GEOCHEMISTRY AND MINERALOGY OF CARBONATE ROCK SAMPLES FROM ALDABRA ATOLL, INDIAN OCEAN

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INTRODUCTION

The stratigraphy and petrology of Aldabra have been described by Braithwaite *et al.* (1973) and Braithwaite (1975). Little is known about the geochemistry of the rocks present, apart from the analyses of two samples published by Stoddart *et al.* (1971). Accordingly, data are given in this paper which may contribute to the geological study of the island and also to the studies of soil chemistry and plant nutrition.

The samples were taken from the stratigraphic units identified by Braithwaite *et al.* (1973). These units are listed in Table 1, with the addition of beachrock. The numbers of samples within each unit are indicated. The sampling locations are given in Table 2 and shown in Figure 1.

METHODS

The rock samples have been analysed by X-Ray Fluorescence Spectrometry (Leake *et al.*, (1969)) for Ca, Mg, Na, K, Fe, Sr, Cu, Pb, Al, Zn, P, Ni, Co, Ba, S and Si. In the presence of very high levels of calcium the X-RF flowmeter became saturated and thus gave underestimates of the calcium present. Therefore analyses for calcium were also carried out by wet chemistry (acid digestion and EDTA titration; Bisque, 1961). Both data sets are reported. The wet digestion method also permits analyses of the amounts of acid insoluble residue to be carried out.

In addition, carbonate staining (Wolf *et al.*, 1967a) was also carried out on the hand specimens from which the samples for the X-RF analyses were taken. Acid Alizarin Red S solutions were used to differentiate aragonite and calcite from other minerals; a cobaltous nitrate boiling test to differentiate between aragonite and calcite and an alkaline Alizarin Red S solution to distinguish magnesium rich carbonates. As staining is not always a wholly reliable method of mineral identification, especially some shell materials, the mineralogy of seven of the samples was checked by X-Ray Diffraction using rock powders. The rocks were classified petrologically using the method of Folk (1959). The porosity of three samples was also estimated, using a

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Table 1. Stratigraphic units studied (after Braithwaite *et al.*, 1973)
(See Figure 1 for location of samples)

Unit No.	Unit Name	Samples Studied
1	Esprit limestone	1
2	Esprit phosphorites: oolites	2
3	Esprit phosphorites: conglomerates	3
4	Picard calcarenites	4a, b
5	Picard calcarenites + "soils"	-
6	Takamaka limestone	6
7	Soils filling subaerial fretting	7
8	Hard calcarenites	8a, b
9	Aldabra limestone	9a, b, c, d, e, f, g, h, i, j, k, l
10	Solution pit fillings	10a, b
11	Crab burrowed calcarenites	-
12	Algal stromatolites	-
13	Beachrock	13a, b, c, d

comparison of particle density and bulk density and a value of 2.7 for the specific gravity of calcite.

The samples were all near-surface samples but the actual surface was excluded from the chemical analyses (except for 13d which was a surface sample).

RESULTS

The petrology and mineralogy of the samples are shown in Table 2. The geochemical data are shown in Table 3a and 3b. The porosity data are shown in Table 4.

DISCUSSION

Substantive conclusions about each stratigraphic unit are not possible from the data presented since the samples are individuals from units which are often petrologically heterogeneous and which show considerable lateral and vertical facies diversity. However, some broad interpretations can be made. In terms of mineralogy and porosity, extreme diversity is evident. Frequently the samples appear to be simple bioclastic deposits, cemented by high magnesium calcite or aragonite.

Phosphates are present in small amounts in several rocks, as well as in the Esprit phosphorites. The X-Ray diffraction results suggest that a calcium phosphate form may be present (possibly $Ca_3(PO_4)_2.nH_2O$ with peaks at d spaces of 3.446, 2.808 and 1.937 or $Ca_4P_2O_9$ at 2.784 and

2.716). Phosphate in these forms is relatively insoluble at the soil pH values encountered and this probably accounts for the formation of residual soils with a high total phosphate content but a low available phosphate content (Trudgill, 1978).

The main features of element distribution are summarised in Table 5 which lists those rocks in which relatively high concentrations occur. Two conclusions can be drawn. Firstly, that the rock element concentrations frequently bear relationship to the presence of carbonates laid down in association with organisms known for their association with particular elements (Wolf *et al.*, 1976b); secondly that the soils and solution pit fillings show markedly high concentrations of many elements, suggesting a residual origin for these deposits.

Silicon is of interest since it appears to be absent from many samples, apart from the pit fillings, soils and two samples of Aldabra Limestone. This is of interest in the context of the foliar chemistry of grasses which are known for their high silica content. Indeed Renvoize (personal communication) reports a scarcity of silica bodies in Aldabran grasses (Table 6). A specimen of *Sporobolus virginicus* from Esprit was analysed for silica by acid digestion and molybdenum blue spectrophotometry (Allen, 1974) and it was found to contain 0.16 mg/g (dry weight). This is low when compared with values of 0.1 to 1.5% for many U.K. grasses (Allen, 1974, Table A5).

These data are of use in indicating possible trends of concentrations of elements present in the rock samples. It is to be hoped that further work on the inputs, outputs and storage of elements may be made in the future because a geochemical study of a discrete island unit may prove to be a viable and interesting topic.

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Table 2. Location, petrology and mineralogy of samples

No.	Location*	Petrology	Mineralogy
1	Esprit	Calcarenite	1. A + HMC mix.
2	Esprit	Oolite	P 1. LMC cement 2. P + C
3	Esprit	Calcirudite	1. LMC, Fe 2. C + Fe
4a	Picard	Calcarenite	1. C + A in points
b	Picard	Calcarenite	-
6	Picard	Calcilutite	1. LMC + HMC, Fe
7	Dune Jean Louis	"Soil"	1. C 2. C
8a	Cinq Cases	Calcarenite	-
b	Cinq Cases	Calcarenite	1. C + A
9a	Anse Var	Calcarenite	1. grains HMC, cement A
b	Anse Var	Calcarenite	1. grains A, cement HMC
c	Passe Houareau	Calcarenite	1. HMC
d	Dune Jean Louis	Calcarenite	1. A
e	Picard	Calcirudite, corals	1. clasts A, cement C
f	Passe Houareau	Calcirudite, corals	1. HMC + A 2. C + P
g	Passe Gionnet	Calcirudite	-
h	Dune Jean Louis	Calcirudite, shells	1. C
i	Dune Jean Louis	Calcirudite, *Halimeda*	1. clasts A, cement C
j	Dune Jean Louis	*Chama* shell	1. A + C mix
k	Anse Var	*Goniastrea* coral	1. septae A, C between
l	Anse Var	*Platygyra* coral	-
10a	Picard	-	2. C
b	Ile Malabar	-	2. C + P
13a	Picard	Calcirudite	1. clasts A + C, cement A
			2. A + HMC
b	Picard	Calcirudite	-
c	Picard	Calcirudite	-
d	Picard	Calcirudite	-

Abbreviations and key

*See Figure 1.
HMC = high magnesium calcite
LMC = low magnesium calcite
A = aragonite
C = calcite
P = phosphate
Fe = iron
1. = carbonate staining
2. = X-Ray Diffraction

Note: The first mentioned mineral is dominant over the second mentioned, unless the word 'mix' is used which implies roughly equal quantities

Table 3a. Geochemistry of carbonate rock samples. Ca and Mg in %; others in ppm

- = no data available 0.0 = below detectable limits

10,000.0 ppm = 1.00000 % A.I.R. = acid insoluble residue

No.	A.I.R.	Ca (1)*	Ca (2)*	Mg	Na	K	Fe	Sr	Cu	Pb	Al
1	0.62	28.9	35.0	1.6	0.0	177.1	3108.1	-	0.4	-	7973.1
2	2.38	22.2	22.0	0.8	1892.0	141.4	4762.9	313.5	133.5	13.9	1,3251.2
3	2.83	24.3	27.4	1.5	0.0	124.3	2538.2	467.1	15.1	3.1	5891.9
4a	0.19	31.6	37.2	0.9	0.0	1174.2	2281.6	389.8	111.4	5.5	5828.9
b	4.97	27.6	33.2	1.8	0.4	4198.0	2175.9	-	0.0	-	5937.6
6	-	19.0	28.8	1.9	0.0	3351.7	2272.8	1527.0	0.0	5.9	1,8882.5
7	18.34	3.1	3.0	0.1	37,1512.4	321.6	3,4829.5	151.5	68.4	23.1	1,3189.6
8a	2.21	29.8	35.6	0.7	0.0	206.1	2362.4	697.6	62.9	17.7	6880.1
b	1.45	24.3	30.0	1.0	0.0	251.0	4414.6	985.7	54.6	15.9	2,1861.7
9a	0.58	28.9	34.2	2.4	0.0	181.4	3548.2	1438.1	0.0	5.8	1,0410.4
b	0.71	26.9	32.8	2.2	0.0	212.6	2594.3	942.4	11.4	7.7	1,1098.6
c	1.70	38.2	-	1.6	0.0	289.1	2201.2	668.6	0.0	7.5	6154.0
d	0.42	38.3	36.4	1.7	0.0	138.9	2303.7	888.0	0.0	5.5	5879.4
e	2.37	24.9	30.8	2.0	0.0	299.9	2646.1	1782.0	0.0	8.3	9140.9
f	0.83	24.8	13.2	1.6	1128.7	338.3	2379.8	394.7	5.3	8.0	6115.3
g	3.20	28.1	34.0	2.5	7225.4	7469.0	2193.2	1040.2	0.0	0.0	5592.9
h	1.99	26.7	35.5	1.0	0.0	288.7	5908.9	-	18.6	-	1,3654.7
i	2.97	21.1	31.0	1.2	0.0	363.0	2857.8	839.3	0.0	8.9	1,3084.0
j	1.44	30.4	36.0	0.6	0.0	175.5	2215.4	533.7	4.6	5.6	5655.0
k	4.73	19.7	29.6	2.4	0.0	747.7	2248.1	-	0.0	-	1,4644.8
l	8.31	30.2	33.9	1.1	0.0	728.9	3926.8	-	16.4	-	1,1167.2
10a	1.16	29.4	35.5	1.4	3799.3	635.0	4748.4	1139.5	0.0	6.7	1,3986.1
b	9.86	25.3	31.7	2.2	7.8	3472.9	1,3054.3	913.5	0.0	0.0	3856.3
13a	-	29.4	-	2.0	0.0	359.5	2261.9	1701.0	-	8.1	5939.0
b	-	19.1	-	1.3	0.0	4168.0	4052.1	-	7.2	-	5481.6
c	-	28.5	-	3.9	0.0	153.5	2167.0	1498.8	0.0	0.7	8190.6
d	-	27.5	-	1.9	1,6169.0	632.9	2779.0	1655.0	6.5	6.5	5481.6

* Ca (1) = XRF; Ca (2) = wet digestion (Bisque, 1961)

Table 3b. Geochemistry (ppm) of Aldabra rock samples (continued)
(For notes see Table 3a)

No.	Zn	P	Ni	Co	Ba	S	Si
1	19.9	9,1864.5	17.2	6.3	0.12	1656.1	0.0
2	440.8	44,6340.0	6.6	8.2	0.11	1213.9	0.0
3	10.5	33,1202.3	9.3	7.0	0.10	2328.2	0.0
4a	2.9	1,2165.4	11.4	1.0	0.10	2363.6	0.0
b	1.5	3267.8	8.6	2.7	0.10	2320.7	0.0
6	0.23	6345.5	8.2	0.0	0.09	1669.4	0.0
7	18.6	2199.3	38.3	23.9	0.20	998.9	2338.8
8a	37.4	8,0180.9	10.0	1.6	0.09	1148.9	0.0
b	149.8	29,0165.0	14.7	0.0	0.13	2141.4	0.0
9a	134.4	7,3274.6	10.3	7.3	0.11	1322.4	0.0
b	27.1	17,0094.0	10.2	0.0	0.13	1682.0	0.0
c	0.0	6468.5	10.5	0.0	0.11	1908.3	0.0
d	2.5	3,2812.6	10.4	0.0	0.10	1297.7	0.0
e	16.7	5038.2	9.2	7.0	0.11	1516.9	0.0
f	0.0	3436.8	8.4	2.1	0.09	3373.7	0.0
g	9.5	9648.0	8.2	6.0	0.12	3069.0	0.0
h	343.2	1,8402.7	12.0	0.0	0.12	785.5	0.0
i	-	43,9886.2	8.2	0.0	0.12	1897.6	4870.0
j	-	1,7418.3	8.1	6.5	0.10	1947.2	0.0
k	68.0	4293.5	8.2	2.8	0.10	2178.1	0.0
l	82.2	1,8421.6	11.9	2.8	0.13	1709.8	1442.2
10a	39.2	5,4402.1	9.6	0.0	0.10	1248.5	1327.7
b	378.8	9,5065.1	25.8	3.4	0.20	2337.8	2,2025.8
13a	-	3018.7	8.7	1.6	0.10	1789.1	0.0
b	11.6	5993.4	9.7	1.2	0.09	2043.8	0.0
c	0.0	1978.5	9.9	1.0	0.10	1591.8	0.0
d	-	2057.6	9.0	4.6	0.09	2379.3	0.0

Table 4. Porosity of selected Aldabra rock samples (%)

Sample 9a		Sample 9f		Sample 9h	
	42		48		10
	19		12		16
	26		1		14
	30		7		12
	24		25		7
			1		7
					8
					26
mean	28.2	mean	15.6	mean	12.5
standard deviation	8.66	standard deviation	16.76	standard deviation	6.24

Table 5. Rocks with high concentrations of the elements measured (Approximate ranges of high values indicated in brackets)

Aluminium (over ca. 1000 ppm): shelly calcirudites, hard calcarenite, solution pit filling, Esprit phosphorites, beachrock, Takamaka Limestone

Barium: slightly higher (0.2 ppm) in solution pit fillings

Cobalt (ca. 10-20 ppm): solution pit fillings, phosphorites, some calcarenites, some shells and corals

Copper (ca. 100 ppm and over): phosphorites, some calcarenites, beachrock, solution pit fills

Iron (over ca. 2000 ppm): solution pit fills, phosphorites, beachrock, some corals

Potassium (over ca. 1000 ppm): shelly calcirudites, beachrock, solution pit fills, algal limestones

Magnesium (over 2 per cent): beachrock, shells, corals, solution pit fills, algal material

Sodium (over ca. 2000 ppm): beachrock, some corals, "soils"

Nickel (over 20 ppm): "soils", solution pit fills

Lead (over ca. 100 ppm): algal material, some calcarenites, Esprit phosphorites, solution pit fills

Sulphur (over ca. 2000 ppm): corals, shells, solution pit fills, phosphorites

Silicon (over 2 per cent): solution pit fills

Strontium (over ca. 1500 ppm): corals, beachrock, algal material

Zinc (over ca. 300 ppm): Esprit phosphorites, shells, solution pit fills

Table 6. Silica in Aldabra grasses (S.A. Renvoize, personal communication) (microscopal examination)

Stenotaphrum clavigerum	Sparse silica bodies and silica-containing cells, up to 8 μm long
Panicum aldabrense	No silica seen
Sclerodactylon macrostachyum	No silica seen
Sporobolus virginicus	No silica bodies seen but silica-containing cells, 4 μm long frequent