. Beachrocks in southern coasts is comprise higher percentage of Aragonite which is the polymorph of $CaCO_3$, frequently founded in most of the sites in the world. Further the composition shown similarities with Indian (Tiruchendru) and Japan (Okinawa) beachrock occurrences. Comparative to the composition of southern coast beachrock, XRD analysis did not indicate any $CaCO_3$ polymorphs Uswetakeyyawa, beachrocks. Instead it indicated the presence of Kutnohorite ($Ca(Mn,Mg,Fe)(CO_3)_2$).

Keywords: Beachrock, formation mechanism, mineralogical analysis,WDXRF

1 Introduction

Beachrock is considered as the consolidated deposit that formed as a result of lithification of beach sand and gravels by calcium carbonate cementation that generally occurs in tropical and subtropical coasts[1][2]. Beachrocks are comprised of multiple layers varying from 0.5m to 2.5m thickness and hundreds of meters wide and kilometers long outcrops, inclined towars the sea[3][4]. The formation is mainly considered as a result of $CaCO_3$ cementation consisting with High-Magnesian Calcite (HMC) or Aragonite (Ar)[3]. The beachrock can alter the nearshore hydrodynamics, lock the beach profile, change the sediment supply and act as the barrier[4]. Coastal erosion is

becoming a significant problem on the world's coast mainly affecting to the life time of the beachrocks and coastline. To preserve coastlines, many countries apply some solutions by construction of artificial reefs, detached breakwaters, headlands and hard shore protections. However, those are expensive, need long time periods to implement and require large amounts of materials[5][6][7]. So number of countries such as Japan tend to conduct research on formation mechanism of beachrock to improve an alternative countermeasure against erosion by man-made rocks which is made of sea water, sand and bacteria actions. By considering that application, this study is focused on elemental and mineralogical analysis of beachrock along the southern coast, between Ahangama to Kaikawala and Uswetakeiyawa in the western coastal region of Sri Lanka, because understating the elemental and mineralogical compositions is important in making artificial beachrocks.

The elemental concentrations of beach rock samples have been analyzed using non-destructive technique of Wave Length Dispersive X-ray Fluorescence (WDXRF) Spectrometry. The presence of minerals in beach rock samples in southern coast is identified by Fourier Transform Infrared (FT-IR) Spectroscopic technique. The constituents of minerals present in the beach rocks are detrmined by X-ray diffractive (XRD) technique.

Uswetakeiyawa beachrock was mainly analyzed by using Energy Dispersive X-ray analysis (EDX) in Scanning Electron Microscope (SEM).

2 Study Area and Sample Locations

2.1 Sample Locations in Southern Coast

Sample collection was carried out along the coastal tide line which lies between Ahangama to Kaikawala which is located approximately 130km South from Colombo. Samples were collected from nine locations along the tide line and total number of samples collected are fifteen at each location (Table 1 and Figure 1).

Table 1: Sample Locations Map Between Ahangama To Kaikawala Tide Line in Southern Coast [7].

Location	GPS coordinate	
	Latitude	Longitude
L1	5.96441^0	80.38536^0
L2	5.96557^0	80.37448^0
L3	5.96738^0	80.37178^0
L4	5.96898^0	80.36705^0
L5	5.9837^0	80.32923^0
L6	6.00275^0	80.25447^0
L7	6.37133^0	80.00905^0
L8	5.96053^0	80.39842^0
L9	5.96756^0	80.37403^0

Figure 1: Sample Location Map Between Ahangama to Kaikawala Tide Line [7].

2.1 Sample Locations in Western Coast

Table 2 shows the twelve sample locations selected along the shore at Uswetakeiyawa beach [8].

Table 2: Sample Locations Along Western Coast [8].

Locaion No	GPS coordinate	
	Latitude	Longitude
S 1	202897N	99224E
S 2	203163N	99180E
S 3	203353N	99130E
S 4	203498N	99097E
S 5	202877N	99233E
S 6	202898N	99225E
S 7	202917N	99222E
S 8	203432N	99113E
S 9	203383N	99120E
S 10	203360N	99133E
S 11	203290N	99135E
S 12	207474N	98169E

Sample collection was carried out along the coastal tide line along the Uswetakeiyawa beach located approximately 14 km North from Colombo. Samples were collected from eight locations (Table 2) along the tide line as shown in Figure 2.

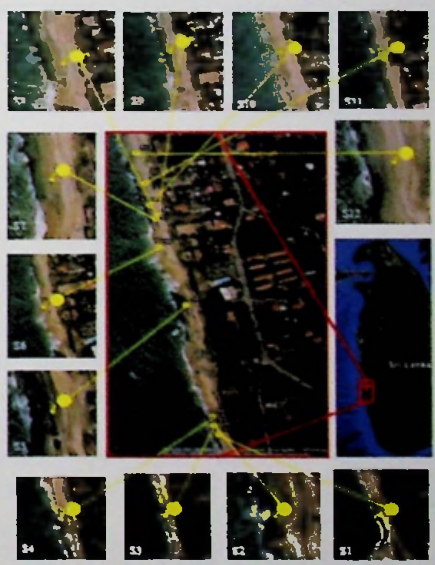

Figure. 2: Location Map of Uswetakeyyawa, Sri Lanka with Sample Locations [8].

3. Method

3.1 Sample Preparation

About 1kg of beachrock samples were collected from beach surface in each location and transported to the laboratory and cleaned, weathered surface removed and dried under ambient temperature. XRD, FT-IR and XRF analysis require powdered samples. Hence, those samples were crushed into small pieces and powdered using Temma Mill and dried for 24hrs at 110 C° and sieved to obtain particle sizes not greater than 150 microns.

3.2 Elemental Analysis

3.2.1 XRF Analysis

The elemental concentrations of the beachrock of Southern coast was identified using the Brunker S8 Tiger XRF available in Geological Survey and Mines Bureau, Sri Lanka. Samples were crushed and sieved having particle size less than 150 microns and then mixed with LC2900 binder and then pressed into pellets.

3.2.2 EDX Analysis

In Western coast, surficial environment of the beachrock were identified using Energy Dispersive X-ray analysis in SEM available in Department of Material Science and Engineering, University of Moratuwa. Crushed rock pieces of around 1 cm maximum size were observed to determine the element present in the samples. Further, tried to closely examine the rock surface by using Scanning Electron on dried beachrock specimens.

3.3 Mineralogical Analysis

3.3.1 FT-IR Method

The presence of minerals in beach rock samples was identified by FT-IR spectroscopic technique. Bruker Alpha series FT-IR instrument which is available in Department of Material Science and Engineering, University of Moratuwa was used to identify the functional groups and chemical bonds of minerals. Here KBr pellet technique was followed for the mineralogical analysis. Spectra which was in the range of 4000–400 cm^{-1} used for the each and every samples.

3.3.2 XRD Analysis

Qualitative mineralogical analysis of beachrock samples was done by recording the X-ray patterns of beach rock samples at room temperature using Rikagu Ultima IV (Bruker Ultima IV) multipurpose XRD system available at Instrumental center in the department of Applied Science, University of Jayawardanapura and Department of Material Science and Engineering, University of Moratuwa. Here CuKβ radiation ranging from 5° to 70°2θ was used and analysis was done using Match software for phase identification from powder diffraction with CuKβ radiation [7].

4 Results and Discussion

4.1 Elemental Analysis

XRF anlysis on the beachrocks in Southern coastal region reveals that CaO is present as higher percentage, and MgO, SiO_2, TiO_2, K_2O are present as other major oxides. Also percentages of some minor elements such as V, Cr, Co, Ni, Cu was determined. (Table 3)

According to the results of XRF, the beach rock composition in Southern

coastal region shows some of similarities with the beach rock composition in India (Tiruchendru), Japan (Okinawa) and Bangladesh (Satkhira) (Figure 4).

Table 3: Results of XRF Analysis of Southern Coast - Sample L5-2.

Element	Content (ppm)	Element	Content (ppm)
Trace elements			
Sc	13	Zr	114
V	20	Nb	5
Cr	79	Mo	6
Cd	n.d	Sn	n.d
Ni	11	Sb	n.d
Cu	9	Cs	52
Zn	8	Ba	37
Ga	4	La	16
As	9	Ce	16
Rb	n.d	Pb	3
Sr	3047	Th	36
Y	1	U	32

Major elements (Oxides) (%)			
SiO_2	2.86	Na_2O	0.38
TiO_2	0.16	K_2O	0.42
Al_2O_3	0.64	P_2O_5	0.14
CaO	55.39	Fe_2O_3	0.86
MgO	1.58		

Table 4: Atomic and Weight Percentage Data from EDX Analysis-Sample Locaton 5-Western Coast Sri Lanka.

Element	Weight %	Atomic %
OK	53.79	69.94
MgK	8.77	7.51
AlK	9.64	7.43
SiK	6.15	4.55
ClK	0.23	0.14
CaK	16.10	8.35
TiK	1.47	0.64
FeK	3.86	1.44

The Ca percentage of southern beachrocks is comparatively higer than the Uswetakeyyawa beach rocks. Both Uswetakeyyawa beach rock and southern beach rock indicate comparatively higher presentage of Ti and Fe compared to other heavy minerals present as trace amount.

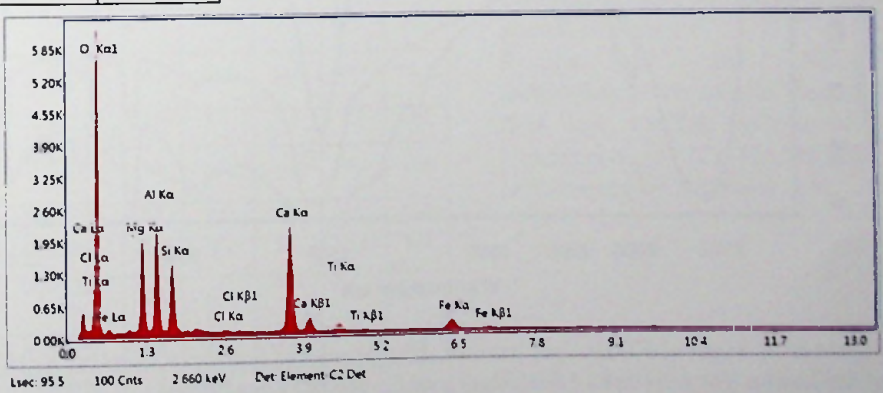

Figure 3: Result of EDX Analysis-Sample Locaton 5-Western Coast Sri Lanka.

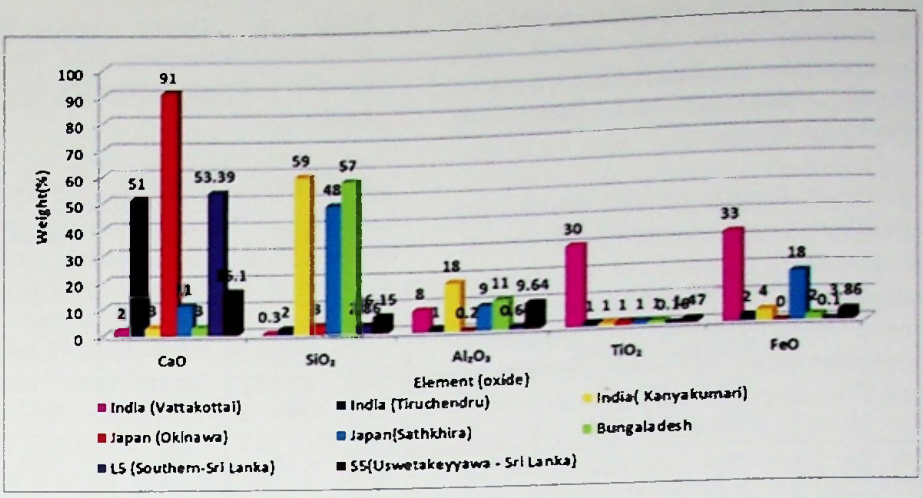

Figure 4: Comparison of Beachrock Composition Around the World [7].

4.2 FT-IR Method

Using the spectra between 4000-400 cm^{-1} the absorption frequencies of the peaks in the spectra of each samples were given by the FT-IR method (Figure 5). Using available literature, minerals such as feldsphar (Orthoclase, Albite), Clay minerals (Kaolinite,Montromorilinite) carbonate minerals (Calcite,Aragonite,Dolomite) were identified.

4.3 XRD Analysis

By performing standard interpretation technique of XRD analysis, mineral compositionsof Aragonite, Calcite, Orthoclase, Quartz, Albite, Kaolinite and Lime was determined. Aragonite was identified as the major mineral in the samples. The XRD spectrum of beachrocks for L3 in southern coastal region is presentent in Figure 6 and identified mineral percentages of each locations are presented in the Table 5.

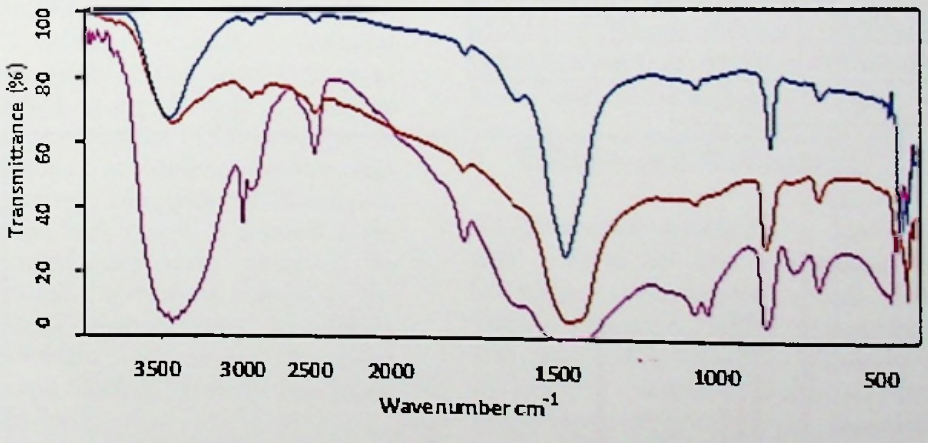

Figure 5: A Typical FT-IR Spectrum of Beachrocks of Southern Coastal Region of Sri Lanka (for L3[Pink], L5-1[Blue] and L5-2[Red] Locations).

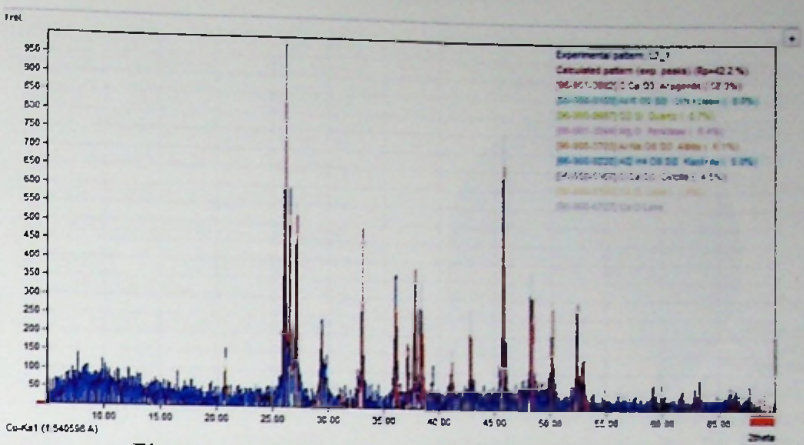

Figure 6: XRD Spectrum of Beachrock for L3 [7].

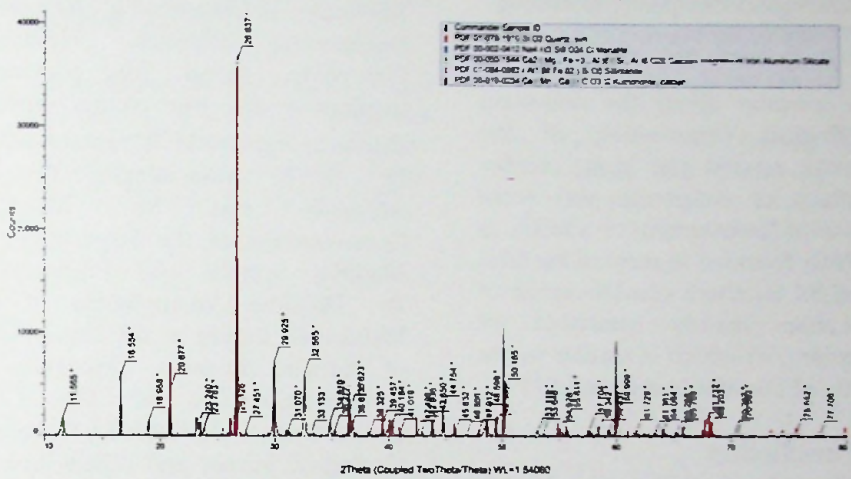

Figure 7: XRD Spectrum of Beachrock for Uswetekeyyawa S2.

Table 5: Summary of XRD Results for Southern Coast [7].

Mineral	L3	L5 –1	L5-2	L8	L9
Aragonite (%)	58.3	35.7	32.5	40.1	28.2
Calcite (%)	4.5	8.9	7.9	7.8	21.1
Orthoclase (%)	9.6	20.1	-	24.1	18.8
Quartz (%)	8.7	9.6	33.5	4.5	12.4
Albite(%)	6.1	17.1	24.4	12.4	10.4
Kaolinite (%)	5.0	6.1	-	8.2	6.5
Lime (%)	1.4	1.5	1.0	1.7	1.4
Periclase (%)	6.4	1.1	0.9	1.2	1.2

The XRD pattern for the samples of Uswetakeyyawa coastal region is shown in Figure 7.

Results of the XRD for Uswetekeyyawa coastal region didn't find any $CaCO_3$ polymorphs. But, Kutnohorite ($Ca(Mn,Mg,Fe)(CO_3)_2$) can identify by XRD anaylsis.

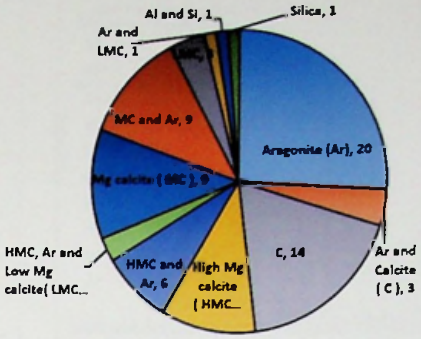

Figure 8: Beachrock Cement Mineralogical Composition Among the 77 Site in the World [4].

When consider about the dominant mineralogical composition of the beachrock around the globe, higher percentage of Aragonite (Ar) rocks which is a polymorph of $CaCO_3$ is frequently founded in most of the sites (Figure 8). Southern coastal region of Sri Lanka mainly consisted of Aragonite (Ar) which is similar to the majority of the sites in the world[7].

5 Conclusion

Overall results shows Location L3, L5, L8 and L9 of southern coastal region of Sri Lanka is mainly consisted of Aragonite (Ar) which is similar to the majority of the potential sites in the world. Further, the composition of southern bechrock has shown similarities with Indian (Tiruchendru) and Japan (Okinawa) beachrock occurrences. The minerals such as, Aragonite, Calcite, Orthoclase, Quartz, Albite, Kaolinite and lime were qualitatively and quantitatively determined. However, beachrocks in Uswettakeywa do not consist with Aragonite or Polymorphs of $CaCO_3$. However, we could find the Kutnohorite ($Ca(Mn,Mg,Fe)(CO_3)_2$) and it reveals the presence of the iron in the beach rocks. Although, the cementing material of beachrock is generally $CaCO_3$, under special conditions, principally where iron is present in the beach deposit, iron oxides may form the cement [9]. Hence we can conclude that this may lead the cementation process of Uswetakeyyawa beachrock. Further analysis has to be done to confirm this.

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