

## DAHLLITE FROM ST. PAUL'S ROCKS (ATLANTIC)

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### INTRODUCTION

The small islet group of St. Paul's Rocks or St. Paul lies in the middle of the Atlantic Ocean, in Lat.  $0^{\circ} 55' 28''$  N. and Long.  $29^{\circ} 22' 32''$  W. It is on the great "Mid-Atlantic Ridge," about half-way between the coast of Liberia and that of northeastern Brazil.

The group has a total length of about three-tenths of a mile north and south, and a breadth of about one-seventh of a mile east and west. It consists of four rocky islets, the highest point being about 64 feet above the level of the sea.

The islets have been visited for scientific purposes several times. The first landing was by C. Darwin from the *Beagle* in 1832,<sup>1</sup> and the second during the *Challenger* expedition in 1873.<sup>2</sup> Later landings were those from the *Quest* of the Shackleton-Rowett Expedition in 1921, and from the *Meteor* of the Deutsche Atlantische Expedition in 1925.<sup>3</sup>

During the visit of the *Quest* rock specimens were collected by Dr. G. Vibert Douglas, which were entrusted to me for petrographic study. The main results of this will appear in the forthcoming Report of the Expedition, which will be published by the Trustees of the British Museum, to whom I am indebted for their permission to publish in advance of them my study of the St. Paul phosphate rocks. I would also express my thanks to Dr. L. J. Spencer for his kindly aid in the matter.

All the islets consist of a black, very dense and compact dunite, which was studied many years ago by Father A. Renard of Belgium.<sup>4</sup> According to my studies this dunite is composed of about 74 per cent of very fresh olivine, about 24 per cent of pyroxene (chiefly the jadeite, enstatite, and diopside molecules), and about 2 per cent of deep brown picotite. This peridotite shows evidence of metamorphism by pressure, in this respect and in its general character making St. Paul unique among deep-water

<sup>1</sup> Darwin, *Geol. Observ. Volcan. Islands*, 3d ed., p. 37, 1891.

<sup>2</sup> John Murray et al., *Voyage of H. M. S. Challenger*, Narrative, I, (1), p. 201, 1885.

<sup>3</sup> O. Pratz, *Die deutsche Atlantische Expedition "Meteor," Vorbericht*, p. 59, 1925.

<sup>4</sup> A. Renard, *Neues Jahrb.*, 1879, p. 390; *Voyage of H. M. S. Challenger*, Narrative, Appendix B, 1882, *ditto*, I, (1), p. 206, 1885.

oceanic islands. Renard arrived at results essentially the same as mine.

DAHLITE. Darwin<sup>5</sup> states that "the rocks of St. Paul appear from a distance of a brilliant white colour." This was also noted by the *Challenger* expedition, which recommends the erection of a lighthouse because of the consequent danger to navigation. The white appearance is caused by a deposit of guano formed from the droppings of the numerous sea-birds.

This substance, which is essentially tricalcium phosphate, occurs in two forms. One variety is a grayish white, glossy incrustation, with a pearly luster and thinly laminated structure. According to Darwin its hardness is approximately 5. He believed it to be "an impure phosphate of lime," as it does not effervesce with acids. None of this variety was present on any of the specimens at my disposal, and those examined by Renard showed only small quantities of it.<sup>6</sup> The physical characters observed by him correspond to the description by Darwin. An analysis by Renard (made on 0.0175 gram) yielded: CaO 50.51, P<sub>2</sub>O<sub>5</sub> 33.61, with traces of FeO, MgO, and SO<sub>3</sub>. He concludes that it is essentially tri-calcium phosphate, with some calcium sulphate.

The second variety of phosphate rock is dull, rusty, and earthy-looking, with a very rough feel, and easily scratched by a knife. The colors are mostly in dull, light yellows, and some of the specimens are banded with darker streaks.

This variety is mentioned by Darwin, who speaks of a calcareo-ferruginous soft stone that forms veins. Douglas, in his notes, states that this rock forms dikes, but the chemical and microscopical study proves that this is not the case. Pratje speaks of great cracks (in the dunite) filled with a "sehr widerstandsfähigen sedimentären Material, das als Rippen herausgewitterte." He attributes their formation to the accumulation of material washed down by the spray and rains from the guano deposits above.

The appearance of this substance is most unpromising, but thin sections of several specimens were made and one from the Northeast Islet was specially studied. According to Douglas this forms a dike—really the filling of a crevice—in the dunite. This

<sup>5</sup> Darwin, *Voyage of H. M. S. Beagle*, Chap. 1; Geol. Observ. Volcan. Islands, 3d ed., p. 38, 1891.

<sup>6</sup> Renard, *Neues Jahrb.*, 1879, p. 390; *Challenger Voyage*, Narrative, 2, Appendix B, p. 21, 1882.

specimen is dense and aphanitic, most of it being a pale, dull yellow, with thin, almost black bands.

Thin sections show that the pale yellow portions are composed of a transparent, almost isotropic substance, most of which is colorless, but with yellowish patches. The texture of this is largely spherulitic. Scattered through this, and making up most of the dark bands, are many small, irregular areas of opaque black and slightly translucent dark brown, which look more like stains than grains. Here and there are small, very irregular patches of a colorless mineral that is birefringent and of slightly higher refractive index than the main substance. No cleavage is to be seen, but some small irregular areas are apparently twinned.

The optical properties of the main colorless (megascopically yellowish) substance were studied by Dr. Merwin and its X-ray structure was examined by Dr. Posnjak of the Geophysical Laboratory, to both of whom I am deeply indebted for their kind assistance.

The spherules are radiately fibrous, the fibers having parallel extinction, with  $\epsilon$  in the direction of the elongation. Merwin reports that the mineral is uniaxial, with  $\omega=1.603$  and  $\epsilon=1.598$ , "for the bulk of the material, but some of the spherules have an outer layer of somewhat higher refractive index." Posnjak states

TABLE 1. ANALYSES OF DAHLITE

	1	2	3	4	5	6
P <sub>2</sub> O <sub>5</sub>	35.75	38.44	38.40	39.04	0.273	1.00
CaO	56.47	53.00	53.65	51.15	1.084	4.00
MgO	0.30	n.d.	n.d.	n.d.	.008	
(Al, Fe) <sub>2</sub> O <sub>3</sub>	n.d.	.....	0.57	3.04		
FeO	n.d.	0.79	n.d.	n.d.		
(Na, K) <sub>2</sub> O	n.d.	0.11	n.d.	n.d.		
SiO <sub>2</sub>	0.01	.....	.....	.....		
H <sub>2</sub> O+	3.91	1.37	2.10	(?)	0.217	1.07
H <sub>2</sub> O	0.53					
CO <sub>2</sub>	3.36	6.29	5.30	3.90	0.076	
SO <sub>3</sub>	0.36	.....	.....	.....	0.005	
	100.69	100.89	100.02	97.13		

1. Dahllite. St. Paul's Rocks (Atlantic). Washington analyst.
2. Dahllite. Bamle, Norway. Bäckstrom analyst. Brögger and Bäckstrom, *Ofv. Ak. Stockholm*, 45, p. 493, 1888. Ref. in *Zeits. Kryst.*, 17, p. 426, 1890.
3. Dahllite, Mauillac, Quercy, France. Pisani analyst. A. Lacroix, *C. R. Acad. Sci.*, 150, p. 1390, 1910.

4. Dahllite (podolite), Utschina River, Podolia, Russia. Tschervinsky analyst. *Neues Jahrb. Centralbl.*, 1907, p. 279.

5. Molecular ratios of 1.

6. Oxide ratios of 1.

that the diffraction pattern appears to be completely identical with that of the fluor-apatite examined for comparison.

The material is completely soluble in dilute hydrochloric acid, with slight effervescence. An analysis made by me of the carefully selected yellow portion, which was part of that examined by Merwin and Posnjak, gave the results shown in No. 1 of Table 1. Some analyses of dahllite from other localities are given for comparison.

My analysis shows the presence of about 0.9 per cent of gypsum, while the formula for the dahllite portion may be calculated as  $40\text{CaO} \cdot 10\text{P}_2\text{O}_5 \cdot 8\text{H}_2\text{O} \cdot 3\text{CO}_2$ . This may be compared with that of Schaller for dahllite,<sup>7</sup>  $10\text{CaO} \cdot 3\text{P}_2\text{O}_5 \cdot \text{CO}_2 \cdot \text{H}_2\text{O}$ , which he regards as the "correct" formula for dahllite. If we consider the unsatisfactory character of the material and its mode of origin,<sup>8</sup> the formula given above may be written as:  $30\text{Ca}_3(\text{P}_2\text{O}_5) \cdot 8\text{Ca}(\text{OH})_2 \cdot 2\text{CaCO}_3$ . This reduces to the simplest general formula  $3\text{Ca}_3(\text{P}_2\text{O}_5) \cdot \text{Ca}((\text{CO}_2, (\text{OH})_2)$ . It is clear from the analyses here given (and from many others) that the composition of dahllite is somewhat variable, especially as regards  $\text{CO}_2$  and  $\text{H}_2\text{O}$ , so that the formula  $3\text{Ca}_3(\text{P}_2\text{O}_5) \cdot \text{Ca}((\text{CO}_2, (\text{OH})_2)$  may be regarded as the general one for this mineral.<sup>9</sup>

The pale yellowish mineral is, thus, obviously a dahllite, but one with more hydroxyl than carbon dioxide replacing the fluorine and chlorine of apatite. This chemical identification is confirmed by the observations of Merwin and Posnjak, although the refractive indices found by the former are somewhat lower than those found by Larsen<sup>10</sup> for dahllite from an unnamed locality, ( $\omega = 1.620$ ,  $\epsilon = 1.609$ ). The mineral is certainly not identical with martinite,  $5\text{CaO} \cdot 2\text{P}_2\text{O}_5 \cdot 1\frac{1}{2} \text{H}_2\text{O}$ , from Curaçao<sup>11</sup> and from Ascension Island.<sup>12</sup>

<sup>7</sup> W. T. Schaller, *U. S. Geol. Survey, Bull.* 509, p. 98, 1912.

<sup>8</sup>  $\text{CO}_2$  was determined by me as the difference between the loss on ignition and the total  $\text{H}_2\text{O}$ .

<sup>9</sup> The formula given by Doelter (*Handb. Mineralchemie*, III, (I), p. 578, 1918), namely,  $4(\text{Ca}, \text{Fe}, \text{Na}_2, \text{K}_2) \text{P}_2\text{O}_8 \cdot 2\text{CaCO}_3 \cdot \text{H}_2\text{O}$ , is evidently erroneous.

<sup>10</sup> E. S. Larsen, *U. S. Geol. Survey, Bull.* 679, p. 196, 1921.

<sup>11</sup> Cf. Dana, *System*, 6th ed., p 830; E. S. Larsen, *U. S. Geol. Survey, Bull.* 679, p. 105, 1921.

<sup>12</sup> G. Richards, *Am. Mineral.*, 13, p. 399, 1928.