

CRISTOBALITE IN BENTONITE

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INTRODUCTION

While examining a bentonite from Casper, Wyoming, in 1934 the author noticed certain lines in the x-ray powder photograph which he was unable to assign to either montmorillonite or any other mineral likely to be associated with it. More recently a sample of bentonite from a locality near Gillette, Wyoming, was received. It is a good example of bentonite since it is uniform in grain size, has a cream color and swells when placed in water. It also contains the unknown mineral which has proved to be cristobalite.

X-RAY EVIDENCE

When the powder of the Gillette bentonite was first x-rayed without any attempt at separation of any of the constituents, it was found to consist of montmorillonite (Table 1) and the then unknown mineral. Unfiltered Fe radiation was used. The precision cameras had an effective radius of 57.3 mm. and the samples were 0.8 mm. in diameter. With this installation it is possible to detect as little as 2 per cent of quartz. None was discovered. Neither was any feldspar or mica detected, which would be more difficult to find in amounts of less than 5 per cent.

An attempt was then made to separate the montmorillonite from the unknown substance by making a colloidal suspension of the montmorillonite in distilled water. This suspension after standing for 24 hours was decanted and then centrifuged for three minutes at 1220 g. Assuming that the density of the cristobalite particles is 2.3 and that of the suspension is close to 1.0, and applying Stokes' law, it follows that all particles larger than 1.25 microns should have been thrown out of suspension. The material still in suspension was recovered by evaporation over a steam radiator and then x-rayed. The film showed good patterns of cristobalite and montmorillonite, but no other lines. It is in no way different from that of the uncentrifuged material. Table 1 shows a comparison of this film with that of cristobalite obtained by devitrifying pyrex glass at 650°C. for 45 days, and with natural cristobalite crystals from Crater Lake, Oregon (Dutton, 3). Also, the lines of montmorillonite obtained from a sample of bentonite from Belle Fourche, South Dakota, are shown for comparison. This montmorillonite was also centrifuged, but it contains no detectable amounts of cristobalite. Since the humidity of the atmosphere makes a difference in the spacing of at least one of the

montmorillonite lines it must be mentioned that the material was *x*-rayed in a steam heated building with a humidity below 30 per cent.

TABLE 1. X-RAY POWDER PHOTOGRAPHS OF BENTONITE AND CRISTOBALITE
(UNFILTERED Fe RADIATION)

Cristobalite Crater Lake		Devitrified Pyrex		Bentonite Gillette		Montmorillonite Belle Fourche	
<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>
8.873	2	8.993	1	12.7	10+	12.3	10+
4.446	5	4.445	3	4.43	5	4.41	2
4.035	10+	4.031	10+	4.031	10		
3.462	1 <i>b</i>	3.459	0.5			3.391	0.5
3.126	4	3.126	2 <i>b</i>	3.115	2 <i>b</i>	3.082	2
2.845	4	2.849	2	2.838	1		
2.746	1	2.737	1	2.721	1		
2.485	4	2.481	3	2.472	3 <i>b</i>	2.530	2
2.338	0.5						
2.236	0.5						
2.123	1	2.124	0.5	2.116	1		
2.020	1			2.020	0.5		
1.932	2	1.934	1	1.932	0.5		
1.872	2	1.875	2	1.872	1		
1.734	0.5						
1.694	2	1.698	2	1.686	1	1.681	0.5
1.653	0.5			1.649	0.5	1.637	0.5
1.614	3	1.614	2	1.610	0.5		
1.574	0.5						
1.534	2	1.538	1	1.536	0.5		
1.495	2	1.499	1	1.495	3	1.487	3
1.435	2	1.435	1	1.435	0.5		

b = broad line.

High temperature cristobalite which has been investigated by Wyckoff (4) gives a somewhat different powder photograph from the low temperature modification which has been described by Barth (5). The latter agrees very well with the spacing and intensities given in Table 1.

ABUNDANCE OF CRISTOBALITE

The question remains as to how much cristobalite is present in the Gillette bentonite. A partial analysis by Dr. R. B. Ellestad was made of the material which stayed in suspension after centrifuging. The alkalis were not determined (Table 2) but must be high judging by the defi-

TABLE 2. CHEMICAL ANALYSES

	Bentonite in Suspension, Gillette	Bentonite Natural, Gillette	Average* Montmorillonite
SiO ₂	68.61	68.7	49.16
Al ₂ O ₃	13.07		22.81
Fe ₂ O ₃	2.22**		0.70
FeO			
MgO	2.88		3.48
CaO	0.41		1.64
Na ₂ O	not det.		0.36
K ₂ O	not det.		
TiO ₂	0.09		
MnO			0.04
H ₂ O+	4.19		21.39
H ₂ O-	4.69		
Ignition loss			
Less total H ₂ O	1.30		
Total	97.46		99.58

* Average of seven analyses which are quoted by Mehmel (6).

** Total iron as Fe₂O₃.

ciency of the total percentage. Some sulfate is also present according to Dr. Ellestad.

Assuming that all SiO₂ belongs to the two minerals cristobalite and montmorillonite, it is not difficult to find the percentage of each based on the amount of Al₂O₃ and Fe₂O₃ present. As is well known montmorillonite varies in composition between wide limits. The average computed from five analyses quoted by Mehmel (6, p. 13) is given in the last column of Table 2. If in our analysis about one-half of Fe₂O₃ is added to Al₂O₃ as a constituent of montmorillonite, that is $13.1 + 1.1 = 14.2\%$, and compared with the average montmorillonite, we obtain the proportion $14.2:22.8 = X:100$, in which X is the percentage of montmorillonite in the mixture, $X = 62.3\%$.

Therefore, approximately 37.7 per cent of cristobalite should be present. This is probably somewhat too high on account of the presence of small amounts of other minerals, and perhaps glass. It is thought that 30 per cent cristobalite comes probably closer to the truth. The composition of the uncentrifuged bentonite cannot be very different because an approximate analysis (without hydrofluorization) for SiO₂ shows 68.7 per cent. Also the powder photograph is practically the same as that of the centrifuged portion as mentioned above.

ORIGIN OF CRISTOBALITE

Practically all geologists believe that many bentonitic clays are derived from the decomposition of volcanic ash beds and therefore are associated with eruptions. It is also generally known, due to the work of Fenner (2) and others, that cristobalite has not been synthesized at room temperatures. The lowest temperature recorded by Chrustschoff (1) is 180°–228°C. He claims he obtained it in five hours from amorphous silica in an aqueous solution of hydrofluorboric acid. Fenner (2, p. 358) who made similar experiments at 350°–380°C. did not obtain cristobalite, but quartz. Since Chrustschoff's conditions probably did not closely approach those in nature and low temperature cristobalite is metastable at room temperatures, it may be assumed that it is a mineral of fairly high temperatures. Since this temperature could not have existed in the sediments in which the mineral is found, it must have formed in the outlet of a magma chamber or, in other words, in the throat of a volcano from which it was blown as ash. It is inconceivable that there could have been sufficient heat available for its formation in its journey through the atmosphere.

CONCLUSIONS

Two bentonites from Wyoming contain as much as 30 per cent of cristobalite, even in fractions as fine as 1.25 microns. The place of origin of the cristobalite must be sought in volcanic vents from which the original volcanic ash was derived. Preliminary tests of other bentonites and fuller's earths also indicate the presence of cristobalite.

In conclusion the writer wishes to acknowledge the kind assistance of Dr. R. B. Ellestad and Messrs. Lynn Gardiner and T. E. Gillingham. A grant from the Graduate School of the University of Minnesota has made the investigation possible.

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