MINERALOGICAL MAGAZINE, SEPTEMBER 1978, VOL. 42, PP. 401-4

Sasaite, a new phosphate mineral from West Driefontein Cave, Transvaal, South Africa

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SUMMARY. A new mineral, sasaite, occurs as white chalky nodules in the soil of a dolomitic cave and seems to be derived from the action of bat guano on clay minerals. Under the microscope it consists of an agglomeration of plates 10-20 μm on greatest dimension and with a rhombic shape. Its formula is $(Al, Fe^{3+})_{14}(PO_4)_{11}(OH)_7SO_4.83H_2O$ and it is orthorhombic or quasi-orthorhombic. Preliminary crystallographic data based on an orthorhombic cell are *a* 21·50, *b* 30·04, *c* 92·06 Å, Z10, based on a calculated density of 1·747 (observed 1·75). The optical indices are α 1·465, β 1·473, γ 1·477 all $\pm$0·001, and the principal vibration directions are parallel or quasi-parallel to the crystallographic axis.

SASAITE forms soft white chalky nodules, up to 2 cm in diameter, generally pure and monomineralic, in the reddish soil of the dolomite cave of West Driefontein near Carlstonville, western Transvaal (Martini *et al.*, 1977). Apart from nodules, it is found as an efflorescence on mud-cracks in the Deep Range Chamber, in the same cave. It is also found in the Apocalypse pothole, located in the same area, as a more restricted occurrence.

The name sasaite is derived from South African Speleological Association, the members of which explored West Driefontein Cave for the first time and discovered the mineral. Type material is deposited in the Museum of the Geological Survey, Pretoria, South Africa.

Chemistry. Wet chemical analysis of sorted material from the Deep Range Chamber in West Driefontein cave gave: Al_2O_3 21·65, Fe_2O_3 1·05, MnO 0·01, MgO 0·07, CaO 0·12, SrO 0·02, SO_3 2·77, P_2O_5 24·16, H_2O 49·50, F 0·03, insol. (detrital quartz and organic matter) 0·07, sum (less O for F) 99·44%. SiO_2 is not detectable (< 0·1%); K_2O < 0·01%; Na_2O < 0·01%, $(NH_4)_2O$ < 0·02%. According to these data, on a basis of fourteen cations, the formula is: $(Al_{13.460}Fe_{0.417}Ca_{0.068}Mg_{0.055})_{\Sigma 14}(PO_4)_{10.789}(OH)_{7.316}(SO_4)_{1.097}.83.51 H_2O$, or after simplification: $(Al,Fe^{3+})_{14}(PO_4)_{11}(OH)_7SO_4.83\,H_2O$.

Semi-quantitative microprobe analyses on four other samples collected at various places in West Driefontein Cave and yielding a similar X-ray pattern indicate that SO_3 is fairly constant but Fe_2O_3 and the P_2O_5/Al_2O_3 ratio vary slightly. These last data suggest the possibility of some replacement of PO_4 by OH.

At ambient temperature the mineral loses water rapidly in amounts varying according to the air humidity; about 12% of the total weight in ordinary atmosphere, 22% in a silica-gel desiccator. After two weeks it hydrates entirely again in a water-saturated atmosphere. It is readily soluble in strong acids.

Thermal data. Micro-differential thermal analyses and thermo-gravimetric experiments show endothermic reactions at 100 °C (20% loss in weight due to vaporization of water liberated below 100 °C), at 120 °C (9% loss of water), and at 150 °C (17% loss of water). A weak exothermic inflection at 800 °C might perhaps indicate that $AlPO_4$ is building a tridymite or cristobalite structure. In addition, there is a regular slight loss of weight from 150 to 500 °C (3% loss of water from OH?) and from 800 to 1200 °C (3·5% loss of SO_3?).

The mineral is infusible, and on calcination turns a light buff colour.

Crystallography. Under the microscope the mineral appears as platelets of up to 10-20 μm in greatest dimension, with a characteristic rhombic shape, building up vermicular forms consisting of long piles with a twisted *c*-axis (fig. 1). The faces {110} are always well developed, but small faces corresponding to {100} and {010} are also observed. The cleavage {001} is perfect.

The X-ray pattern shows a large number of lines, all well-marked and sharp when the mineral is fresh (Table I). As soon as dehydration starts, even at 1% loss of H_2O, most reflections shrink to varying extents, depending on the percentage of water loss (Table II). Partly-dehydrated material shows broader and less distinct peaks due to a loss in crystallinity. An attempt to index the pattern has

TABLE I. *X-ray data of fresh material (hydrated)*

d_{obs}	I	d_{calc}	hkl
11·52	100	11·460	008
10·74	10	10·750	200
8·75	4	8·742	220
8·18	1	8·168	224
7·51	22	7·510	040
7·13	18	7·116	138
6·99	23	6·979	234
6·30	21	6·342	316
5·95	7	5·946	244
5·78	7	5·800	327
5·42	14	5·375	400
5·24	1	5·245	250
4·966	2	4·9605	256
		4·9726	407
		4·9772	062
4·881	5	4·8738	0.5.11
		4·8763	160
		4·8828	2.3.14
4·822	12	4·8154	163
		4·8209	347
4·666	1	4·6505	3.0.15
		4·6514	1.1.19
		4·6629	259
		4·6801	433

d_{obs}	I	d_{calc}	hkl
4·570	1	4·5698	167
		4·5735	0.5.13
4·381	2	4·3709	440
4·214	18	4·2197	268
4·104	2	4·0967	523
		4·1005	516
		4·1018	175
		4·1044	360
3·935	2	3·9511	530
3·846	5	3·8306	529
		3·8608	5.1.10
3·695	10	3·6837	539
3·518	13	3·4967	550
		3·5168	605
		3·5214	283
3·368	5	3·3683	627
3·315	15	3·3182	5.3.15
3·262	18	3·2538	562
		3·2727	385
3·216	16	3·2157	2.8.12, 6.2.11
		3·2244	5.5.11
3·091	10	3·0825	649
		3·0986	0.9.11

d_{obs}	I	d_{calc}	hkl
3·066	14	3·0707	652
		3·0711	298
		3·0714	700
2·985	3	2·9846	6.0.17
		2·9848	5.5.16
		2·9850	4.7.14
		2·9854	395
2·926	12	2·9203	1.10.6
		2·9267	719
		2·9280	0.10.7
2·901	42	2·8932	2.10.0
		2·9126	734
		2·9139	660
2·863	18	2·8547	0.10.0
		2·8558	1.10.9
		2·8585	1.9.16
2·835	11	2·8241	668
		2·8251	2.10.7
2·810	7	2·8071	584
2·734	6	2·7382	749
2·702	8	2·7049	755
		2·7092	1.11.0
2·653	1		
2·632	1		

d_{obs}	I
2·603	2
2·542	6
2·478	3
2·372	7
2·302	1
2·250	2
2·229	2
2·185	5
2·172	3
2·141	3
2·105	5
2·073	1
2·049	1
2·026	3
1·978	10
1·916	4
1·872	6
1·829	2
1·804	2
1·763	2
1·753	2

Philips diffractometer, Co-$K\alpha$ radiation, quartz as standard.

TABLE II. *X-ray data of material dried in silica-gel*

d_{obs}	I	d_{calc}	hkl
10·67	10	10·680	200
9·33	100	9·350	008
8·69	8	8·665	220
7·39	43	7·410	040
6·74	10	6·762	234
6·47	22	6·472	138
6·03	13	6·053	316
5·81	2	5·789	244
5·52	5	5·502	327
5·36	17	5·340	400
5·18	1	5·171	251
		5·183	250
4·738	10	4·7258	163
4·638	3	4·6277	347
4·331	5	4·3323	440
4·037	13	4·0429	268

d_{obs}	I	d_{calc}	hkl
3·923	4	3·9212	530
3·566	3	3·5463	539
3·469	13	3·4633	605
		3·4658	550
		3·4664	283
3·440	7	3·4406	284
3·289	3	3·2931	627
3·220	8	3·2101	385
		3·2194	562
3·091	18	3·0824	5.3.15
		3·0848	6.2.11
		3·0879	5.5.11
3·044	7	3·0419	652
		3·0514	700
		3·0521	2.8.12

d_{obs}	I	d_{calc}	hkl
2·989	7	2·9827	298
		2·9935	649
2·700	7	2·9640	0.9.11
2·888	32	2·8806	734
		2·8882	660
2·859	27	2·8512	719
		2·8562	2.10.0, 0.10.7
		2·8577	1.10.6
2·761	7	2·7556	0.10.10
		2·7594	2.10.7
		2·7682	1.10.9
2·674	12	2·6696	755
		2·6712	1.9.16
		2·6718	749
		2·6734	1.11.10

d_{obs}	I
2·513	6
2·458	2
2·379	7
2·335	3
2·320	3
2·262	3
2·235	3
2·177	1
2·166	2
2·125	7
2·060	3
2·015	5
1·980	1
1·964	2
1·912	1

Philips diffractometer, Co-$K\alpha$ radiation, quartz as standard.

FIG. 1. Electron microscope photo of sasaite. Note the rhombic shape of the platelets and their accumulation along twisted axes.

been conducted on the assumption, based on the optical data, that the mineral is orthorhombic, that the strongest line is the single $00l$ reflection (from the X-ray pattern of material sedimented on a glass plate), that the $a:b$ ratio is obtained from the rhombic shape of the platelets, and that the shrinkage due to desiccation must be taken into account. As the calculated d-values do not always coincide with the observed values, and because the cell is unusually large, the data presented here are preliminary: a 21·50, b 30·04, c 92·06 Å, Z = 10; calculated density 1·747 (observed by pycnometer, 1·75). For silica-gel-dried material the values are: a 21·36, b 29·64, c 74·95 Å. It is possible that the mineral is monoclinic or triclinic and that smaller cells could be calculated.

It is reasonable to assume that sasaite has a sheet structure like vashegyite and kingite (McConnell, 1974), the minerals bearing the closest resemblance to it; it has been proposed that replacement of P and Al by protons plays an important role in the structure of these minerals. By similarity it is possible that this is also the case with sasaite.

Optical data. The mineral is transparent and colourless. For fresh material in white light $\alpha = 1{\cdot}465$, $\beta = 1{\cdot}473$, $\gamma = 1{\cdot}477$, all $\pm 0{\cdot}001$. For silica-gel-dried material, $\alpha = 1{\cdot}491 \pm 0{\cdot}001$, $\beta = 1{\cdot}500 \pm 0{\cdot}001$, $\gamma = 1{\cdot}504 \pm 0{\cdot}002$. Partly hydrated material shows intermediate values. The optical orientation is: $\alpha \parallel [001]$ ($\pm 1°$), $\beta \parallel [010]$ ($\pm 3°$), $\gamma \parallel [100]$ ($\pm 3°$).

Origin. Sasaite is to be added to the long list of cave minerals derived from bat guano. Due to the oxidation of the organic matter, various inorganic ions are produced, including PO_4^{3-} and SO_4^{2-} (Bridge, 1973). Water that has leached guano is generally strongly acidic and reacts with the clay minerals of the cave soil, forming various minerals including sasaite. In the West Driefontein Cave, the other phosphate species found in soil are variscite, strengite, phosphosiderite, leucophosphite, and apatite. Evansite, montgomeryite, crandallite, brushite, gypsum, and manganese-dioxide minerals have been found in the same cave (Martini *et al.*, 1977). They also are derived from the bat guano but they do not occur in soil and are constituents of guano or form speleothems.

Acknowledgements. Dr. R. A. Edge and Mr. D. J. Nel of the laboratory of the Geological Survey gave useful advice and assisted in the analytical chemistry part of the investigations. Mr. C. H. Johnston assisted in the microprobe and electron microscope work. I am indebted to Mr. C. P. Venter of the geophysics section, who prepared computer programs and to Mr. D. J. Winterbach who edited the manuscript.

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[*Manuscript received 9 November 1977*]