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Volcanics from the Walvis Ridge

THE Walvis Ridge is a non-continuous aseismic feature[1] in the south-eastern Atlantic Ocean with a general trend north-east/south-west. Close to the principal interruptions of the ridge is a north–south topographic lineation shown on Simpson's map[1] (Fig. 1). The ridge appears to be attached at its north-east end to the shelf of Angola and South-west Africa and at its south-west end to the east flank of the Mid-Atlantic Ridge through two volcanic islands, Tristan da Cunha and Gough (Fig. 1). These two islands are made up of recent alkali-basalt-trachyte suites[2,3]. The geology of the Walvis Ridge has remained relatively unknown. To my knowledge, the only geological sampling so far conducted on the ridge has yielded sediment cores ranging in age from Pleistocene to Upper Cretaceous[4] and ice-rafted material consisting of arkosic rocks[5] (Fig. 1). Here I shall present data on the first rocks found *in situ* which could help to assess the composition of the Walvis Ridge.

Two successful dredges (CN18–DR3 and CH19–DR4) were made during the cruise in August 1971 of RV Jean Charcot from the north flank of the Walvis Ridge near its north-east junction with the continental shelf of South-west Africa and Angola (Fig. 1, Table 1). One biological trawl (CH18, CY4) also recovered four fragments of pumices near the south flank of the ridge (Fig. 1, Table 1). In addition, a sediment core (Fig. 1, Table 1) containing several angular rock fragments was recovered at about 2° E on the northern section of the north–south segment of the Walvis Ridge during the cruise in 1962 of the RV Vema from Lamont-Doherty Geological Observatory. The lack of striation, the highly angular character of the rocks, and the homogeneity of the rocks from each dredge exclude the possibility of an ice-rafted origin for the specimens described here. Because of the highly fragmented nature of the samples, pillow-lava structures are only recognized on the largest specimen (> 30 cm in diameter;

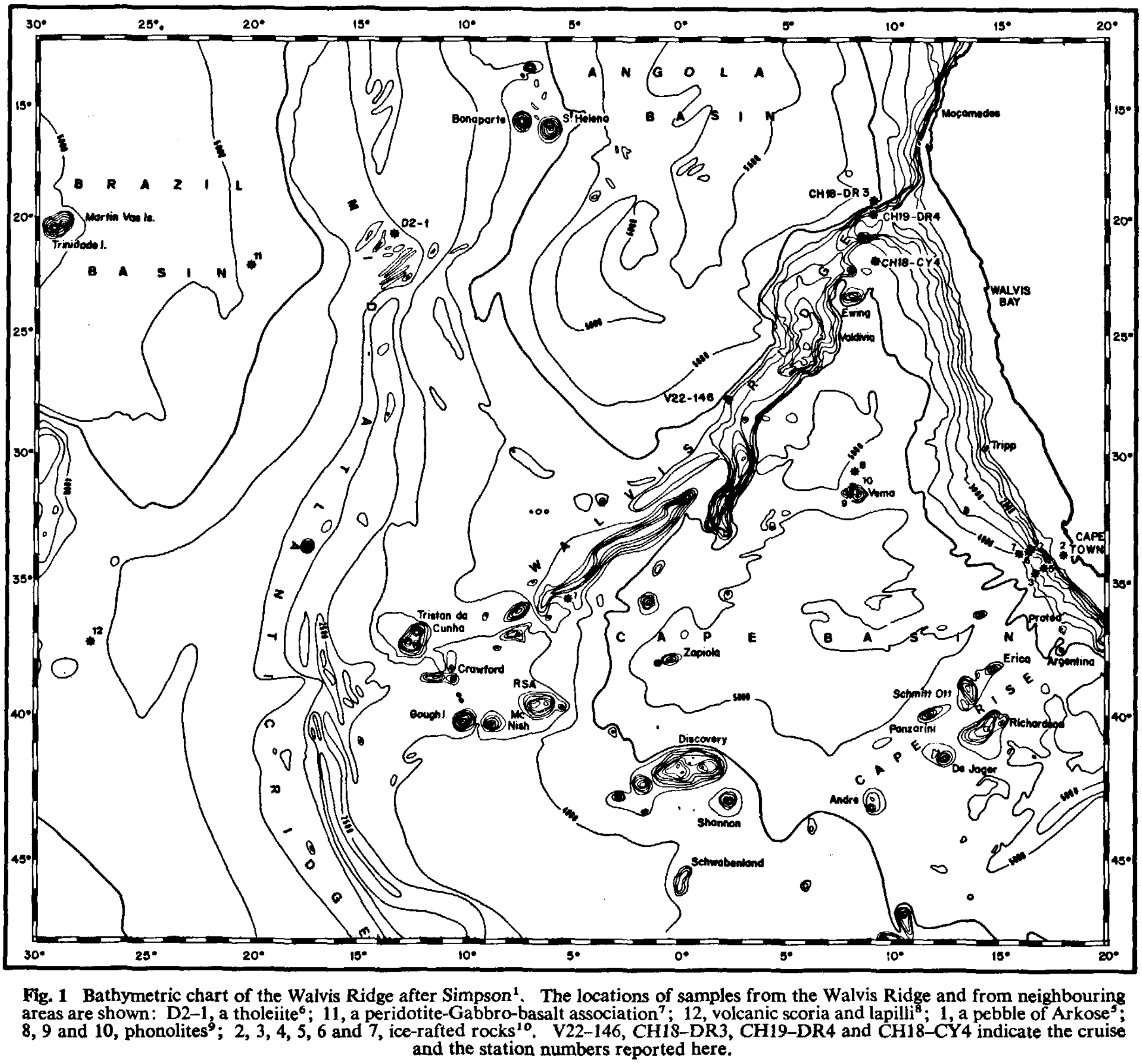

Fig. 1 Bathymetric chart of the Walvis Ridge after Simpson[1]. The locations of samples from the Walvis Ridge and from neighbouring areas are shown: D2–1, a tholeiite[6]; 11, a peridotite-Gabbro-basalt association[7]; 12, volcanic scoria and lapilli[8]; 1, a pebble of Arkose[5]; 8, 9 and 10, phonolites[9]; 2, 3, 4, 5, 6 and 7, ice-rafted rocks[10]. V22–146, CH18–DR3, CH19–DR4 and CH18–CY4 indicate the cruise and the station numbers reported here.

dredge CH18–DR3, sample 33). Among the collected specimens, dredge CH19–DR4 contains indurated carbonate rocks composed of planktonic foraminiferas, coccoliths, pelecypods and calcite. The pelecypods have been dated as Lower Cretaceous (Pastouret, personal communication). There are also highly vesiculated porphyritic basalts (dredges CH18–DR3 and CH19–DR4, Fig. 1 and Table 1) with vesicles up to 2 cm in diameter filled with smectite. Although approximately 150 kg of angular rocks have been recovered from the Walvis Ridge, about fifty specimens have been macroscopically and microscopically examined. Only ten representative specimens are reported here. The rocks from the ridge have been grouped and described according to their locations (Fig. 1, Table 1).

lower than that of the ferrugineous basalts (Table 3). The content of TiO_2 ($>2\%$) is similar to the titania content of the ferrugineous basalts (Table 3).

The rock specimen from station V22–146 was found buried in a graded sandy sediment containing shells and rock fragments. Phenocrysts and microphenocrysts of plagioclase are set in an intersertal matrix of plagioclase laths, pyroxene granules and iron ore minerals (Table 2). The low content of smectite ($<3\%$) and the low content of oxidized iron mineral ($<2\%$) indicate the relative freshness of sample 146 compared with the other samples from the Walvis Ridge (Table 2). The chemistry of sample 146 shows contents of K_2O and CaO that are similar to those of the quartz-bearing basalts (Table 3).

Table 1 Locations and Type of Rocks recovered from the Walvis Ridge

Cruise	Station	Specimen No.	Latitude, S	Longitude, E	Depth, m	Rock types
CH18	DR3	WD3–3	19° 22.3′	9° 20′		Ferrugineous basaltic rock
		A	19° 25.0′	9° 21.5′	3,840	Ferrugineous basaltic rock
		33				Ferrugineous basaltic rock
		WD3–5				Pyroclast
CH19	DR4	WD4–3	19° 50.8′	9° 1′	2,738	Quartz-bearing basalt
		WD4–1	19° 35.0′	9° 1.3′		Quartz-bearing basalt
		B				Quartz-bearing basalt
		C				Quartz-bearing basalt
		A				Quartz-bearing basalt
		4				Limestone
		5				Calcarenite with pelecypods
V22	146		32° 21′	2° 10′	2,177	High alumina alkali basalt
CH18	CY4		21° 58.8′	9° 19.7′	4,163	Pumices
			21° 59.8′	9° 18.3′		

Station CH18–DR3 is made up of ferrugineous basaltic rocks which are characterized by the occurrence of purple haematitic material. The haematite is found in irregular veinlets cross-cutting plagioclase laths, as the replacement product of olivine outlined minerals and as the reaction rim around granules of ilmenomagnetite. The modal composition of the rocks is shown in Table 2; it is interesting to note that the most weathered specimen (33) is easily friable and has a clouded groundmass of a reddish yellow limonite-smectite association, while the least weathered specimens (WD3–3 and A) show the presence of K-feldspar towards the margins of plagioclase phenocrysts. As the plagioclase phenocrysts are fresh, it is unlikely that weathering has given rise to these K-feldspars. The chemical analyses are shown in Table 3. The high content of Fe_2O_3 ($>12\%$) is compatible with the abundant haematite content of the rocks.

In addition to the ferrugineous basalts, pyroclasts containing angular fragments (1 to 40 mm in diameter) of ferrugineous basalts set in a reddish-brown quartz arenite groundmass were recovered from station CH18–DR3. The quartz-arenite groundmass is sorted and consists of rounded sand-size quartz, microcline, plagioclase, mica and zeolite. The individual grains are separated from each other by a reddish-brown limonitic cement. The chemistry of an extrusive separated from its groundmass (Table 3, WD3–5) is similar to the ferrugineous basalts, except that the SiO_2 content is high (51%) because of the presence of veinlets and pockets of rounded quartz grains.

The samples recovered from station CH19–DR4 consist of quartz-bearing basalts characterized by the presence of quartz in veins and in the matrix of the rocks. The quartz-bearing basalts differ from the ferrugineous basalts because of their higher content of smectite and lower content of haematite (Table 2). The haematitic material has replaced crystals outlined with olivine and has formed reaction rims around granules of pyroxenes. The content of K_2O (1 to 2%) and the total content of iron (9 to 12%) of the quartz-bearing basalts are

The high content of Al_2O_3 (17%) and of TiO_2 (2%) is similar to both quartz-bearing basalts and ferrugineous-basaltic rocks.

For comparison, the average chemical analyses of alkali-basalts from Tristan da Cunha[3] and Gough[2] Islands are shown in Table 3, together with the average composition of tholeiites from the Mid-Atlantic Ridge[6,11]. The high total alkalis (about 4%), the high titania and the low silica contents evidently make sample 146 similar to the alkali-basalts from the neighbouring islands rather than to the tholeiites from the Mid-Atlantic Ridge.

Table 2 Modal Analyses of Rocks from the Walvis Ridge

Minerals	CH18–DR3 WD3–3	CH18–DR3 A	CH19–DR4 WD4–3	CH19–DR4 B	CH19–DR4 C	CH19–DR4 A	V22 146
Plag. phenoch. (1.0 to 5.0 mm length)	12.0	23.9	1.4	1.1	0.3	4.4	22.9
Plag. microph. (0.4 to 1.0 mm length)	2.3	2.0	1.1	3.8	0.7	2.7	0.6
Plag. matrix (0.05 to 0.3 mm length)	21.3	23.1	41.0	38.3	46.7	51.0	26.1
Clinopyroxene	0.8	Tr	29.4	3.2	2.5	6.8	8.6
Iron ore	9.8	8.6	5.0	4.6	6.1	8.5	0.5
Oxidized iron ore	27.5	25.1	1.6	4.3	4.6	6.4	1.8
Phyllosilicates	3.5	NS	1.4	5.8	NS	1.0	NS
Smectite	NS	NS	NS	5.8	6.1	0.3	0.2
Quartz	NS	NS	Tr	Tr	3.5	2.7	NS
Olivine outlined xtls.	0.8	0.9	ND	ND	ND	ND	NS
Groundmass	20.0	15.5	18.7	32.7	29.1	15.9	19.3

Phyllosilicates consist of sericite and undifferentiated clay size material. Groundmass consists of palagonite, dark-brown or reddish brown mesostasis, and cryptocrystalline felsic aggregates. ND indicates that ferromagnesian minerals were not determined because of intense weathering. NS, not seen; Tr, trace. Smectite detected by X-ray diffraction.

The highly vesicular nature of some volcanics found on the Walvis Ridge at sites CH18–DR3 and CH19–DR4 (Fig. 1) suggests an extrusive phase in relatively shallow water (say

Table 3 Chemical Analyses of Rocks from the Walvis Ridge

Weight % of oxides	WD3–3	CH18–DR3 A	33	WD3–5	WD4–3	WD4–1	CH19–DR4 B	C	A	V22 146	Tristan da Cunha	Gough	Mid-Atlantic Ridge
SiO_2	46.80	47.00	45.78	51.42	49.18	51.42	51.19	51.72	50.77	46.97	43.1	47.7	49.27
Al_2O_3	16.37	16.50	16.33	14.31	16.00	16.37	17.04	15.37	15.60	17.81	13.1	15.2	17.44
Fe_2O_3	12.82	13.01	12.53	11.93	6.62	7.51	9.47	9.40	9.38	2.00	5.5	2.3	2.18
FeO	1.98	2.10	1.90	0.58	5.01	2.36	1.80	2.20	2.67	7.19	8.5	8.7	6.26
MgO	2.85	2.81	2.04	2.30	4.84	2.48	2.72	2.12	2.81	5.39	9.0	9.7	7.11
CaO	6.67	6.50	6.01	4.58	9.54	7.24	7.56	6.17	7.37	10.88	12.4	8.9	11.40
Na_2O	2.76	2.86	2.80	2.71	2.60	3.00	2.83	3.10	2.74	2.85	2.7	2.7	2.87
K_2O	2.82	2.89	3.25	3.87	1.02	1.01	1.61	1.39	1.22	1.42	1.6	1.6	0.16
TiO_2	3.41	3.33	3.29	2.31	2.21	3.28	2.46	3.22	2.90	2.33	3.6	3.2	1.45
Ignition	1.88	2.19	4.81	4.27	1.83	4.43	2.87	3.62	3.02	2.66			
Total	98.35	99.18	98.73	98.27	98.85	99.09	99.54	98.30	98.47	99.49			

The alkali basalts from Tristan da Cunha[3] and Gough[2] Islands are reported as well as the Mid-Atlantic Ridge tholeiites[6,11]. The SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, K_2O and TiO_2 were determined by X-ray fluorescence. Na_2O was determined using a Perkin–Elmer AAS. The FeO content was determined separately by the wet method. Ignition includes CO_2+H_2O.

<1,000 m). It is likely that at one time elevated submarine volcanoes were active near the continental margin of South-west Africa. The volcanics taken from the Walvis Ridge near its intersection with the continental margin of Africa (Fig. 1) are too weathered to permit any detailed comparative studies with the adjacent petrographic provinces such as Angola and South-west Africa. Fresher specimens or a better understanding of the weathering problem in oceanic rocks are necessary before any such studies can be made.

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Sunrise Effects on the Latitudinal Variations of Topside Ionospheric Densities and Scale Heights

IONOSPHERIC sunrise represents the transition period between quasi-equilibrium conditions attained during the night and those attained during the day. The arrival of sunrise is manifested by a rapid increase in electron temperatures and a less rapid increase in ion temperatures at all altitudes[1]. In a plasma distribution that tends towards equilibrium, a sharp increase in particle temperature results in a redistribution of the plasma. In the topside ionosphere, this is manifested by a diffusive flux of ions and electrons.

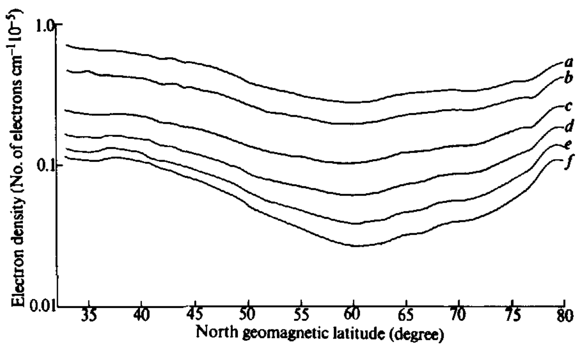

Fig. 1 Smoothed mean electron density variations at fixed topside altitudes during local sunrise as a function of north geomagnetic latitudes. Altitudes: *a*, 400 km; *b*, 450 km; *c*, 550 km; *d*, 650 km; *e*, 750 km; *f*, 850 km.

The raw data I have used were ionograms obtained by the Alouette I topside sounder as the satellite traversed above regions near and over the North American continent experiencing local sunrise at ionospheric heights. More than 600 ionograms were obtained from October 28, 1963, to November 21, 1963. It is important to note that the data available for the sunrise period are limited by the necessary geometry of the satellite path crossing the night-day shadow line while the satellite is within the radio horizon of a receiving station. During this time, the satellite's path was fortuitously almost parallel to the line of constant zenith angle. So, as the satellite traversed the latitudinal regions along its path, χ, the solar zenith angle remained nearly constant. During later passes, the same latitudinal range was traversed, but with different nearly-constant solar zenith angles. Thus, for the data reported here, there was no problem of simultaneous variations of ionospheric parameters due to latitude and solar zenith angle changes[2], and solar zenith angle effects may easily be isolated.