UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

THERMAL CONDUCTIVITY OF SOME ROCK-FORMING MINERALS: A TABULATION

By

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Open-File Report 88-690

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1988

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INTRODUCTION

This compilation supplements Robertson's (1988) study of the thermal properties of rocks. The data were discussed by Diment (1967) and a version of table 1 circulated about that time. The table was subsequently updated to 1969 and an edited version of that table is presented here. The table contains measurements from the literature as well as those we made in the laboratory. Our data are identified by listing sample source but no reference in the "Remarks" column of the table.

Our measurements, as well as those in the literature prior to 1969, were mostly made on relatively large samples (in our case 0.64 x 3.81 cm machined disks). This means that in studying monomineralic aggregates, we must expect some impurity and some porosity. However, information on anisotropy can be obtained by cutting the disks in appropriate directions. In more recent years, Horai and Simmons (1969) and Horai (1971) used a needle probe technique to measure the conductivity of finely ground samples of minerals. Great purity of sample can be achieved, but all information as to anisotropy is lost. Moreover, questions remain as to the systematics of the orientation of small grains in the needle probe cell and the correction for fluid content. Comparison between the disk and needle-probe measurements is fairly good, but the scatter is large, as might be expected.

Our principal conclusions remain as they were circa 1967 (Diment, 1967), namely:

1. Substitution of a heavier cation for a lighter one in an isomorphous series usually reduces the thermal conductivity as demonstrated by measurements on some oxides, silicates, carbonates, and sulfates.

2. A plot of conductivity versus density suggests that minerals of the same mean atomic weight increase in conductivity with density in a manner analogous to that noted by Birch (1960, 1961) for the velocity of compressional waves, although the situation for conductivity is more complex.

3. The sheet silicates investigated are all anisotropic by a factor between 5 and 6 but the principal conductivities differ considerably. The true micas exhibit principal conductivities of about 2 and 12 mcal/cm sec deg C, perpendicular and parallel respectively to the plane of perfect cleavage. The conductivities can be somewhat less than this, depending on the amount of iron and layer-bonding imperfections. For talc and the chlorites, the perpendicular and parallel conductivities are about 4 and 24 mcal/cm sec deg C. Measurements on aggregates of pyrophyllite and serpentine suggests that pyrophyllite belongs with the talc-chlorite group and that serpentine is closer to the micas or intermediate in conductivity.

4. The range in values obtained for a given mineral, particularly that for a monomineralic aggregate, often exceed 10 percent because of impurities, alteration, imperfection, and a small but significant porosity. Thus, most values, especially those measured at low pressures, may be too low.

COMMENTS AFFECTING CALCULATION OF CONDUCTIVITY OF ROCK FROM MINERAL COMPOSITION

A few generalizations regarding the conductivity of rocks follow from this and other studies cited in the references:

1. Foliated rocks such as quartz-mica schists, green schists, and gneisses exhibit a mean anisotropy (ratio of conductivity parallel and perpendicular to plane of foliation) of about 1.3 (for example, Diment and Werre, 1964; Robertson, 1988, table 2).

2. The degree of alteration of rocks is important in determining their conductivities. For example, ultramafic rocks are usually serpentinized to some degree; thus, their conductivities are somewhat lower than would be suspected both because of the low conductivity of the serpentine and its peripheral distribution about the unaltered crystals. The amount of chlorite in mafic rocks is the most important variable in controlling their conductivity. Unaltered basalts, diabases, and gabbro have conductivities of about 5, whereas in the green schist facies their conductivity is between 8 and 9 (for example, Birch, 1954). As the degree of metamorphism increases further, conductivities decrease as the amphiboles and micas increase at the expense of the chlorites.

3. The conductivities of a surprising number of igneous and metamorphic rocks fall between 6.5 and 8.5. The distribution is especially peaked when the average of the principal conductivities of the foliated rocks is used. Thus we suppose that regional contrast in conductivity has little effect on heat flow, except in rather special situations. However, local refraction effects may be sizable where rocks of anomalous conductivities are present: the purer quartzites (12-15), unaltered ultramafic rocks (∿13), dolomitic marbles (∿12), anorthosites and unaltered mafic rocks (∿5).

EXPLANATION OF SYMBOLS AND ABBREVIATIONS FOR TABLE 1

Sample No. Assigned sample number indicates that measurement was made in our laboratory. No sample number means that conductivity measurement was obtained from literature or from another source. See Remarks column.

Mineral. Chemical formulae are generally for pure end members and are the formulae to which the theoretical densities (column 7) correspond. For many samples, the chemical composition is poorly known.

Conductivity. Brackets mean that measurement was made on the same sample at different temperature, pressure, or degree of saturation. Parentheses indicate that there is some reason to suspect the value, that is, a large departure of observed density from theoretical density, or systematic discrepancies in values in a given report. The measurements were made in an apparatus similar to that described by Birch (1950).

Orientation and state. || and ⊥, directions of maximum and minimum conductivity of a crystal or an aggregate. A, aggregate; xl, crystal. Occasionally direction is given with respect to a crystal face. R and S, shelf dried and saturated conditions. MIX, determinations of Horai and Simmons (1969) made on mixtures of crystals and fluid with values derived from the variational bounds.

Porosity. The porosity was determined from the difference in weight of water-saturated sample (water immersion under partial vacuum) and a dried sample (heated under partial vacuum at 80 °C).

Measured density. Measured density was computed from weight and measurement of linear dimensions. Weight used is room dried or saturated, depending on the state given in "Orientation and state". A few samples were chipped prior to weighing, thus density may be low.

Theoretical density. Data from Robie, and others (1966). They refer to idealized formula given under "Mineral".

Temperature. The temperature at which the conductivity measurement was made.

Pressure. The axial pressure on the sample.

Remarks. Wards, sample from Wards Natural Science Establishment, Inc.; USNM, sample from U.S. National Museum: their number follows in parentheses. X-ray, indicates that composition was verified by X-ray diffraction. Heavy reliance has been placed on Clark's (1966) tabulation, and in some cases the original sources have not been checked.

TABLE 1.--Thermal conductivity of rock-forming minerals

Sample No.	Mineral	Conductivity (mcal/cm·s·°C)	Orientation and state	Porosity (percent)	Density Measured (g/cm³)	Density Theoretical (g/cm³)	Temperature (°C)	Pressure (bars)	Remarks
					Silica group				
----	α Quartz, SiO_2.....	24.3	∥	---	----	2.648	30	---	Birch and Clark (1940) from curve of K versus T.
----	α Quartz...........	14.7	⊥	---	----	2.648	30	---	Ratcliff (1959) from curve of K versus T.
675	Novaculite..........	16.1	A/R	0.4	2.50	-----	35	34	Wards. White xls <0.1 mm.
		16.1	A/R	.4	2.63	-----	35	34	
		16.5	A/R	.2	2.51	-----	35	34	
		16.5	A/R	.0	2.63	-----	35	34	
		16.2	A/S	.0	2.63	-----			
499	Jasper.............	17.4	A/R	---	2.80	-----	30	25	Wards. Colchester, Vt. Brick red, massive; ~6 percent hematite.
		17.3	A/R	---		-----	30	100	
498	Chert..............	13.0	A/R	---	2.58	-----	30	25	Wards, Joplin, Mo. Light gray. xls <0.1 mm.
		13.2	A/R	---	2.58	-----	30	100	
		13.1	A/R	---	2.58	-----	30	25	
		13.2	A/R	---	2.58	-----	30	100	
514	Flint..............	8.1	A/R	---	2.60	-----	30	25	Wards. Dover Cliff, England.
		8.1	A/R	---	2.60	-----	30	100	Dark gray. xls <0.1 mm.
500	Opal...............	3.3	A/R	---	1.89	-----	30	25	Wards. Virgin Valley, Nev.
		3.3	A/R	---	1.89	-----	30	100	White. xls <0.1 mm.
----	Silica glass........	3.3	Glass	---	----	-----	30		Ratcliffe (1959) from curve K versus T.
					Feldspar group				
----	Orthoclase $KAlSi_3O_8$.	5.8	100/R	---	---	2.55±	25	---	Sass (1965, p. 4046). Plenty River, Northern Territory, Australia.
		6.4	010/R	---	---	----	---		
		6.0	001/R	---	---	----	---		
		5.4	100/R	---	---	----	25	---	Sass (1965). Olary, southern Australia.
		5.0	001/R	---	---	----	25	---	Sass (1965). Broken Hill, N.S.W., Australia.
		5.6	MIX	---	2.58	----	25	---	Horai and Simmons (1969).
----	Microcline $KAlSi_3O_8$.	5.5	001/R	---	---	2.56	---		Sass (1965). Londonderry, Western Australia.
		6.5	001/R	---	---	----	25	---	Sass (1965).
	Microcline perthite..	5.2	100/R	---	---	----	25	---	Sass, 1965. Londonderry, Western Australia.
		6.9	010/R	---	---	----	---	---	
		6.3	001/R	---	---	----	---	---	
		5.9	001/R	---	---	----	25	---	Sass, 1965, Spargoville, Western Australia.
	Albite $NaAlSi_3O_8$.	5.6	A/R	---	---	2.62±	25	---	Sass (1965). Londonderry, Western Australia.
----	Oligoclase $Ab_{88}An_{12}$.	4.8	001/R	---	---	----	25	---	Sass (1965). Langesurd Fjord, Norway.
		4.8	A/R	---	2.61	----	30	---	Birch and Clark (1940). Sylmar, Pa.,
		4.8	MIX	---	2.64	----	---	---	Horai and Simmons (1969).
----	Labradorite $Ab_{40}An_{60}$	4.2	A/R	---	2.70	----	30	---	Birch and Clark (1940). Quebec. 1% quartz, 4.6% sericite, serpentine, and carbonate.
	Labradorite $Ab_{35}An_{65}$..	4.0	A/R	---	2.74	----	30	---	Birch and Clark (1940). Stillwater complex, Montana.
	Bytownite........... $Ab_{20}An_{80}$.	4.4	A/R	---	2.74	----	30	---	Birch and Clark (1940). Transvaal. 5% pyroxene.
	Anorthite...........	6.5	001	---	----	2.76±	25	---	Sass (1965). Albany, N.Y.
	Anorthosite..........	4.3	MIX	---	----	2.70	---	---	Horai and Simmons (1969).
	Anorthosite bytounite	4.5	A/R	---	2.74	----	100	---	Birch and Clark (1940). Transvall.

TABLE 1.--Thermal conductivity of rock-forming minerals--Continued

Sample No.	Mineral	Conductivity (mcal/cm·s·°C)	Orientation and state	Porosity (percent)	Density Measured (g/cm³)	Density Theoretical (g/cm³)	Temperature (°C)	Pressure (bars)	Remarks
					Feldspathoids				
674	Sodalite $Na_8(AlSiO_4)_6Cl_2$.	7.5	A/R	0.0	2.29	---	35	34	Wards. Bancroft, Ontario. Royal Blue. Average xl diameter 4 mm. X-ray.
		7.7	A/S	.0	2.29	---	---	---	
		7.5	A/R	.1	2.30	---	---	---	
666	Nepheline $NaAlSiO_4$	3.3	A/R	---	2.60	2.623	35	34	Wards. Bancroft, Ontario. White, massive. X-ray.
		3.2	A/S	---	2.60	---	---	---	
		3.5	A/R	---	2.58	---	---	---	
					Olivine group				
----	Dunite (Fosterite) Mg_2SiO_4.	10.6	A/R	---	3.27-	3.214	30	---	Birch and Clark (1940; tables 3, 5, 7). Balsam Gap, N.C. Average xl diameter 1 mm. 97 percent Olivine $Fo_{92}Fa_8$, serpentine, 1 percent hornblende, chromite, carbonate.
		12.2	A/R	---	3.25	---	---	---	
		10.5	A/R	---	---	---	---	---	
391	Dunite..............	13.1	||/S	---	3.10	---	33	50	Sample from E.C. Robertson. Addie, N.C. Fine grained, vaguely banded.
		8.9	⊥/S	---	3.13	---	32	50	
	Dunite..............	10.1	A/S	---	3.12	---	32	50	Sample from E.C. Robertson. Macon City, Corundum Hill, N.C.
		10.3	A/S	---	3.12	---	32	50	
----	Dunite..............	15.2	||	---	---	---	24	---	Diment (1964); from F. Birch (unpub. data). Twin Sisters, Wash. Slightly less serpentinized than dunite from Balsam Gap.
		13.2	⊥	---	---	---	24	---	
----	Hortonolite dunite $(Mg,Fe)_2SiO_4$.	8.7	A	---	3.76	---	~20	---	Clark (1966, p. 463). Bushveld, Transvaal.
509	Dunite (Fayalite)....	9.1	A/R	---	4.24	4.393	30	25	Wards. Rockport, Mass. $Fa_{95.3}$, $Fo_{4.7}$ X-ray.
		9.0	A/R	---	4.24	---	30	100	
		9.3	A/R	---	4.26	---	30	25	
		9.4	A/R	---	4.26	---	30	100	
668	Monticellite $CaMgSiO_4$.	7.9	A/R	1.7	3.03	3.046	35	34	Wards. Crestmore, Calif. Massive, dark yellow brown. X-ray.
		7.7	A/S	1.7	3.03	---	---	---	
		7.8	A/R	1.8	3.04	---	---	---	
					Pyroxene group				
398	Jadeite $NaAlSi_2O_6$.	15.4	A/R	---	3.31	3.32	34	50	USNM (112701). Burma. Light-green xls <1 mm. 0.3 sample altered to unknown light-brown material.
399	Jadeite.............	11.3	A/R	---	3.11	3.31	34	50	USNM (112538). Manzanal, Montagua Valley, Guatemala. Uniform light green. xls <1 mm.
----	Hypersthenite $(Mg,Fe)SiO_3$.	10.3	A	---	3.26	---	30	---	Birch and Clark (1940; tables 3, 5, 7). Stillwater complex, Montana. Mean xl. diameter 2.5 mm. 93.5% hypersthene (Mg/Fe_6). 4% hornblende, 2.5% magnetite and hornblende.
----	Enstatite...........	11.8	MIX	---	3.27	---	---	---	Horai and Simmons (1969).
----	Bronzitite $(Mg,Fe)SiO_3$.	9.68	A	---	3.29	---	30	---	Birch and Clark (1940; tables 3, 5, 7). Pilansberg, Transvaal. Mean xl diameter 2.5 mm. 92.5% bronzite, 3.8% plagioclase, 1.7% hornblende, 2% magnetite.
----	Diopside $CaMgSi_2O_6$.	10.2	A	---	3.24	3.277	---	---	F. Birch (unpub. data).
----	Diopside............	10.8	MIX	---	3.27	---	---	---	Horai and Simmons (1969).
673	Augite $Ca(Mg,Fe,Al)(Al,Si)_2O_6$.	9.9	A/R	.7	3.41	---	35	34	Wards, Hybla, Ontario. Cleavage fragments. Greenish black. X-ray.
		10.1	A/R	.6	3.41	---	---	---	
		10.1	A/S	.6	3.41	---	---	---	
----	Pyroxenite..........	9.70	A	---	3.31	---	~20	---	Clark (1966, p. 463). Cleveland Peninsula, southeast Alaska. Mean of 3.

TABLE 1.--Thermal conductivity of rock-forming minerals--Continued

Sample No.	Mineral	Conductivity (mcal/cm·s·°C)	Orientation and state	Porosity (percent)	Density (g/cm³) Measured	Density (g/cm³) Theoretical	Temperature (°C)	Pressure (bars)	Remarks
----	Pyroxenite..........	8.68	A	---	3.25	---	~20	---	Clark (1966, p. 463). Percy Islands, southeast Alaska. Mean of 3.
----	Pyroxenite..........	11.8	A	---	3.29	---	~20	---	Clark (1966, p. 463) after Birch (unpub. data). Bushveld, Transvaal.
388	Pyroxenite..........	7.9	A/S	---	3.50	---	33	50	E.C. Robertson, Klukwan, southeast Alaska. 70% augite, 5% enstatite, 15% hornblende, 5% magnetite, 5 percent diopside. X-ray. Average xl diameter 3 mm to 2 cm.
		8.2	A/S	---	3.48	---	33	50	
		7.6	A/S	---	3.43	---	31	---	
					Amphibole group				
524	Tremolite $Ca_2Mg_5Si_8O_{22}(OH)_2$.	10.8	⊥/R	---	2.76	2.976	30	25	Wards. Balmat, N.Y. White acicular xls to 3 cm. X-ray.
		11.0	⊥/R	---	2.76	-----	30	100	
		13.7	||	---	2.77	-----	31	25	
		14.1	||	---	2.77	-----	31	100	
669	Actinolite $Ca_2Fe_5Si_8O_{22}(OH)_2$.	7.1	⊥/R	.7	2.98	3.4	35	34	Wards. California. Medium green. Acicular, fiberous xls to several centimeters. X-ray.
		12.6	||/R	.4	3.00	-----	---	---	
		13.0	||/S	.4	3.00	-----	---	---	
661	Hornblende $NaCa_2(Mg,Fe,Al)$ $(Si,Al)_8O_{22}(OH)_2$.	4.5	⊥/R	.3	3.50	---	35	34	Wards. Porter, N.Y. Brownish black. Large cleavage fragments. X-ray.
		6.9	||/R	.2	3.25	---	---	---	
		6.3	||/R	.7	3.45	---	---	---	
----	Hornblende..........	6.5	MIX	---	3.25	---	---	---	Horai and Simmons (1969).
----	Hornblendite........	6.75	A	---	3.22	---	~20	---	Clark (1966, p. 463). Duke Island, southeast Alaska. Mean of 4.
----	Hornblendite........	7.16	A	---	3.12	---	~20	---	Clark (1966, p. 463), after Birch (unpub. data).
					Sheet silicates				
----	Muscovite $KAl_2(AlSi_3O_{10})(OH)_2$.	1.67	⊥/R	---	2.83	2.834	45	1	Clark, 1941.
		1.74	⊥/S	---	2.83	---	45	680	
491	Muscovite...........	9.3	||/R	---	---	---	30	25	USNM (90241). Batenellerville, N.Y.
		9.3	||/R	---	---	---	30	150	
		1.22	⊥/R	---	---	---	32	25	
		1.26	⊥/R	---	---	---	32	150	
----	Phlogopite..........	12	||/R	---	---	---	~30	---	Goldsmid and Bailey (1960, p. 865).
515	Phlogopite..........	1.1	⊥/R	---	2.76	---	30	25	Wards. Quebec. Dark brown to black. Single xl. X-ray. β index 1.572.
		1.2	⊥/R	---	2.76	---	---	100	
		1.1	⊥/R	---	2.81	---	---	25	
		1.2	⊥/R	---	2.81	---	---	100	
		8.3	||/R	---	2.56	---	---	25	
		8.4	||/R	---	2.56	---	---	100	
490	Biotite.............	1.21	⊥/R	---	---	---	32	25	USNM(30764) Burgess, Ontario.
		1.28	⊥/R	---	---	---	---	150	
518	Biotite.............	7.5	||/R	---	---	---	33	100	Wards. Bancroft, Ontario. Black. Single xl. X-ray. β=1.624.
517	Lepidolite $K(Li_2,Al)Si_4O_{10}(OH)_2$.	1.13	⊥/R	---	2.78	---	33	25	Wards. Freeman Co., Calif. Purple. Single xl.
		1.15	⊥/R	---	2.78	---	---	100	
521	Lepidolite..........	5.5	A/R	---	2.85	---	29	25	Wards. Winnepeg River, Manitoba. Blue flakes.
		5.5	A/R	---	2.85	---	---	100	
516	Pyrophyllite $Al_2Si_4O_{10}(OH)_2$.	2.6	⊥/R	---	2.77	2.845	30	25	Wards. Moore Co., N.C. Light gray. Large sheets. Highly oriented. X-ray.
		2.7	⊥/R	---	2.77	---	---	100	
		2.7	⊥/R	---	2.69	---	---	25	
		3.0	⊥/R	---	2.69	---	---	100	
		12.2	||/R	---	2.69	---	---	25	

TABLE 1.--Thermal conductivity of rock-forming minerals--Continued

Sample No.	Mineral	Conductivity (mcal/cm·s·°C)	Orientation and state	Porosity (percent)	Density Measured (g/cm³)	Density Theoretical (g/cm³)	Temperature (°C)	Pressure (bars)	Remarks
		13.7	∥/R	---	2.69	---	---	100	
		16.1	∥/R	---	2.69	---	---	100	
		15.5	∥/R	---	2.72	---	---	25	
		16.2	∥/R	---	2.72	---	---	100	
035	Pyrophyllite.........	11.8	A/R	---	2.77	---	33	25	Wards. Hillsboro, N.C. White with red
		12.0	A/R	---	2.77	---	33	100	stain. Radiating xls <1 cm. X-ray.
670	Pyrophyllite.........	9.2	A/R	7.5	2.62	---	35	34	Wards. Africa. Dark gray. Massive
		9.2	A/R	---	2.63	---	---	---	wonderstone. X-ray.
		11.7	A/S	---	2.63	---	---	---	
528	Pyrophyllite.........	10.4	A/R	---	3.05	---	30	25	Wards. Hillsboro, N.C. Pink acicular
		11.0	A/R	---	---	---	---	100	xls to 8 mm. Metallic impurity.
----	Pyrophyllite.........	11.9	---	---	---	---	0	---	Clark (1966, p. 470); from Carte, 1955.
		10.0	---	---	---	---	100	---	Values read from curve. Conductivity
		8.5	---	---	---	---	200	---	⊥ to bedding ~0.5 that of ∥.
		7.5	---	---	---	---	300	---	
		6.7	---	---	---	---	400	---	
519	Talc (Steatite)	4.2	⊥/R	---	2.85	2.788	30	25	Murray Co., Ga. Massive, medium to
	$Mg_3Si_4O_{10}(OH)_2$.	4.2	⊥/R	---	2.85	---	30	100	dark green, transluscent. X-ray.
		22.0	∥/R	---	2.85	---	30	25	
		23.1	∥/R	---	2.85	---	30	100	
525	Talc (Steatite)......	29.0	∥/R	---	2.73	---	29	25	Swain Co., North Carolina. White
		29.8	∥/R	---	2.73	---	29	100	sheetlike. Translucent. X-ray.
397	Talc (Steatite)......	23.8	∥/R	---	2.75	---	34	50	USNM(18898). Nantshata, Swain Co., North Carolina. White. Weakly translucent.
----	Talc.................	7.1	A	---	2.79	---	30	170	Birch (1954, p. 10).
----	Soapstone............	12.0	A	---	2.84	---	---	---	Clark (1966, p. 463); from Birch (unpub. data.).
----	Chlorite.............	12.5	A/R	---	2.79	---	30	170	Birch (1954, p. 10). Harvard Museum.
520	Chlorite.............	4.6	A/R	---	2.89	---	---	25	Wards. Cotopaxi, Colo.
		5.0	A/R	---	2.89	---	---	100	
		7.2	A/R	---	2.92	---	---	25	
		7.3	A/R	---	2.92	---	---	100	
456	Prochlorite $Mg_4Fe_2Al_4SiO_{10}(OH)_8$.	10.7	A/S	---	2.97	---	30	---	USNM(36083). Southbury, Conn.
457	Prochlorite..........	9.7	A/S	---	2.95	---	29	---	
522	Prochlorite..........	9.4	A/R	---	---	---	30	25	Wards. Chester, Vt. Dark green,
		9.8	A/R	---	---	---	---	100	massive; X-ray; 15% magnetite.
526	Clinochlore	24.3	∥/R	---	2.59	---	29	25	USNM, Swain Co., North Caroline. Light
	$Mg_5Al_2Si_3O_{10}(OH)_8$.	25.1	∥/R	---	2.59	---	---	100	green; single xl; X-ray.
		4.6	⊥/R	---	2.58	---	---	25	
		4.8	⊥/R	---	2.58	---	---	100	
435A	Serpentine	5.5	⊥/S	---	2.61	~2.6	32	50	Sample from H. H. Hess (V1301). Puerto
to	$Mg_6Si_4O_{10}(OH)_8$	6.0	⊥/S	---	2.64	---	---	---	Cabello, Venezuela. Massive aggre-
439B	(Antigorite).	6.5	∥/S	---	2.64	---	---	---	gate.
		6.6	∥/S	---	2.61	---	---	---	
		6.7	∥/S	---	2.61	---	---	---	
		6.6	∥/S	---	2.63	---	---	---	
386	Serpentine (Antigorite).	5.3	A/S	0.7	2.66	---	34	50	USNM(96916) Cogne, Posta Valley, Italy. Dark green, opaque, probably impure.
383	Serpentine (Williamsite).	7.4	A/S	---	2.58	---	33	50	USNM(82513) Lancaster Co., Pa. Green, Green, translucent; 5 percent chromite(?) in 1 mm xls.
384	Serpentine (Yu Yen Stone).	5.6	A/S	---	2.56	---	34	50	USNM(94356) Manchuria. Milky white; uniform; translucent.

TABLE 1.--Thermal conductivity of rock-forming minerals--Continued

Sample No.	Mineral	Conductivity (mcal/cm·s·°C)	Orientation and state	Porosity (percent)	Density (g/cm³) Measured	Density (g/cm³) Theoretical	Temperature (°C)	Pressure (bars)	Remarks
387	Serpentine...........	6.4	A/S	---	2.52	---	34	50	USNM(47657). Gordon's Quarry,
		6.5	A/S	---	2.52	---	34	---	Montville, N.J. Amber colored,
									uniform, translucent.
385	Serpentine...........	6.7	A/S	---	2.58	---	34	50	USNM(R3077). Afghanistan. Milky white,
		7.1	A/S	---	2.57	---	34	---	uniform, very translucent.
		7.1	A/S	---	2.57	---	34	---	
----	Serpentine A	5.9	A/R	---	2.65	---	30	170	Birch (1954, p. 10). Samples from
	B	4.3	A/R	---	2.44	---	30	170	Harvard Museum.
325A to 336B	Serpentinite.........	5.4	A/S	2.5	2.64	---	32	50	Mayaguez, Puerto Rico. Diment (1964). Mean of 20.
325A to 326B	Serpentinite.........	6.0	A/S	---	2.64	---	32	50	Same as above. Based on extrapolation to zero porosity.
433A to 434D	Serpentinized peridotite.	5.5	A/S	---	2.57	---	32	50	Sample from H.H. Hess (QTH-A), Thetford, Quebec. Mean of 7. Diment (1964).
----	Serpentinized peridotite.	6.34	A/R	---	2.62	---	16	---	King Mine, Thetford Mines, Quebec. Misener and others (1951). Mean of 5.
----	White serpentine.....	6.27	A/R	---	1.71	---	17	---	Do.
----	Serpentine	7.70	A/R	---	2.80	---	24	---	Do.
	(altered to brucite).	7.50	A/R	---	2.76	---	25		
					Al_2SiO_5 group				
672	Kyanite..............	29.3	A/R	---	3.45	3.674	35	34	Wards. Kenya, Africa. Light xls to 2
		31.6	A/S	.7	3.45	---	---	---	cm; impure; quartz <5%.
		28.3	A/R	.7	3.54	---	---	---	
505	Kyanite..............	17.4	A/R	---	2.93	---	35	34	Wards. Ogilsbee, Calif.
		17.4	A/R	---	2.93	---	---	---	
		16.9	A/R	---	2.89	---	---	---	
		16.6	A/R	---	2.89	---	---	---	
508	Andalusite...........	15.7	A/R	---	3.10	3.144	30	25	Wards. White Mountain, Monterey Co.,
		16.0	A/R	---	3.10	---	---	100	Calif. Light-gray to brown xls <2 mm;
		15.9	A/R	---	3.09	---	---	25	impure; quartz <5%; X-ray.
		16.4	A/R	---	3.09	---	---	100	
		15.5	A/R	---	3.08	---	---	25	
		16.2	A/R	---	3.08	---	---	100	
		14.5	A/R	---	3.07	---	---	25	
		15.2	A/R	---	3.07	---	---	100	
----	Andalusite...........	(26.3)	---	---	---	---	0	---	Clark (1966, p. 467); from Euken and Kuhm (1928).
660	Sillimanite..........	25.9	A/R	0.0	3.16	3.247	35	34	Wards. Dillon, Montana. White fibrous
		27.0	A/S	.0	3.16	---	---	---	xls <2 cm; impurities <5%; quartz and
		24.0	A/S	.1	3.16	---	---	---	feldspar.
					Garnet group				
----	Almandine(?) $Fe_3Al_2(SiO_4)_3$.	8.5	A/R	---	3.93	4.318	---	---	Diment (1964); from Birch (unpub. data). Massive, red.
----	Grosslarite $Ca_3Al_2(SiO_4)_3$.	12.7	A/R	---	3.49	3.595	---	---	Diment (1964); from Birch (unpub. data).
663	Spessartite $Mn_3Al_2(SiO_4)_3$.	7.2	A/R	.9	3.88	4.190	35	34	Wards. Westchester, Pa. Massive,
		7.6	A/S	.9	3.88	---	---	---	Brownish red, X-ray.
		7.2	A/R	1.8	3.82	---	---	---	
					Miscellaneous silicates				
494	Epidote	6.0	A/R	---	---	---	31	---	Wards. Calumet, Colo. Olive-green xls
	$Ca_2(Al,Fe)_3Si_3O_{12}(OH)$	5.9	A/R	---	---	---	31	---	to 4 mm. >5 percent quartz. X-ray.
495	Epidote..............	7.0	⊥/R	---	---	---	32	---	Wards. North Carolina. Olive green
		7.4	∥/R	---	---	---	31	---	xls <0.15 mm. X-ray.

TABLE 1.--Thermal conductivity of rock-forming minerals--Continued

Sample No.	Mineral	Conductivity (mcal/cm·s·°C)	Orientation and state	Porosity (percent)	Density Measured (g/cm³)	Density Theoretical (g/cm³)	Temperature (°C)	Pressure (bars)	Remarks
0001	Epidosite............	7.2	A/R	---	3.25	---	33	100	South Mountain, Pa.
0002		7.0	A/R	---	3.30	---	33	100	
0003		9.5	A/R	---	2.99	---	33	100	
0004		10.0	A/R	---	3.05	---	33	100	
671	Idocrase.............	6.4	A/R	0.8	3.33	---	35	34	Wards. Sanford Mine, Maine. Dark green xls <1 cm. Quartz <1 percent. X-ray.
		6.7	A/R	0.9	3.33	---	---	---	
662	Cordierite $Mg_2Al_3(AlSi_5O_{18})$.	7.9	∥/R	0.0	2.58	2.51	35	34	Wards. Albany Co. Wo. Pale blue single xl. X-ray.
		8.1	∥/R	---	2.57	---	---	---	
		8.0	∥/S	---	2.57	---	---	---	
		7.4	⊥/R	0.8	2.59	---	---	---	
		7.3	⊥/R	---	2.59	---	---	---	
665	Scapolite $(Na,Ca)_5[(Al,Si)_4O_8]_3CO_3$.	4.2	X/R	0.8	2.75	---	35	34	Wards. Quebec. White. Single xl. X-ray.
		4.2	X/R	0.6	2.76	---	---	---	
		4.2	X/S	0.6	2.76	---	---	---	
		4.6	Z/R	0.6	2.70	---	---	---	
		4.7	Z/R	0.6	2.73	---	---	---	
					Oxides				
----	Magnetite Fe_3O_4.	12.5	A/R	---	4.6	5.200	30	170	Birch (1954, p. 10), Harvard Min. Museum.
		---	---	---	---	---	---	---	
393	Magnetite............	10.1	A	---	4.79	---	32	50	E. C. Robertson. Klukwah, S.E. Alaska, 6 mm average xl diameter. <5% impurities.
		9.9	A	---	4.82	---	33	---	
394	Magnetite............	10.1	A	---	4.68	---	33	50	R. A. Robie. Lover's Pit, Mineville, N.Y. Average xls diam. 1.5 mm. 10% impurities.
		10.9	A	---	4.64	---	32	---	
----	Magnetite............	11.2	A	---	4.92	---	32	50	R. A. Robie. Lover's Pit, Mineville, N.Y. Average xls diam. 4 mm. 5% impurities.
		11.5	A	---	4.96	---	33	---	
----	Magnetite............	11.9	xl/R	---	---	---	22	---	Clark (1966, p. 465) after Birch (unpublished). Single xl.
----	Hematite Fe_2O_3.	25	A/R	---	4.1	5.274	30	170	Birch (1954, p. 10). Harvard Min. Museum.
----	Hematite.............	28.9	---	---	---	---	30	---	Clark (1966, p. 466) after Koenigsberger and Weiss (1911).
		35.1	---	---	---	---	---	---	
694	Ilmenite $FeTiO_3$.	6.0	A/R	0.0	4.72	4.786	35	34	Wards. Egersund, Norway. xls <6 mm. X-ray.
		6.0	A/S	0.0	4.72				
		5.9	A/R	0.1	4.69	---	---	---	
695	Chromite $(Fe,Mg)Cr_2O_4$.	4.8	A/R	3.3	4.30	---	35	34	Wards. Texas, Pa. Massive. Dark grey. xls <1 m. X-ray.
		5.2	A/R	0.9	5.22	---	---	---	
		5.7	A/S	0.9	5.22	---	---	---	
----	Spinel $MgAl_2O_4$.	33	---	---	---	3.582	35	---	Artificial. Clark (1966, p. 465). After McCarthy and Ballard (1951).
		26	---	---	---	---	68	---	
		28	---	---	---	---	70	---	Artificial. Clark (1966, p. 465) after Tuchschmidt (1883).
693	Rutile TiO_2.	11.7	A/R	0.0	4.18	4.250	---	---	Wards. Mexico. Massive brownish red. X-ray.
		12.2	A/S	0.0	4.18	---	---	---	
		11.2	A/R	0.4	4.09	---	---	---	
----	Rutile...............	30	∥/?	---	---	---	36	---	Clark (1966, p. 466) after McCarthy and Ballard (1951).
		21	⊥/?	---	---	---	44	---	
		33	∥/?	---	---	---	67	---	
		17	⊥/?	---	---	---	67	---	
667	Corundum Al_2O_3.	40.8	∥/R	0.0	3.86	3.988	35	34	Wards. Zoutpanberg dist. Transvaal. Light bluish grey xl. X-Ray.
		41.2	∥/S	0.0	3.86	---	---	---	
		36.4	∥/R	0.0	3.85	---	---	---	
		36.8	⊥/R	0.0	3.79	---	---	---	
		37.3	⊥/R	0.0	3.79	---	---	---	

TABLE 1.--Thermal conductivity of rock-forming minerals--Continued

Sample No.	Mineral	Conductivity (mcal/cm·s·°C)	Orientation and state	Porosity (percent)	Density (g/cm³)		Temperature (°C)	Pressure (bars)	Remarks
					Measured	Theoretical			
----	Corundum............	55	⊥	---	---	---	23	---	Clark (1966, p. 466) after McCarthy and Ballard (1951).
		60	||	---	---	---	26	---	
		41	||	---	---	---	70	---	
		40	⊥	---	---	---	77	---	
----	Corundum............	71	60° from C axis.	---	---	---	70	---	Clark (1966, p. 466) after Weeks and Seifert (1953).
				Hydroxide					
396	Brucite $Mg(OH)_2$	12.9	A/R	---	2.36	2.368	33	50	USNM(105408) Gabbs, Nev. White. Weakly translucent.
				Sulfides					
688	Pyrite FeS_2.	49.1	A/R	1.4	4.75	5.016	35	34	Wards. Rico, Colo. Brass yellow. xls. <0.5 mm. X-ray. <5% sphalerite.
		56.1	A/R	0.7	4.78	---	---	---	
		60.7	A/S	0.7	4.78	---	---	---	
----	Pyrite..............	(90.6)	---	---	---	---	0	---	Clark (1966, p. 465) after Eucken and Kuhn (1928).
690	Pyrrhotite $Fe_{1-x}S$.	8.4	A/R	0.1	4.67	---	35	34	Wards. Falconbridge, Ont. Brass yellow. xls<1 mm. X-ray. <2% impurities.
		8.6	A/S	0.1	4.67	---	---	---	
		8.3	A/R	0.2	4.65	---	---	---	
689	Calcopyrite $FeCuS_2$.	17.7	A/S	0.0	4.15	---	35	34	Wards. Royn Dist., Que. Massive. Brass yellow with some iridescent coloring. Pyrite impurity.
		19.0	A/R	0.0	4.15	---	---	---	
		17.6	A/R	0.1	4.14	---	---	---	
691	Sphalerite ZnS.	26.9	A/R	0.0	4.04	4.088	35	34	Wards. Ottawa Co. Okla. Massive brownish yellow.
		29.8	A/S	0.0	4.04	---	---	---	
		26.9	A/R	0.0	4.03	---	---	---	
----	Sphalerite..........	(63.6)	---	---	---	---	---	---	Clark (1960, p. 465) after Eucken and Kuhn (1928).
692	Galena PbS.	6.3	A/R	0.0	7.41	7.597	35	34	Wards. Galena, Ill.
		6.3	A/S	0.0	7.41	---	---	---	
		7.2	A/R	0.0	7.40	---	---	---	
				Halides					
----	Halite NaCl.	16.7	xl	---	---	2.163	0	---	Clark (1966, p. 465) from Eucken (1911).
		11.6	---	---	---	---	100	---	
----	Halite..............	13.8	xl	---	---	---	30	---	Clark (1966, p. 465) from Lees (1892).
----	Halite..............	13.9	xl	---	---	---	29	---	Clark (1966, p. 465) from Herrin and Clark (1956).
----	Halite..............	10.0	xl	---	---	---	8	---	Clark (1966, p. 465) from Griffiths and Kaye (1923).
----	Halite..............	13.6	xl	---	---	---	19	---	Clark (1966, p. 465) from Leney and Wilson (unpub.).
----	Halite..............	8.8	xl	---	---	---	30	---	Clark (1966, p. 465) from Bridgman (1924).
		7.6	---	---	---	---	75	---	
----	Halite..............	14.6	xl	---	---	---	0	---	Clark (1966, p. 465) from Birch and Clark (1940).
		10.1	---	---	---	---	100	---	
		7.5	---	---	---	---	200	---	
		6.0	---	---	---	---	300	---	
		5.0	---	---	---	---	400	---	
----	Halite..............	14.7	xl	---	---	---	35	---	Clark (1966, p. 465) from Ballard, McCarthy, and Davis (1950).
		13.0	---	---	---	---	70	---	
----	Halite (artificial).	(21.3)	xl	---	---	---	0	---	Clark (1966, p. 465) from Eucken and Kuhn (1928).
----	Halite (artificial).	(22.8)	xl	---	---	---	0	---	Same.

TABLE 1.--Thermal conductivity of rock-forming minerals--Continued

Sample No.	Mineral	Conductivity (mcal/ cm·s·°C)	Orientation and state	Porosity (percent)	Density Measured	Density Theoretical (g/cm^3)	Temperature (°C)	Pressure (bars)	Remarks
----	Rocksalt............	12.8	A	---	2.18	---	-27	---	Herrin and Clark (1956). Oklahoma. Mean of 2.
----	Rocksalt............	12.8	A	---	2.10	---	-27	---	Herrin and Clark (1956). Carlsbad, N.M.
----	Rocksalt............	13.3	A	---	---	---	---	---	Clark (1966, p. 464) from Leney and Wilson (unpubl.).
----	Rocksalt............	16.2	A	---	---	---	-27	---	Clark (1966, p. 464) from Coster (1947). Masjid-i-Sulaman, Iran.
----	Rocksalt............	17.2	A	---	---	---	---	---	Clark (1966, p. 464) from Benfield (1939). Holford, England.
----	Sylvite KCl.	16.6 11.8	xl xl	--- ---	--- ---	1.987 ---	0 100	--- ---	Clark (1966, p. 465) from Eucken (1911).
----	Sylvite (artificial).	15.6 15.3	xl xl	--- ---	--- ---	--- ---	12 72	--- ---	Clark (1966, p. 465) from Ballard, McCarthy and Davis (1950).
----	Sylvite............	(22.1)	xl	---	---	---	0	---	Clark (1966, p. 465) from Euken and Kuhn (1928).
696	Fluorite CaF_2.	19.1 19.5 19.3 18.0	xl/R xl/S xl/R xl/S	0.0 0.0 0.0 0.0	3.16 3.16 3.19 3.19	3.181 --- --- ---	35 --- --- ---	34 --- --- ---	Wards. Roseclare, Ill. Clear to dark purple. Xl. frag.
----	Fluorite............	9.6	---	---	---	---	---	---	Clark (1966, p. 464) from Herschel et al. (1881).
----	Fluorite............	(24.6) (19.1)	x/1 ---	--- ---	--- ---	--- ---	0 100	--- ---	Clark (1966, p. 465) from Euken (1911).
----	Fluorite (artificial).	23.2	x/I	---	---	---	36	---	Clark (1966, p. 465) from Ballard, McCarthy, and Davis (1950).
				Calcite group					
----	Calcite $CaCO_3$.	7.55 8.67	⊥ ||	--- ---	2.71 2.71	2.712 ---	30 30	--- ---	Birch and Clark (1940, Tables 3 and 7). Single xl.
----	Calcite............	9.5	MIX	---	2.72	---	---	---	Horai and Simmons (1969).
----	Marble............	6.65 6.76	⊥ ||	--- ---	2.69 2.69	--- ---	30 30	--- ---	Birch and Clark (1940, Tables 3 and 7). Proctor, Vt. Av. xl. diam. 0.4 mm.
----	Limestone............	5.48 7.80	⊥ ||	--- ---	2.69 2.69	--- ---	30 30	--- ---	Birch and Clark (1940, Tables 3 and 7). Pennsylvanian limestone. Nazareth, Pa.
----	Limestone............	6.52	A/	---	2.61	---	30	---	Birch and Clark (1940, Tables 3 and 7). Solenhofen, Bavaria. Av. xl diam. 0.001-0.01 mm.
----	Limestone............	6.6	A/R	---	---	---	30	---	Diment and Robertson (1963). Value for "pure" limestone based on regression line through samples of varying shale content. Paleozoic limestones from Oak Ridge, Tenn.
----	Limestone............	6.77	A/S	0.4	2.70	---	---	---	Robertson (1959). Mean of 41 samples of massive Paleozoic limestone from Sandhill well, Wood Co., W. Va.
----	Magnesite $MgCO_3$.	23.8	---	---	2.95	3.009	---	---	Birch (1942, p. 263) after Tadokoro (1921).
394	Magnesite............	21.6	A/R	---	2.95	---	34	50	USNM(48273). Wells Island, Thousand Island Park, N.Y. White, weakly translucent. Av. xl. diam. 1.5 mm.
395	Magnesite............	10.1	A/R	---	2.66	---	34	50	USNM(16070). Gilroy, Calif. Chalky white, opaque, microcrystalline. Veined with chalcedony (?).

TABLE 1.--Thermal conductivity of rock-forming minerals--Continued

Sample No.	Mineral	Conductivity (mcal/cm·s·°C)	Orientation and state	Porosity (percent)	Density Measured (g/cm³)	Density Theoretical (g/cm³)	Temperature (°C)	Pressure (bars)	Remarks
507	Magnesite............	17.9	⊥/R	---	2.90	---	---	25	Wards. Washington. Med. gray with
		18.5	⊥/R	---	2.90	---	---	100	dark bands. Av. xl. diam. 0.5-1 mm.
		16.7	⊥/R	---	2.88	---	---	25	X-ray.
		16.8	⊥/R	---	2.88	---	---	100	
		18.3	||/R	---	2.92	---	---	25	
		19.3	||/R	---	2.92	---	---	100	
		18.5	||/R	---	2.92	---	---	25	
		19.0	||/R	---	2.92	---	---	100	
680	Magnesite............	15.8	A/R	0.2	2.93	---	35	34	Wards. Snarum, Norway. White to light
		17.5	A/R	0.0	2.98	---	---	---	gray. X-ray.
		19.0	A/S	0.0	2.98	---	---	---	
501	Rhodochrosite	9.1	A/R	---	3.57	3.698	31	25	Wards. Catamarca Province, Argentina.
	$MnCO_3$.	9.2	A/R	---	3.57	---	---	100	Pink. Xls. 2-3 mm. X-ray.
		9.2	A/R	---	3.58	---	---	25	
		9.4	A/R	---	3.58	---	---	100	
684	Siderite	7.1	A/R	0.4	3.56	3.944	35	34	Wards. Quebec. White. X-ray.
	$FeCO_3$.	7.5	A/S	0.4	3.56	---	---	---	
		6.8	A/R	0.5	3.55	---	---	---	
685	Smithsonite	7.9	A/R	0.0	4.37	4.434	35	34	Wards. Wanlockhead, England.
	$ZnCO_3$.	8.2	A/R	0.0	4.29	---	---	---	Acicular xls.
		8.3	A/S	0.0	4.29	---	---	---	
681	Dolomite	11.4	A/R	0.1	2.84	2.866	35	34	Wards. Lee, Mass. White. Xls <0.5 mm.
	$CaMg(CO_3)_2$.	12.2	A/R	0.0	2.84	---	---	---	X-ray.
		12.5	A/S	0.0	2.84	---	---	---	
682	Dolomite............	11.2	A/R	0.2	2.84	---	35	34	Wards. Thornwood, N.J. White. xls
		11.6	A/S	0.2	2.84	---	---	---	1-6 mm. X-ray.
		10.7	A/R	0.3	2.83	---	---	---	
----	Dolomite............	13.2	A	---	---	---	---	---	Carte (1954) Borehole HB15. Transvaal. Mean of 8.
----	Dolomite............	11.0	A	---	---	---	25	---	Clark (1966, p. 462) after Bullard (1939). Gerhardminnebron Bore, Transvaal. Mean of 7.
----	Dolomite............	11.4	A/S	0.4	2.81	---	---	---	Robertson (1959). Mean of 52 samples of massive Paleozoic dolomite from Sandhill well, Wood Co., W. Va.
					Aragonite group				
683	Aragonite	4.8	A/R	0.9	2.84	2.930	35	34	Wards. Tano Tuscany. White to light
	$CaCO_3$.	4.7	A/S	0.9	2.84	---	---	---	gray. Radiating xls to 2 cm. X-ray.
		4.9	A/R	0.6	2.84	---	---	---	
502	Aragonite (?)........	6.0	A/R	---	2.69	---	31	25	Wards. Flagstaff, Ariz. Golden brown
		6.0	---	---	---	---	---	100	acicular xls <3 mm. X-ray.
		6.0	A/R	---	2.69	---	---	25	
		5.9	---	---	---	---	---	100	
		6.0	A/R	---	2.68	---	---	25	
		6.0	---	---	---	---	---	100	
		6.0	A/R	---	2.68	---	---	25	
		6.0	---	---	---	---	---	100	
686	Witherite	5.4	A/R	0.0	4.25	4.308	35	34	Wards. Sttingstones Mine,
	$BaCO_3$.	5.5	A/S	0.0	4.25	---	---	---	Northumberland, England. Honey brown.
		5.4	A/R	0.0	4.25	---	---	---	Acicular xls to 3 cm. X-ray.
687	Cerussite	3.2	A/R	0.9	5.61	6.581	35	34	Wards. New Mexico. Massive dark gray.
	$PbCO_3$.	3.3	A/S	0.9	5.61	---	---	---	xls <0.5 mm. X-ray.
		3.2	A/R	0.9	5.71	---	---	---	
504	Strontianite	3.4	A/R	---	3.73	3.785	31	25	Wards. Fidelgo Island, Wash. White.
	$SrCO_3$.	3.4	A/R	---	3.73	---	---	100	xls 1-2 mm. X-ray.
		3.2	A/R	---	3.74	---	---	25	
		3.2	A/R	---	3.74	---	---	100	
----	Strontianite.........	4.5	xl	---	---	---	0	---	Clark (1966, p. 467) after Muller
		3.7	xl	---	---	---	100	---	(1913).

TABLE 1.--Thermal conductivity of rock-forming minerals--Continued

Sample No.	Mineral	Conductivity (mcal/cm·s·°C)	Orientation and state	Porosity (percent)	Density Measured (g/cm³)	Density Theoretical (g/cm³)	Temperature (°C)	Pressure (bars)	Remarks
					Sulfates				
----	Barite $BaSO_4$.	4.1	---	---	---	---	0	---	Clark (1966, p. 467) after Muller (1913).
		3.6	---	---	---	---	100	---	
512	Barite..............	5.0	⊥/R	---	4.05	4.480	31	25	Wards. Murray Co. S. C. Light gray with dark bands. Xls<1 mm. Small amount of Ca and Sr impurities. X-ray.
		4.9	⊥/R	---	4.05	---	---	100	
		7.1	||/R	---	3.98	---	---	25	
		7.2	||/R	---	3.98	---	---	100	
		6.8	||/R	---	3.94	---	---	25	
		6.8	||/R	---	3.94	---	---	100	
513	Barite..............	4.2	A/R	---	4.23	---	31	25	Wards. Kings Creek, S. C. White, Massive. X-ray.
		4.2	A/R	---	4.23	---	---	100	
		4.0	A/R	---	4.26	---	---	25	
		4.0	A/R	---	4.26	---	---	100	
----	Celestite $SrSO_4$.	4.5	---	---	---	3.972	0	---	Clark (1966) after Muller (1913).
		3.7	---	---	---	---	100	---	
678	Celestite...........	3.3	||/R	0.2	3.93	---	35	34	Wards. Torreon, Coahuila, Mexico. Pale blue single xl.
		2.8	⊥/R	0.2	3.93	---	---	---	
		3.3	⊥/R	0.7	3.93	---	---	---	
		3.2	⊥/R	0.7	3.93	---	---	---	
503	Anhydrite $CaSO_4$.	12.5	A/R	---	2.93	2.963	29	25	Wards. Nova Scotia, Can. Medium gray. Xls 0.5-4 mm. X-ray.
		12.6	A/R	---	2.93	---	---	100	
----	Anhydrite...........	13.4	A/R	---	2.91	---	---	---	Clark (1966, p. 463) after Eucken (1911). Mean of 3.
----	Anhydrite...........	11.7	A/R	---	---	---	---	---	Masjid-i-Sulaiman, Iran (Coster, 1947). Mean of 3.
----	Anhydrite...........	13.7	A/R	---	2.93	---	---	---	Caprock, Louisiana. Herrin and Clark (1956).
----	Anhydrite...........	12.9	A/R	---	2.82	---	---	---	Carlsbad, N.M., Herrin and Clark (1956).
----	Gypsum $CaSO_4 \cdot 2H_2O$.	3.1	---	---	---	2.310	---	---	Masjid-i-Sulaiman, Iran, Coster, (1947).
679	Anglesite $PbSO_4$.	7.4	A/R	3.3	4.03	6.324	35	34	Wards. Dividend, Utah. Dark gray. Massive. X-ray.
		8.0	A/S	3.3	4.19	---	---	---	
		6.6	A/R	3.7	4.19	---	---	---	
----	Polyhalite $K_2Ca_2Mg(SO_4)_4 \cdot 2H_2O$.	3.7	A	---	2.76	2.78 (Dana)	~28	---	Herrin and Clark (1956). Carlsbad, N.M. Mean of 2.
					Phosphates				
677	Apatite $Ca_5(PO_4)_3(OH)$	3.0	A/R	0.5	3.17	3.146	35	34	Wards. Madagascar. Green. Granular.
		3.0	A/R	0.5	3.16	---	---	---	
		3.1	A/S	0.3	3.16	---	---	---	

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