Peccato—for independent determinations of modes and phenocryst ratios for several specimens as a check on our own determinations.

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NEW DATA ON TRIDYMITE

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The chemical composition of natural tridymite is poorly known. Of the ten tridymite analyses cited by Frondel (1962), eight were made before 1878 and the other two are spectrographic analyses in which the percent of SiO_2 was not determined. The only recent complete analysis of tridymite is given by Sato (1962).

Chemical, x-ray, and optical data on tridymite from two localities are given in this paper. One specimen is of the meteorite from Steinbach, Germany[1] (Harvard University Meteorite Collection, spec. no. 3). The other is from a "lithophysae in rhyolite, Mule Springs, 100 M. N. E. of Lakeview, Oregon" (Harvard No. 11285).

The chemical analyses of these two tridymites together with the recent analysis by Sato (1962), are given in Table 1. The samples were prepared by heavy liquid separation and hand picking.

Table 2 lists the optical properties and densities of all three tridymites. The indices of refraction increase as the amount of solid solution of Na, K, Ca, and Al increases, as was noted by Frondel (1962). The exact relationship between the composition and the indices of refraction is still not

[1] The Steinbach meteorite is a stony-iron (siderophyre) and has several synonyms (Prior, G. T., 1953). The tridymite from this meteorite was originally described as asmanite (Story-Maskelyn, 1871).

TABLE 1. CHEMICAL ANALYSES OF TRIDYMITE

	1	2	3
SiO_2	99.47	99.03	96.89
TiO_2	none	0.02	0.86
Al_2O_3	0.17	0.50	0.71
Fe_2O_3	0.03	0.01	trace
FeO	none	none	none
MnO	none	none	none
MgO	trace	trace	none
CaO	trace	trace	none
Na_2O	0.12	0.24	0.72
K_2O	0.01	0.08	0.16
H_2O^+	0.00	0.1	0.12
H_2O^-	0.1	none	0.08
P_2O_5	none	none	trace
Total	99.90	99.98	99.54

1. Tridymite from the Steinbach Meteorite.
Analyst Jun Ito, Department of Geological Sciences, Harvard University, 1965.
2. Tridymite from Mule Springs, Oregon. Analyst Jun Ito, 1965.
3. Tridymite from Kusatsu, Japan (Sato, 1962).

known because of a sparsity of data. The range of indices of refraction for a number of tridymite samples examined by the author was from $\alpha = 1.471$, $\beta = 1.472$, $\gamma = 1.474$, (for synthetic tridymite made from high purity silica glass in a platinum crucible with a sodium tungstate flux), to

TABLE 2. PHYSICAL PROPERTIES OF TRIDYMITE

	1	2	3
	Na light (±0.001)	Na light (±0.001)	
α	1.472	1.475	1.478
β	1.473	1.476	1.480
γ	1.475	1.478	
$2V$	75°±5°	68°±5°	≅0
Specific gravity	2.254 ±0.005	2.26 ±0.01	2.2 ±0.1

1. Tridymite from the Steinbach meteorite.
2. Tridymite from Mule Springs near Lakeview, Oregon.
3. Tridymite from Kusatsu, Japan (Sato, 1962).

TABLE 3. X-RAY DATA FOR TRIDYMITE

1		2		3		4		
I (est.)	*d*, Å	*I* (est.)	*d*, Å	*I*	*d*, Å	*I*	*d*, Å	(*hkl*)
100	4.328	100	4.30	132	4.311	180	4.332	220
								$\bar{2}01$
								040
				6	4.258	2	4.234	201
80	4.090	90	4.09	200	4.095	170	4.107	002
5	3.865					20	3.860	$\bar{2}21$
45	3.822	60	3.80	100	3.813	100	3.822	041
								221
4	3.668	<1	3.60	2	3.655	10	3.657	
2	3.448			2	3.466	4	3.453	$\bar{2}31$
3	3.389	<1	3.343			6	3.396	231
						<1	3.297	310
		30	3.249	30	3.246	2	3.261	150
2	3.213			<1	3.209	3	3.210	$\bar{2}02$
		4	3.162	12	3.171	<1	3.173	$\bar{2}12$
<1	3.129	<1	3.140	3	3.126	<1	3.135	202
<1	3.086	<1	3.091	2	3.105	<1	3.080	212
				<1	3.056	<1	3.046	$\bar{1}51$
<1	3.016	<1	3.018	<1	3.023	4	3.016	$\bar{2}22$
14	2.970	16	2.964	32	2.968	48	2.975	042
<1	2.945					4	2.948	222
<1	2.804	2	2.844	4	2.842			
				2	2.815			
4	2.774			2	2.779	15	2.777	160
<1	2.737	<1	2.741	2	2.746			
2	2.613	1	2.659	5	2.664	4	2.611	$\bar{3}12$
3	2.572			2	2.599			
4	2.530	1	2.546	3	2.544	2	2.538	312
10	2.496	16	2.483	26	2.485	28	2.501	400
		<1	2.446	2	2.444	26	2.489	260
								410
		<1	2.414	2	2.415			
2	2.406	3	2.384	7	2.384	8	2.381	261
1	2.336			2	2.344	4	2.340	$\bar{2}23$
7	2.308	8	2.305	26	2.304	28	2.309	043
						2	2.291	223
1	2.236	<1	2.217	1	2.236	3	2.238	$\bar{3}42$
<1	2.204			2	2.200	1	2.202	342
<1	2.186	<1	2.189					
<1	2.158						*	

1. Tridymite from the Steinbach meteorite; intensity data from films and diffractometer charts; spacings measured from a film taken with iron radiation.

2. Tridymite from Mule Springs near Lakeview, Oregon; intensity data from films and diffractometer charts; spacings measured from a film taken with copper radiation.

3. Tridymite from Kusatsu, Japan, type M of Sato (1964b, p. 133).

4. Tridymite type S of Sato (1964c, p. 217, specimen A).

TABLE 3—(*continued*)

1		2		3		4		
I (est.)	*d*Å	*I* (est.)	*d*Å	*I*	*d*Å	*I*	*d*Å	(*hkl*)
1	2.135			2	2.138	1	2.137	262
3	2.119	<1	2.119	2	2.124	9	2.117	402
6	2.088	4	2.078	8	2.081	12	2.088	081
								441
3	2.051	4	2.045	16	2.046	10	2.050	004
<1	2.032						*	
<1	2.011	<1	2.004	<1	2.014			
<1	1.982	4	1.974	6	1.975		*	
				2	1.956			
<1	1.938	<1	1.935	2	1.937		*	
1	1.908	<1	1.899	2	1.902		*	
1	1.876	<1	1.872	<1	1.873	4	1.873	204
<1	1.853	<1	1.850	2	1.846	4	1.853	044
1	1.829	3	1.827	3	1.831	9	1.829	$\bar{4}23$
<1	1.814			3	1.819			
1	1.782	3	1.776	2	1.779	5	1.783	423
								$\bar{5}22$
				1	1.764			
				2	1.745			
		<1	1.736	2	1.733			
1	1.718	<1	1.705	10	1.707	7	1.713	$\bar{4}43$
4	1.695	5	1.690	3	1.690	14	1.695	083
<1	1.682	1	1.674	3	1.675		*	
<1	1.664							
<1	1.655	1	1.644			2	1.656	382
4	1.635			3	1.623	15	1.636	480
								2.10.0
<1	1.615	2	1.622	3	1.615		*	
4	1.602	2	1.594	4	1.596	14	1.600	2.10.1
				1	1.582			
1	1.549	4	1.545	6	1.545	4	1.549	$\bar{4}34$
				5	1.544			
2	1.533	6	1.529	12	1.530	15	1.534	045
2	1.518	<1	1.510	2	1.512	9	1.519	$\bar{2}.10.2$
								2.10.2
<1	1.496						*	
<1	1.486						*	
<1	1.475							
1	1.465			1	1.466	<1	1.467	473
<1	1.452							
2	1.441	<1	1.445	3	1.443	9	1.443	$\bar{3}.10.2$
		2	1.435	4	1.435	<1	1.439	$\bar{3}74$
						<1	1.435	700
						<1	1.432	3.10.2
<1	1.413	2	1.414	3	1.415	<1	1.415	374
2	1.402	4	1.396	2	1.402	5	1.402	

* Sato (1964c) reports lines from other specimens of tridymite type S corresponding to lines present in the Steinbach pattern.

$\alpha = 1.478$, $\beta = 1.479$, $\gamma = 1.482$, (for tridymite from Deception Island, Antarctica, the christensenite of Barth and Kvalheim, 1944).[1]

The x-ray powder data are listed in Table 3. Following Sato's (1964a, b, c) criteria for distinguishing between tridymite S and tridymite M on the basis of their X-ray patterns,[2] the Steinbach tridymite is similar to type S and the Mule Springs tridymite is similar to type M.

Sato (1964b) determined the lattice constants and space group of low tridymite type M from Kusatsu, Japan to be: orthorhombic $a = 9.940$ Å, $b = 17.21$ Å, $c = 40.92$ Å; space group $C222_1$. This is similar to the data of Lukesh and Buerger (1942) for tridymite from Plumas County, California and San Cristobal, Mexico. The tridymite from Mule Springs has a space group and lattice constants similar to the tridymite from the above three localities (personal communication from Wayne A. Dollase, Massachusetts Institute of Technology).

Sato (1964c) determined the lattice constants for low tridymite type S (synthetic) to be: monoclinic, $a = 10.04$ Å, $b = 17.28$ Å, $c = 8.20$ Å, $\beta = 91.50°$. Götz (1962) gives the following data for tridymite from the Steinbach meteorite: orthorhombic, $a = 30.05$ Å, $b = 52.08$ Å, $c = 49.56$ Å. Dollase and Buerger (1966) determined the crystal structure of three meteoritic tridymites including one from Steinbach. The lattice constants given for the meteoritic tridymite are: monoclinic, $a = 18.54$ Å, $b = 4.99$ Å. $c = 23.83$ Å, $\beta = 105.65°$. Götz's values for the Steinbach tridymite are for an apparent pseudocell which is the result of twinning. The relationship between the Steinbach tridymite and Sato's type S is not known.

I am indebted to Dr. Clifford Frondel for his help on this problem and to Dr. Jun Ito for the chemical analyses. This work was supported in part by NASA Grant NSG 282–63 and NSF Grant GU-1015.

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[1] This tridymite was reported to have an emission spectra similar to a mixture of 94.8 weight percent quartz and 5.2 percent nepheline, which is about 1.8 percent Al_2O_3 and 1.1 percent Na_2O for the tridymite.

[2] Sato gives the following major differences between the x-ray patterns for tridymite type S and tridymite type M.

Type S has a doublet at 3.86 and 3.81 Å and triplets at 3.016, 2.975, and 2.948 Å and 2.340, 3.309, and 2.291 Å, also it has a very weak peak at 3.25 Å.

Type M does not have the doublet or the triplets and has a strong peak at 3.25 Å.

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STABILITY, LATTICE PARAMETERS, AND THERMAL EXPANSION OF β-CRISTOBALITE: A DISCUSSION

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Aumento (1966) has stated that I "erroneously calculated" a value of $8.53\times10^{-6}\ °C^{-1}$ for the linear coefficient of expansion of high cristobalite. This unfortunate remark carries with it a disparaging implication of arithmetical ineptitude. The figure is incorrect in the reference, Lukesh (1942), to be sure, but had Aumento quoted a correct value (one based on the data which were available and which he presumably correctly calculated) of 8.93×10^{-6}, the high probability of a typographical error would have been quite obvious to the discerning reader. The reference cited was the abstract of a paper read by title only at the 1941 meeting of the Mineralogical Society of America held in Boston. Since pre-publication proofs of such abstracts are not provided to the authors, the error could not be noted and, hence, remained uncorrected.

That Aumento did not report the correct value is, perhaps, because the rather low values of the lattice constants "seem unacceptable" to him. The fact that the constants were smaller than any previously reported was commented on in the abstract. So, too, was the synthetic origin of the material studied in the earlier work noted, although it was not mentioned there that it was prepared by devitrification of a high quality, laboratory grade vitreous silica. This latter point is of importance because it suggests that the product was considerably less cluttered with impurities than was that used by Aumento. His method of preparation