BERRYITE FROM GREENLAND

S. KARUP-MØLLER
Vejleby pr. Skibby, Denmark

ABSTRACT

Berryite has been found in the cryolite mine at Ivigtut, Greenland. It occurs with other ore minerals and a number of gangue minerals in small massive lumps in the lower part of the siderite-rich cryolite.

The structural cell is monoclinic, but the lattice is geometrically orthorhombic. The monoclinic dimensions are:

$$a = 12.707,\ b = 4.021,\ c = 28.92\ \text{Å},\ \beta = 102°36'$$

The space group is $P2_1$ or $P2_1/m$. X-ray powder data are given.

Electron microprobe analysis of three mineral grains agree best with the composition:

$$Pb_3Bi_7(Ag_{1.5}Cu_{3.5})S_{16}$$

This formula has a calculated density of 6.87 for a Z value of 2, the density could not be measured.

The habit is tabular with repeated twinning on the tabular plates. Cleavage poor parallel to the plates. Polishing hardness: galena < berryite < aikinite. Microhardness on two grains 131–171 (VHN_{100g}). Reflectivity: galena < berryite < aikinite; in air 41.8–43.0 (λ = 546 $m\mu$); reflection pleochroism weak to distinct, white to grey-white in air; anisotropy distinct to strong, green, red-brown and grey-white.

OCCURRENCE

A new occurrence of berryite was found by Professor H. Pauly during the summer of 1961 in the cryolite mine at Ivigtut, Greenland. It occurs together with both ore and gangue minerals as small massive lumps in the lower part of the siderite-rich cryolite (described by Pauly (1960)). About 50 kg. of berryite-bearing material was recognized.

The gangue minerals are fluorite and topaz with minor weberite, ivigtite and quartz. The ore minerals are cosalite, galena, aikinite, berryite and a new Pb-Bi-Ag-sulpho-salt. (Investigation of this has not yet been completed and it is therefore referred to below as mineral X). Insignificant amounts of chalcopyrite, sphalerite, pyrrhotite, marcasite,

Editor's Note: An abstract of the data on this mineral reached Dr. M. Fleischer, chairman of the Commission on New Minerals and Mineral Names of the International Mineralogical Association soon after the data on berryite given in the preceding paper had been circulated to the members of the Commission. The publication of a second name for this mineral has been averted by action of the IMA Commission.

pyrite and native bismuth are also present. The description of all the minerals will be given in a later paper.

Berryite is usually found as regularly developed tablets (Figs. 1, 2, 4 and 6). A few tablets are occasionally slightly bent (Fig. 3). Rarely, the mineral has no regular form (to the right in Fig. 2). The grain size varies considerably (Fig. 6). Single grains can reach a size of $0.1 \times 1.0 \times 1.0$ mm.

Berryite is always enclosed in mineral X and in random orientation (Figs. 4, 6). However many sections of mineral X are free of berryite. When present, berryite is usually in very small amounts but exceptionally it may comprise as much as 15 per cent of the minerals present. When present in relatively large amounts the tablets may be grouped into bunches (Fig. 3). It is often replaced by galena which penetrates the tablets along their length and forms thin oriented lamellae. The lamellae may be connected to large adjoining galena grains (Figs. 2, 5, 6) or isolated (Fig. 1). Occasionally galena crosses the tablets (Figs. 2, 6).

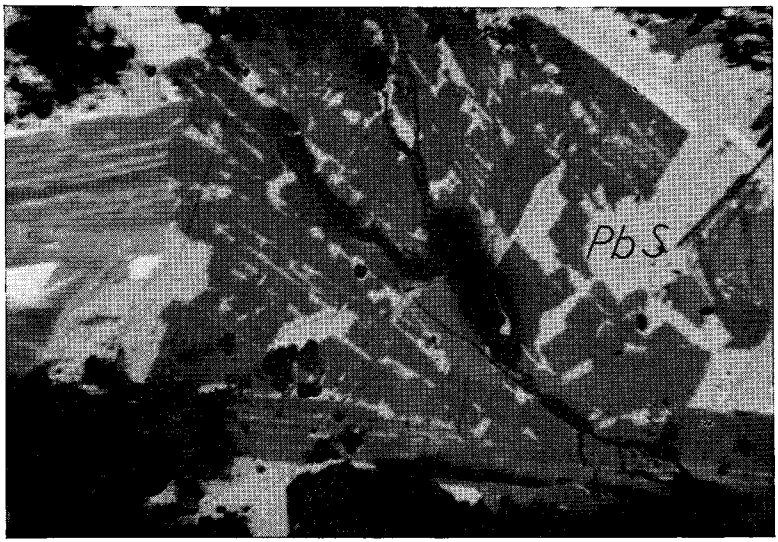

FIG. 1. Polished section. 140×. Nicols crossed at 88°.

The tabular formed berryite grain to the left in the figure is oriented approximately perpendicular to the polished surface of the sample. The large berryite grain which strongly dominates the figure is oriented parallel to the polished surface. Tabular formed galena is enclosed in both berryite grains and is oriented parallel to the host mineral. Therefore the galena grains appear as thin lamellae in the berryite grain to the left in the figure and as irregular bodies in the large berryite grain.

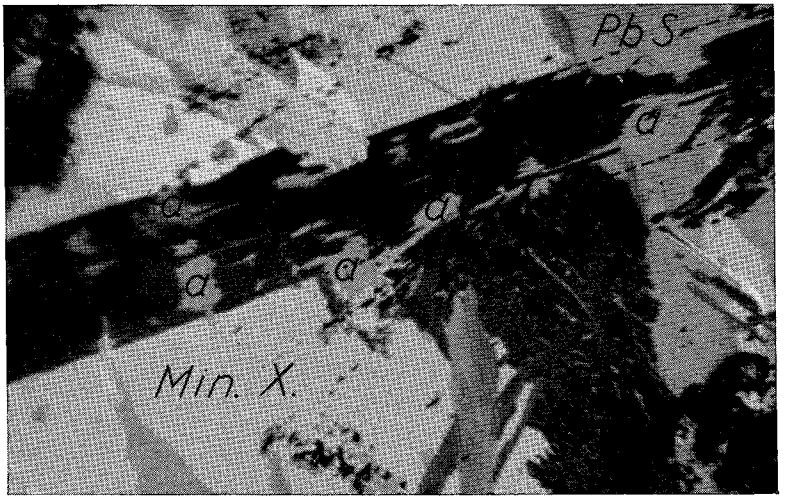

FIG. 2. Polished section. 160×. Nicols crossed at 85°.

Large regularly formed berryite tablet is strongly replaced by galena at several places (at "a"). The original limits of the mineral grain are indicated with dotted lines. Thin galena lamellae extend from the irregularly formed galena areas into the berryite grain parallel to its longitudinal direction. The right part of the figure is dominated by a large irregularly formed berryite grain. Irregularly formed galena is enclosed in the mineral grain.

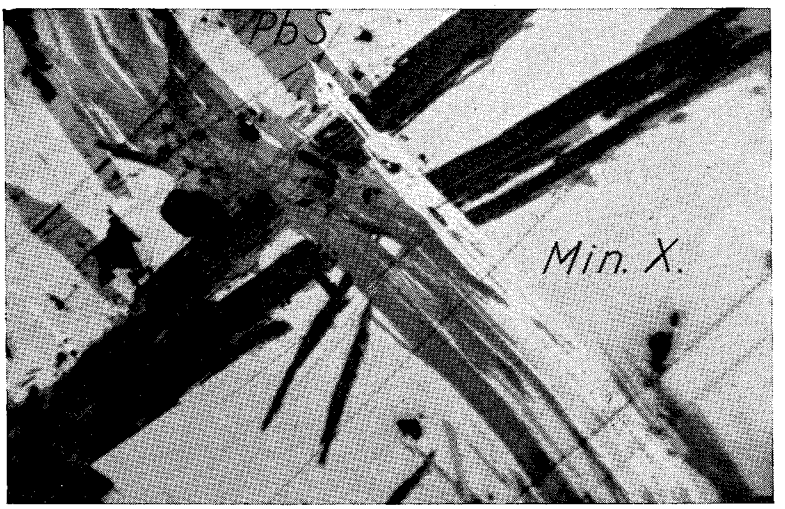

FIG. 3. Polished section. 195×. Nicols crossed at 88°.

Many berryite tablets are grouped together in two bunches. The individual tablets are differently oriented. Within the bunches the strong anisotropic effect of the mineral appears clearly. Several of the berryite tablets are slightly bent.

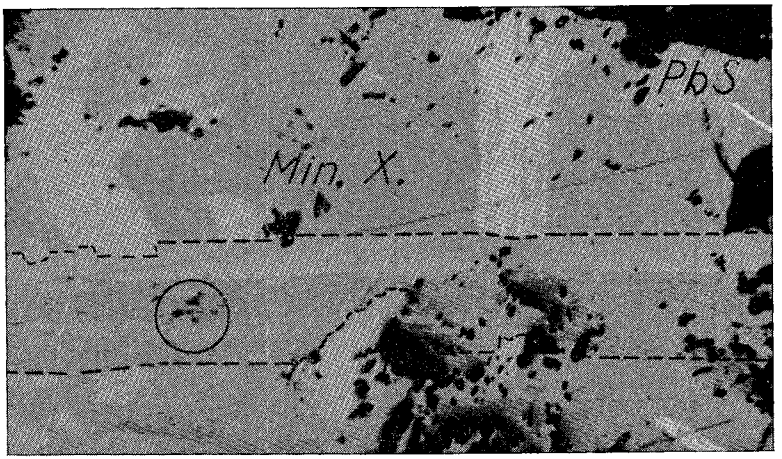

FIG. 4. Polished section. 175×. Nicols crossed at 88°.

A large berryite tablet (bordered with dashed lines) and many small berryite grains are enclosed in a mineral X grain. The orientation is random. The large berryite grain shows repeated twinning. The composition planes for the twinning individuals are parallel to the tabular formed plates of the mineral. The mineral grain has been analysed with an electron microprobe (mineral grain no. 1 in Table 1). The analysed part of the mineral grain is shown with a circle. The holes which the electron beam has burned in the mineral grain can be seen.

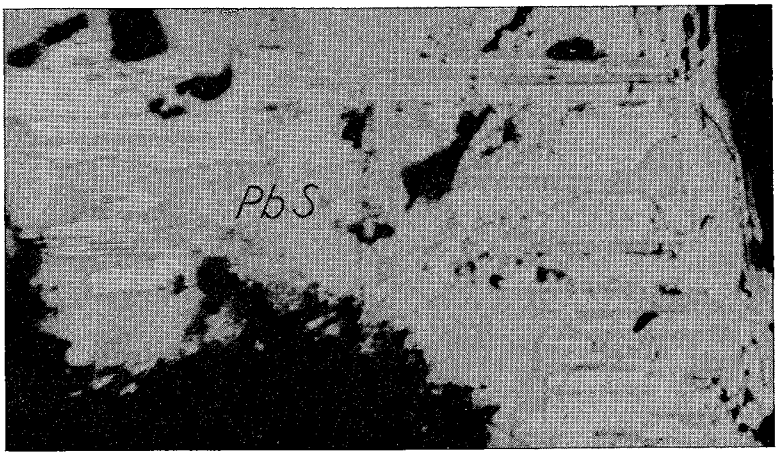

FIG. 5. Polished sections. 180×. 1 nicol. Etched 1–2 secs, with conc. HNO_3.

Galena has been etched by the acid and has developed a greyish colour, whereas berryite has not been influenced by the acid. The two minerals can therefore easily be distinguished from each other in etched sections with only one nicol. Berryite is strongly replaced by galena. Incompletely replaced berryite fragments are enclosed in the galena. The fragments have preserved their original orientations. From this mineral thin galena lamellae stretch into the berryite grain parallel to its longitudinal direction.

FIG. 6. Polished section. 180×. Nicols crossed at 25°. Etched 1–2 secs, with conc. HNO_3.

Several berryite grains of varying size are enclosed with random orientation in a mineral X grain. The greyish colour of the berryite grains is not due to the etching but to the slightly crossed nicols. In contrast to berryite and mineral X, galena is strongly etched by the acid and can therefore easily be recognized. Both berryite and mineral X are replaced by galena. Incompletely replaced fragments of the two minerals are included in galena. The fragments have preserved their original orientation.

ELECTRON MICROPROBE ANALYSIS

Berryite could not be isolated in amounts sufficient for chemical analysis as the mineral is only sparsely present and is intimately intergrown with galena and mineral X. Its chemical composition was therefore determined with an electron microprobe. Three mineral grains were analysed. Figure 4 shows one of these (mineral grain no. 1, Table 1). The part analysed is shown with a circle.

The results of analyses are given in column 1, Table 1. The values are corrected for absorption. The sulphur content was not determined analytically but was found by calculation.

The sum of the weight percentages for each mineral grain should be 100. This, however, is not the case and the discrepancies are considerable. These can be due in part to errors of measurement (caused by errors of consistency and errors of method, Campbell, 1920, page 437) and in part to systematic errors.

TABLE 1. BERRYITE: MICROPROBE ANALYSES AND COMPOSITION

Mineral grain:		1	2	3	4	5		6
No. 1	Pb	19.5	0.4	21.6	10.1	6.3		
	Bi	44.3	0.3	49.2	22.8	14.2	30	
	Ag	4.4	0.8	4.9	4.4	2.7		
	Cu	6.4	0.1	7.1	10.8	6.8		
	S	15.5		17.2	51.9	32.4		
Total		90.1		100.0	100.0	62.4		
No. 2	Pb	19.4	0.1	21.0	9.8	6.0		6
	Bi	44.6	0.2	48.4	22.2	13.8	30	14
	Ag	5.6	0.5	6.1	5.4	3.3		3
	Cu	6.8	0.1	7.4	11.2	6.9		7
	S	15.8		17.1	51.4	31.8		32
Total		92.2		100.0	100.0	61.8		62
No. 3	Pb	17.8	0.5	20.8	9.6	5.9		
	Bi	40.7	0.7	47.5	21.7	13.3	30	
	Ag	5.8	0.5	6.8	6.0	3.6		
	Cu	6.7	0.1	7.8	11.7	7.2		
	S	14.7		17.2	51.0	31.3		
Total		85.7		100.1	99.9	61.3		

1. Weight percent values corrected for absorption.
2. Absolute standard deviation on the values in column 1 found by repeated measurement.
3. Weight percent values obtained by recalculation of the values in column 1.
4. The composition of three berryite grains expressed in mol. percent.
5. Values obtained by recalculation of the values in column 4 so that the sum of the metal atoms becomes 30 (assumed to be the ideal number of metal atoms in the monoclinic unit cell of berryite).
6. Assumed cell content of berryite.

The values in column 1, Table 1, are based on repeated measurements. The size of error of measurement on the values can therefore be estimated by means of the standard deviation. The standard deviations (absolute values) are given in column 2, Table 1. It is evident that these values cannot explain the deviations of the sums from 100 in column 1.

The deviations are considered to be due to systematic errors of such a kind that all weight percent values for each mineral grain deviate from the true value with the same relative amount. Using this assumption the analytical results have been corrected to give the sum of 100 (column 3, Table 1). The "new" values for lead and bismuth deviate less from each other than the corresponding "old" values in column 1. This fact seems to show that the form of correction used is reasonable. The values determined for silver and copper in mineral grain no. 3 (column 1, Table 1) seem to be too large compared with the other values in column 1.

From the analyses (Table 1) the best formula for berryite is:

$$Pb_3Bi_7(Ag_{1.5}Cu_{3.5})S_{16}$$

X-RAY INVESTIGATION

A crystal fragment, measuring 0.02 × 0.02 × 0.5 mm., was extracted from a polished section for Weissenberg and precession study. The Weissenberg diagrams (unfiltered Co radiation, 58 kV, 10mA, 37.5 hour exposures) showed fairly sharp reflections. The reflection intensities indicate that the mineral is monoclinic but the diagrams can also be indexed on an orthorhombic cell (Fig. 7). The only observed systematic absences are $0k0$ with k odd. This leads to the space group $P2_1$ or $P2_1/m$. Reflections with $h = 3n$ have considerably higher intensities than when $h \neq 3n$ but the difference in intensity is not strong enough to be due to a superstructure.

A Guinier powder film (Cu$K\alpha$ radiation, 90 kV, 10 mA and 16 hour exposure) was indexed using information obtained from the Weissenberg diagrams. Reflections with $\sin^2\theta$ less than 0.1 are given in Table 2, together with both monoclinic and orthorhombic indexing of reflections.

The dimensions of the unit cell were determined by the "least-squares method." The calculations were carried out on a GIER digital computer with a program (REFBASE-1) made by E. S. Leonardsen.* The calculations based on the orthorhombic indexing gave the following dimensions: $a = 12.707 \pm 0.009$ Å, $b = 4.021 \pm 0.003$ Å and $c = 56.44 \pm 0.03$ Å. From these values the monoclinic cell dimensions were determined:

$$a = 12.707,\ b = 4.021,\ c = 28.92 \text{ Å},\ \beta = 102°36'$$

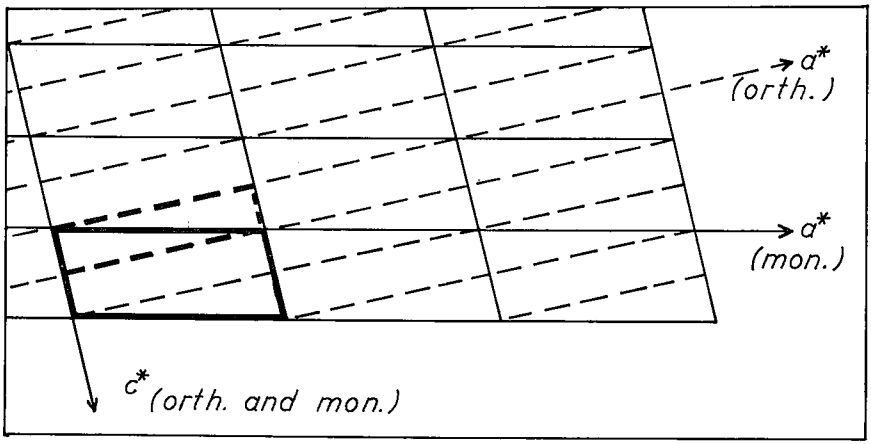

FIG. 7. Reciprocal lattice level (a^* c^*) of berryite showing the relationship between the monoclinic and the orthorhombic geometry of the lattice.

*At firm of Topsø, Copenhagen.

TABLE 2. BERRYITE: *X*-RAY POWDER DATA (Guinier, Cu$K\alpha_1$, λ = 1.54050 Å)

I	*d*(meas.)	*d*(calc.)	*hkl*(ortho.)	*hkl*(mono.)	*I*	*d*(meas.)	*d*(calc.)	*hkl*(ortho.)	*hkl*(mono.)
2	7.073	7.055	008	004	1	3.0909	3.084	2.0.16	207, 20$\bar{9}$
2	6.832	6.808	107	103, 10$\bar{4}$	5	3.0603	3.056	0.1.12	016
2	5.791	5.793	204	201, 20$\bar{3}$	2	3.0385	3.032	3.0.13	305, 30$\bar{8}$
3	4.710	4.704	0.0.12	006	10	2.9140	2.912	311	31$\bar{1}$, 31$\bar{2}$
4	4.226	4.224	301	30$\bar{1}$, 30$\bar{2}$	3	2.8954	2.893	1.0.19	109, 1.0.1$\bar{0}$
3	4.122	4.132	303	300, 30$\bar{3}$	7	2.8826	2.882	313	310, 31$\bar{3}$
2	3.957	3.966	305	301, 30$\bar{4}$	1	2.8678	2.874	1.1.13	116, 11$\bar{7}$
3	3.867	3.867	014	012	7	2.8224	2.822	0.0.20	0.0.10
1	3.8236	3.824	111	110, 11$\bar{1}$	1	2.8086	2.812	2.0.18	208, 2.0.$\bar{10}$
2	3.7544	3.757	113	111, 11$\bar{2}$	2	2.7530	2.754	2.1.12	215, 21$\bar{7}$
6	3.7416	3.750	307	302, 30$\bar{5}$	2	2.7406	2.742	317	312, 31$\bar{5}$
1	3.6322	3.630	115	112, 11$\bar{3}$	2	2.6865	2.685	1.1.15	117, 11$\bar{8}$
1	3.6174	3.608	1.0.15	107, 10$\bar{8}$	2	2.6523	2.652	0.1.16	018
3	3.5264	3.528	0.0.16	008	2	2.6284	2.630	1.0.21	1.0.10, 1.0.$\bar{11}$
10	3.5106	3.510	309	303, 30$\bar{6}$	1	2.5990	2.598	2.1.14	216, 21$\bar{8}$
9	3.4957	3.494	018	014	2	2.5745	2.579	2.0.20	209, 2.0.$\bar{11}$
3	3.3559	3.373	212	210, 21$\bar{2}$	2	2.5311	2.535	3.1.11	314, 31$\bar{7}$
2	3.3233	3.303	214	211, 21$\bar{3}$	2	2.5104	2.510	1.1.17	118, 11$\bar{9}$
6	3.2578	3.267	3.0.11	304, 30$\bar{7}$	1	2.4979	2.495	4.0.14	405, 40$\bar{9}$
3	3.2133	3.212	1.0.17	108, 10$\bar{9}$	2	2.4490	2.447	2.1.16	217, 21$\bar{9}$
4	3.1860	3.177	400	40$\bar{2}$	2	2.4214	2.421	3.1.13	315, 31$\bar{8}$
4	3.1572	3.157	402	40$\bar{1}$, 40$\bar{3}$					

Density and Cell Content

Berryite could not be isolated in an amount sufficient for density determination. The density was therefore estimated by comparison with the density of other minerals with chemical similarities to berryite. From the values in Table 3 it is assumed to be around 7 g.cm.$^{-3}$

Table 3. Density of Different Sulpho-salts

Galenobismutite ($PbBi_2S_4$)	7.19	g. cm^{-3}
Cosalite ($Pb_2Bi_2S_5$)	7.14	"
Aikinite ($PbBiCuS_3$)	7.22	"
Cuprobismuthite ($CuBiS_2$)	6.47	"

With a density of 6.87 g.cm^{-3} the number of formula units (Z) in the monoclinic unit cell would be 2. The number of metal atoms in the cell therefore is 30. The values in column 5, Table 1 have been obtained on this basis by recalculation of the values in column 4. The ideal cell content is given in column 6.

The number of Pb and Bi atoms in the unit cell is even. Pb and Bi can therefore be placed in twofold positions without being statistically distributed. Cu and Ag however must be statistically distributed in twofold positions.

Physical Properties

Cleavage and twinning. Berryite shows poor cleavage and repeated twinning parallel to the tabular plane of the crystals (Fig. 4). The composition of the twin individuals extends through the whole mineral grain. Twinning was observed only in the largest grains of the mineral.

Polishing and micro-hardness. The polishing hardness is judged to be higher than that of galena but lower than that of aikinite. The microhardness was determined by Dr. Bowie in London. Two of the three berryite grains analysed with the electron microprobe were investigated (mineral grain no. 1 and no. 2 in Table 1) with the following results:

Mineral grain no. 1 (VHN_{100g}):171 (average of two measurements).

Mineral grain no. 2 (VHN_{100g}):131–152.

Reflectivity. The reflectivity of berryite was compared with that of the other minerals in the polished samples. It is judged to be higher than that of galena but lower than that of aikinite. Reflectivity measurements were carried out by Dr. Bowie, on one of the three grains analysed with the electron microprobe (mineral grain no. 1 in Table 1). The following results were obtained:

In air ($\lambda = 546\ m\mu$):41.8–43.0.

Colour and pleochroism. In air the reflection colours of berryite are white to grey-white. It is almost impossible by means of colour differences to distinguish it from galena in air. In oil the colours are white to grey-white with a weak touch of cream. The creamy appearance is distinct when berryite adjoins galena. In contrast to berryite, aikinite is distinctly cream to lemon-yellow in both air and oil.

The reflection pleochroism of berryite is weak to distinct in air. In oil the effect is distinctly stronger. The mineral grains are brightest in positions parallel to the polarizer of the microscope.

Anisotropism. Berryite is distinctly to strongly anisotropic in air. In oil this effect is considerably reinforced. It is less anisotropic than aikinite.

When the mineral is close to the extinction positions the anisotropic colours are green or red-brown. By rotating the stage 45° from this position the colours gradually become grey-white. The colours are stronger and more distinct in oil than in air. The anisotropic colours of aikinite are stronger and more varied than those of berryite.

Etch-tests. Berryite was not etched after treatment for 1 minute with the following reagents: HCl (1 part conc. Hcl to 1 part H_2O), HNO_3 (1 part conc. HNO_3 to one part H_2O), KCN (20% solution by weight) KOH (40% solution by weight) and $FeCl_3$ (20% solution by weight). After treatment of the mineral for 10 secs. with conc. HNO_3 it became a greyish colour.

Acknowledgment

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