THE NATURE OF "ARIZONITE"

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"Arizonite" having the composition $Fe_2O_3 \cdot 3TiO_2$ was described by Palmer (4) and frequently has been reported as a constituent of ilmenite black sands (1). Attempts by Pesce (5) to synthesize the mineral were unsuccessful and his work was confirmed by us.

The reported physical properties of "arizonite" were duplicated when ilmenite sand was heated overnight at 900° C. The treatment destroyed the ilmenite structure and the x-ray pattern was quite poor. However, if the sand was ground to 200 mesh and oxidized, the x-ray pattern of Fe_2TiO_5 and rutile was obtained, confirming Ramdohr's observation (8). The end products depend upon the temperature and at lower temperatures Fe_2O_3 and anatase are to be expected.

Prints of the only extant specimen (6) of Arizonite (U. S. National Museum Collection No. 86,973) together with hematite, and ilmenite taken by W. E. Richmond and measurements made on the original films by J. M. Axelrod were obtained through the courtesy of Dr. W. T. Schaller of the U. S. Geological Survey. Mr. Richmond's conclusion was that "the specimen labeled arizonite gives a powder photograph nearly identical with that of hematite. However, there are sufficient differences in the spacings and arrangements of the diffractive lines to preclude its identity with hematite. The powder photographs of hematite, arizonite, and ilmenite are all similar but the spacings of the same diffracting planes of each mineral are different. This probably means that all three minerals have the same structure cell but the cell edge lengths vary slightly with composition." Dr. Schaller also said that beach sands reported to be arizonite gave no x-ray pattern or a very poor pattern. Our examination (Table 1) of the print and the spacing measurements showed that arizonite is an impure mixture of hematite, ilmenite, anatase and rutile. All of the lines in the pattern can be accounted for by these compounds. This is sufficient evidence to discredit the mineral.†

In our opinion "arizonite" is weathered ilmenite, contrary to the opinions of Koenigsburger (2) and Moore (3). Purified ilmenite gained weight on heating at 360°, 600° and 800° C. and extrapolation by meth-

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† We are indebted to Mr. Axelrod who re-examined the x-ray evidence recently and concluded that arizonite is a mixture, principally anatase with hematite doubtfully present (spacings correct, but intensities not checking); and a fine-grained phase present, whose pattern is very similar to that of ilmenite but with spacings different from those of natural ilmenite which he has studied.

ods used by Pilling and Bedworth (7) indicated that ilmenite oxidation could be expected at 100° C. in months and at room temperature in years. Geologically, this is a short time. The occurrence of "arizonite" in tropical beach sands which are exposed to strongly oxidizing conditions and the absence of "arizonite" in massive deposits is in accordance with our hypothesis.

A convenient method for observing alteration of ilmenite by oxidation is to mount the sand in lucite resin, polish and examine the specimen under vertical polarized light. Unaltered ilmenite is black, oxidized ilmenite is red or brown and rutile inclusions are bright. These differences can be recorded by red sensitive film.

TABLE 1. COMPARISON OF ARIZONITE SPACINGS WITH THOSE OF HEMATITE, ILMENITE, RUTILE AND ANATASE

	Arizonite[1]		Hematite[1]		Ilmenite[1]		Rutile[2]		Anatase[2]	
	d (A.U.)	I/I_0	*d* (A.U.)	I/I_0	*d* (A.U.)	I/I_0	*d* (A.U.)	I/I_0	*d* (A.U.)	I/I_0
β of 3.50	3.87	0.3								
	3.67	0.4	3.67	0.6	3.70	0.3				
	3.50	1.0							3.52	1.0
	3.23	0.3					3.24	0.8		
β of 2.66	2.96	0.1								
	2.66	0.9	2.68	1.0	2.73	0.1				
	2.51	0.8	2.50	1.0	2.53	0.8				
	2.48	0.0					2.49	0.6		
β of 2.196	2.419	0.05								
	2.370	0.1							2.37	0.24
	2.196	0.2	2.196	0.4	2.218	0.3				
	2.180	0.0					2.19	0.30		
	2.080	0.0	[3]							
	1.885	0.1			1.890	0.1			1.88	0.40
	1.863	0.0			1.854[6]	0.4				
	1.833	0.2	1.834	0.6						
	b 1.687	0.7	1.690	0.2	1.716	0.8	1.69	1.0	1.70	0.28
	1.660	0.3							1.66	0.24
	1.624	0.05			1.625	0.1	1.62	0.30		
	1.595	0.1	1.595	0.3						
	b 1.478	0.3	1.481	0.5	1.498	0.6	1.485	0.20	1.480	0.24
	1.449	0.2	1.451	0.5	1.462	0.6	1.449	0.20		
	1.359	0.1					1.355	0.30	1.362	0.08
	1.334	0.1			1.335	0.3			1.335	0.08
	1.308	0.0	1.308	0.2						
	1.261	0.2			1.267	0.2			1.262	0.11
	1.162	0.05	1.161	0.2					1.164	0.08
	1.137	0.1	[4]							
	1.101	0.05	1.100							
	1.088	0.05					1.091	0.08		
	1.052	0.05	1.0525							
	1.042	0.05			1.048	0.0	1.040	0.08	1.045	0.03

[1] Spacings measured by U. S. G. S.

[2] Data from Hanawalt card index.

[3] Hanawalt index gives $d=2.07$, $I/I_0=0.2$, obtained by one observer.

[4] Hanawalt index gives $d=1.137$, $I/I_0=0.5$, not obtained by all observers.

[5] Hanawalt index gives $d=1.86$, $I/I_0=0.6$.

REFERENCES

1. HESS, F. L., AND GILLSON, J. L., Titanium Chapter, "Industrial Minerals and Rocks"; *A.I.M.E.*, Maple Press, York, Pa.
2. KOENIGSBURGER, J. G., *Econ. Geology*, **34**, 844 (1939).
3. MOORE, E. S., *ibid.* **34**, 931 (1939).
4. PALMER, CHASE, *Am. Jour. Sci.* (4), **28**, 353–356 (1909).
5. PESCE, B., *Gazz. Chim. ital.*, **61**, 107–111 (1931).
6. Private Communication of May 10, 1944.
7. PILLING, N. B., AND BEDWORTH, R. E., The oxidation of metals at high temperatures: *J. Institution of Metals*, **29**, (No. 1), 529–559 (1923).
8. RAMDOHR, P., *Chemical Abstracts*, **35**, 3564.

THE UNIT CELL OF MALACHITE

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The only unit cell data on record for malachite are those of Brasseur (1932). The authors of this paper, each working independently, found that there is a considerable error in the value of the angle β, as reported by Brasseur.

The axial ratio given in Dana (1909) for malachite is that of Lang (1863–4), who reported the values 0.8809:1:0.4012, with $\beta=61°\ 50'$. In this orientation the prominent cleavage is $\{001\}$. Goldschmidt (1918) chose a setting with the cleavage as $\{101\}$, and gave the axial ratio as 0.7823:1:0.4036, with $\beta=91°\ 03'$.

In his work on the crystal structure of malachite, Brasseur assumed the Goldschmidt value of 91° 03′ for β. The unit cell dimensions reported by him are $a_0=9.38k\text{X}$, $b_0=11.95$, $c_0=3.18$, giving an axial ratio of

MALACHITE. Angle Table*

$a:b:c=0.7914:1:0.2691$; $\beta=98°44'$; $p_0:q_0:r_0=0.3400:0.2660:1$
$r_2:p_2:q_2=3.7598:1.2784:1$; $\mu=81°16'$; $p_0'=0.3440$; $q_0'=0.2691$; $x_0'=0.1536$

Common forms		ϕ	ρ	ϕ_2	ρ_2	C	A
c	001	90°00′	8°44′	81°16′	90°00′	0°00′	81°16′
b	010	0 00	90 00	—	0 00	90 00	90 00
a	100	90 00	90 00	0 00	90 00	81 16	0 00
m	110	51 58	90 00	0 00	51 58	83 08	38 02
p	$\bar{2}01$	−90 00	28 07	118 07	90 00	36 51	118 07

Less common forms: x $\bar{1}02$, γ 011, ϵ 111.

Rare or uncertain forms: 130, 104, 101, $\bar{1}08$, 708, 134, 232, 562, $\bar{1}68$, $\bar{1}98$, $\bar{1}65$, $\bar{8}\cdot 15\cdot 16$, $\bar{1}22$.

* Based on angles of Lang, but with the Ramsdell-Wolfe unit and orientation.

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