Melting and Transformation Temperatures of Mineral and Allied Substances

F. C. KRACEK

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By F. C. Kracek

ABSTRACT

The temperatures of melting, boiling, and change of structural symmetry are compiled for compounds, eutectics, and solid solutions in oxide, silicate, and a few other systems. Primary emphasis is given to compounds of geologic interest; the compilation is not comprehensive of all phase equilibrium studies. Phase diagrams are given for 24 particularly complex systems that would be difficult to describe otherwise; for example, 11 diagrams of quaternary and higher order silicate systems show the temperature-composition stability fields for 56 compounds and for 6 two-liquid composition ranges.

For a given compound, the transition temperatures and the appropriate crystal systems are given for synthetic polymorphs as well as for those which occur naturally as minerals; polymorphs are identified by Greek letters or Roman numerals, and by names, according to usage. Temperatures are given, as available, for the following: decomposition, triple point, Curie point, specific heat anomaly, and solid solution, eutectic, peritectic, and incongruent melting points. Oxygen pressure and total pressure, including atmospheric, are stated if pertinent.

Data listed for 103 chemical elements are symbol, name, atomic number, atomic weight, melting point, boiling point, and any known transition temperature. Compilations of several groups of oxides are presented: 60 single oxides, 12 pairs involving Al_2O_3, and 70 pairs exclusive of Al_2O_3, B_2O_3, and SiO_2. (In a chemical system, each natural and synthetic compound is identified according to the ratio of oxides in mole percent.) Silicate systems compiled and presented are 25 binary systems, 61 ternary systems, and 5 miscellaneous ones; joins for 33 quaternary and higher systems are also listed, data for 11 being illustrated in diagrams, and the rest with references but without temperature data. The following are listed without temperature data; 38 single and binary carbonate systems, 72 miscellaneous, mostly ternary systems, including oxides, phosphates, sulfates, and fluorides, and the pertinent references.

GENERAL DISCUSSION

Scope of the tables.—These tables list the melting (congruent and incongruent) temperatures, boiling temperatures, and transition temperatures for the more important substances of interest to the geologist, the geochemist, and the petrologist. Eutectic and related data are given when the substance under discussion has been studied as part of a binary or higher system. The aim in compiling the tables has been to describe the known thermal reactions of the compounds and the systems briefly, but in enough detail to be of use to an investigator in the field where extensive reference books are not usually available.

Arrangement.—The entries are arranged alphabetically by chemical symbol (elements) or formula (compounds). Compounds composed of two or more oxides (except carbonates, sulfates, and other oxygen salts) are entered in the increasing alphabetical order of the constituent oxides.

Mineralogic names.—Minerals follow the nomenclature employed in Dana, E. S., and Ford, W. E., 1922, A textbook of mineralogy: New York, John Wiley & Sons, 720 p.

Description of systems.—The compositions of solution phases(liquid or solid) expressed in terms of percentage of the end components, molecular or by weight. For the molecular percentage the mole is taken as the accepted gram-formula weight. Thus, for a binary system the composition of a melt at a eutectic or other significant point may be stated as 18 percent of CaO or 82 percent of TiO_2, as shown below. Compositions of compounds in a system, on the other hand, are given in terms of the mole ratio of the components, as is usual in chemical practice:

CaO-TiO_2:-$CaTiO_3$, (1:1), Perovskite, melting point 1970°; eutectic with TiO_2, 18 percent CaO, 1460°.

This signifies that in the system composed of CaO and TiO_2 as components, there is a 1:1 compound, $CaTiO_3 = CaO \cdot TiO_2$, whose mineral name is Perovskite; this mineral melts at 1970°C, and it is a constituent of a eutectic with TiO_2, the eutectic melting at 1460°C. The composition of the eutectic melt is 18 percent CaO, 82 percent TiO_2. Only one of these percentage numbers is required to specify composition in a binary system, as it will be evident that in a system of n components, only $(n - 1)$ percentage values suffice to specify the composition adequately.

Unless otherwise stated, compositions are given in weight percent. Mole percentages are indicated by mole percent; thus, for the composition in the example given above, 18 percent CaO is equivalent to 23.824 mole percent CaO.

Temperature scale.—The practical scale of temperature, originally planned to be a thermodynamic scale (International Critical Tables, v. 1, p. 52) was placed on a working basis by the high temperature gas thermometer work of Day and Sosman (1911, 1922) at the Geophysical Laboratory. Since 1914 the Geophysical Laboratory has used this scale adapted for practical use with thermocouples by L. H. Adams (1919, 1926). The Geophysical Laboratory, for the purposes of consistency, is still using this scale in the temperature measurements it reports. In 1927 the Seventh General Conference in Weights and Measures adopted a scale of temperatures which became known as the International Temperature Scale of 1927. The International Temperature Scale of 1927 was soon recognized to be faulty in the upper reaches of temperature, and a new scale, the International Temperature Scale of 1948, was adopted by the Conference in Weights and Measures in 1948, (H. F. Stimson, 1949). The International Temperature Scale of 1948 is discussed in relation to the International Temperature Scale of 1927, and the Geophysical Laboratory Scale by Sosman (1952); see also R. J. Corruccini (1949).

Sosman (1952) states:

> On the basis of the 1948 scale, the corrections made by Sosman and Anderson in 1933 at 1550°C and lower, none of which exceed +5°C, are reduced to about two-thirds their former(1927 scale) magnitude, and the original Geophysical [Laboratory]temperatures can usually be left without error beyond the experimental uncertainty. Temperatures beyond 1550°, however, will still have to be proportionately increased, to bring them into line with the International 1948 Scale. The melting point of pure silica as cristobalite, for example, originally 1713°, becomes 1723°.

Because of the possibility of further revision of the scale, and to avoid confusion, the temperatures given in this compilation are the unamended, original values, except where specifically denoted by the legend (International Temperature Scale). In particular, the melting-point determinations on silicates done at the Geophysical Laboratory are all referred to the Day and Sosman gas thermometer scale upon which the Adams (1919) standard thermocouple tables (International Critical Tables, v. 1, p. 57) are based.

For the work published from the School of Mineral Industries, Pennsylvania State University, and from the National Bureau of Standards, on the other hand, the data are given in terms of the International Temperature Scale of 1948. Such data are reproduced here without specifically calling attention to the scale used.

Estimated temperature values, as for elements, for which actual measurements have not been made, are enclosed in parentheses.

Precision (as distinct from the absolute accuracy) of the determinations of the transformation, where known, is indicated thus, ±3. Where no bracket is given, the last significant figure given is uncertain.

References to the literature.—Previous investigations are referred to in detail for the more complex systems. They are not given in general for single substances, particularly when the data are available in one or more handbooks in common use; this is done to avoid an unnecessarily long list of citations.

Acknowledgments

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ELEMENTS

Symbol	Name	Atomic No.	1956 Atomic weight	Melting point (degrees C)	Boiling point (degrees C)	Transition point (degrees C)
Ar	Argon	18	39.944	-189.31	-185.87	---------------
Ac	Actinium	89	227	(1200)[a]	(3300)	---------------
Ag	Silver	47	107.880	960.8	2193	---------------
Al	Aluminum	13	26.98	660.1	2450	---------------
Am	Americium	95	(243)	--------	--------	---------------
As	Arsenic	33	74.91	814[b]	615[c]	---------------
At	Astatine	85	(211)	(300)	(380)	---------------
Au	Gold	79	197.0	1063	2707	---------------
B	Boron	5	10.82	2027	3927	---------------
Ba	Barium	56	137.36	710	1638	375
Be	Beryllium	4	9.013	1283	2477	---------------
Bi	Bismuth	83	209.00	271.3	1559	---------------
Bk	Berkelium	97	(245)	--------	--------	---------------
Br	Bromine	35	79.916	-7.2	58.3	---------------
C	Carbon	6	12.011	--------	4347[c]	---------------
Ca	Calcium	20	40.08	850	1482	450
Cd	Cadmium	48	112.41	320.9	765	---------------
Ce	Cerium	58	140.13	804	2927	-133, 393, 440

Cf	Californium	98	(248)	-------	-------	--------------
Cl	Chlorine	17	35.457	-101.0	-34.06	--------------
Cm	Curium	96	(245)	-------	-------	--------------
Co	Cobalt	27	58.94	1495	2877	447, 850, 1150[d]
Cr	Chromium	24	52.01	1903	2642	1840
Cs	Cesium	55	132.91	28.5	685	--------------
Cu	Copper	29	63.54	1083	2582	--------------
Dy	Dysprosium	66	162.51	1500	2327	--------------
E	Einsteinium	99	(255)	-------	-------	--------------
Er	Erbium	68	167.27	1527	(2630)	--------------
Eu	Europium	63	152.0	(830)	(1430)	--------------
F	Fluorine	9	19.00	-219.62	-188.14	-227.60
Fe	Iron	26	55.85	1539	2887	760[d], 910, 1400
Fm	Fermium	100	(252)	-------	-------	--------------
Fr	Francium	87	(223)	(27)	(680)	--------------
Ga	Gallium	31	69.72	29.78	2237	2.6[e]
Gd	Gadolinium	64	157.26	-------	-------	--------------
Ge	Germanium	32	72.60	937.3	(2700)	--------------
H	Hydrogen	1	1.0080	-259.31[f]	-252.89	--------------
D	Deuterium	1	2.00147	-254.52	-249.56	--------------
He	Helium	2	4.003	-272.2[g] -270.97[h]	-268.94	--------------

ELEMENTS

Symbol	Name	Atomic No.	1956 Atomic weight	Melting point (degrees C)	Boiling point (degrees C)	Transition point (degrees C)
Hf	Hafnium	72	178.58	1977	(5200)	1500
Hg	Mercury	80	200.61	-38.87	356.58	---------------
Ho	Holmium	67	164.94	(1500)	(2300)	---------------
I	Iodine	53	126.91	113.7	184.35	---------------
In	Indium	49	114.82	156.17	2047	---------------
Ir	Iridium	77	192.2	2443	4130	---------------
K	Potassium	19	39.100	63.4	766	---------------
Kr	Krypton	36	83.8	-157.21	-153.23	---------------
La	Lanthanum	57	138.92	920	3367	-163, 548, 709
Li	Lithium	3	6.940	180.55	1331	-196
Lu	Lutetium	71	174.99	(1730)	(1930)	---------------
Md	Mendelevium	101	(256)	--------	--------	---------------
Mg	Magnesium	12	24.32	650	1120	---------------
Mn	Manganese	25	54.94	1244	2087	727, 1101, 1137
Mo	Molybdenum	42	95.95	2610	(4800)	---------------
N	Nitrogen	7	14.008	-209.97	-195.82	-237.53
Na	Sodium	11	22.991	97.82	889	---------------
Nb	Niobium	41	92.91	2497	4900	---------------

Nd	Neodymium	60	144.27	1024	(3090)	-164, 508, 714
Ne	Neon	10	20.183	-248.59	-246.08	---------------
Ni	Nickel	28	58.71	1453	2840	350-400[d]
Np	Neptunium	93	(237)	640	--------	---------------
O	Oxygen	8	16.000	-218.76 -218.92[f]	-182.96	-229.37, -249.26
Os	Osmium	76	190.2	2700	(4230)	---------------
P	Phosphorus,	15	30.975	--------	--------	-77.15[j]
	yellow, cubic	---	--------	44.1	280	-2.3[k]
	red, triclinic	---	--------	590[i]	431[c]	---------------
	violet	---	--------	593[i]	--------	---------------
Pa	Protoactinium	91	231	(1200)	(4000)	---------------
Pb	Lead	82	207.21	327.3	1750	---------------
Pd	Palladium	46	106.7	1549.5[l] 1552[m]	3130	---------------
Pm	Promethium	61	(145)	(1000)	(2700)	---------------
Po	Polonium	84	210	254	962	97
Pr	Praseodymium	59	140.92	935	3017	798
Pt	Platinum	78	195.09	1755[l] 1769[m]	3800	---------------
Pu	Plutonium	94	(242)	1300	--------	---------------
Ra	Radium	88	226.05	700	(1500)	---------------
Rb	Rubidium	37	85.48	38.8	700	-30

ELEMENTS

Symbol	Name	Atomic No.	1956 Atomic weight	Melting point (degrees C)	Boiling point (degrees C)	Transition point (degrees C)
Re	Rhenium	75	186.22	3147	(5600)	--------------
Rh	Rhodium	45	102.91	1960	3960	--------------
Rn	Radon	86	222	-71	-61.8	--------------
Ru	Ruthenium	44	101.1	2500	4110	1035, 1200, 1500
S	Sulphur	16	32.066	119.25[n]	444.60	95.5[o]
Sb	Antimony	51	121.76	630.5	1440	95, 413
Sc	Scandium	21	44.96	1400	3900	--------------
Se	Selenium					
	gray trigonal	34	78.96	217.4	685	150[p]
Si	Silicon	14	28.09	1410	2680	--------------
Sm	Samarium	62	150.35	1052	(1590)	917
Sn	Tin	50	118.70	231.9	2690	18[q]
Sr	Strontium	38	87.63	770	1384	--------------
Ta	Tantalum	73	180.95	2997	5400	--------------
Tb	Terbium	65	158.93	(1400)	(2500)	--------------
Tc	Technetium	43	(99)	(2100)	(4600)	--------------
Te	Tellurium	52	127.61	449.8	1097	348?
Th	Thorium	90	232.05	1695	4200	225
Ti	Titanium	22	47.90	1812	3280	884

Tl	Thallium	81	204.39	303.6	1457	232, 153[r]
Tm	Thulium	69	168.94	(1630)	(2100)	--------------
U	Uranium	92	238.07	1133	(3900)	662, 776
V	Vanadium	53	50.95	1917	3380	--------------
W	Tungsten	74	183.86	3380	(5500)	650
Xe	Xenon	54	131.30	-111.8	-108.11	--------------
Y	Yttrium	39	88.92	(1490)	(4400)	--------------
Yb	Ytterbium	70	173.04	824	(1530)	798
Zn	Zinc	30	65.38	419.5	908	--------------
Zr	Zirconium	40	91.22	1852	(4380)	862

[a] Figures in parentheses are estimates.

[b] 36 atmospheres.

[c] Sublimation point.

[d] Curie point.

[e] 11,600 atmosphere.

[f] Triple point.

[g] 25.3 atmosphere.

[h] 2 liquids.

[i] 43 atmosphere.

[j] 1 atmosphere.

[k] 5,800 atmosphere.

[l] Day and Sosman scale.

[m] International, 1948.

[n] Monoclinic.

[o] Rhombic-monoclinic, 1 atmosphere.

[p] Red-gray.

[q] Gray-white

[r] 37,800 atmosphere.

OXIDES

Ag_2O	Dissociation (1 atm) 191°C.
Al_2O_3	(a) High-temperature phases: α, Corundum: trigonal melting point (pure) 2040°C. β aluminas: hexagonal isomorphous compounds from alkali or alkaline earth melts, formed in the ratio 1:11 for Na_2O, K_2O, MgO to Al_2O_3, and 1:6 for CaO, SrO, BaO to Al_2O_3. ζ alumina: $LiAl_5O_8$, cubic, from melts containing Li_2O. (b) Transition aluminas: produced in calcination of aluminum compounds, or in oxidation of aluminum metal. Varieties ρ, x and k result on dehydration of α trihydrate; η and θ from β trihydrate, γ and δ from α monohydrate, but all have been made by suitable dehydration and rehydration treatment of a single sample of fine-grained α trihydrate. All varieties convert to α at or below about 1100°C. δ may result from combustion of aluminum metal. η is obtained in oxidation of aluminum metal at its melting point. k was obtained in thermal decomposition of hydrated aluminum chloride. (Russell and others, 1956.)
As_2O_3	Arsenolite, cubic (labile), melting point 275°C; sublimation point 193°C. Claudetite, monoclinic, melting point 313°C.
As_2O_5	Vitreous only, decomposes (1 atm) 315°C.
B_2O_3	Trigonal melting point 450°C.
BaO	Melting point 1925°C.
BeO	Bromellite melting point 2530°C.
Bi_2O_3	Bismite, I rhombic melting point 820°C; II cubic, glows 680°C transition point II to I, 704°C; boiling point 1890°C.
CO_2	Sublimation point (1 atm) −78° to 48°C; triple point (5.112 atm) −56.60°C.
CaO	Melting point 2570°C; boiling point 2850°C.
CeO_2	Ceria, melting point 2600°C; partly decomposes 2500°C.
Ce_2O_3	Melting point 1692°C.
CoO	Melting point 1935°C.
Co_3O_4	Dissociates (1 atm) at 970°C to CoO and O_2.
Co_2O_3	Dissociates 895°C.
Cr_2O_3	Melting point 1990°C; transition point 33°C.
CrO_2	Loses 0, 300°C.
CrO_3	Melting point 196°C, liquid decomposes to Cr_2O_3 and O_2.
CuO	Tenorite, melting point more than 1240°C (75 atm O_2), dissociates 1104°C (1 atm) to Cu_2O and O_2; eutectic of CuO and Cu_2O 1080°C (0.51 atm O_2) in a melt of 86 percent Cu, 14 percent O_2; C_p anomalies −40°C, −60°C. These depend on thermal history. (Smyth and Roberts, 1920.)
Cu_2O	Cuprite, melting point 1235°C; transition point natural translucent to opaque, 56°C.

FeO	Natural "Jozite" is ferromagnetic. Artificial "Wüstite" is Fe deficient; lower limit stability 570°C decomposes to Fe and Fe_3O_4 below 570°C: ferromagnetic. Artificial, eutectic with Fe solid solution 1371°C; artificial O-rich Wüstite incongruent melting point 1424°C to Fe_3O_4 and liquid (24 percent O); Wüstite forms 2 liquid layers with excess Fe solid solution (0.16 to 22.60 percent O); C_p anomaly in metastable −88°C. (Darken and Gurry, 1945, 1946.) See figure 1.
Fe_3O_4	Magnetite, artificial, forms limited solid solution both with excess Fe and excess O; O rich oxidizes in air (1/5 atm O_2) below 1388°C; melting point 1597°C; magnetic transition point natural 580°C, artificial 510° to 680°C; C_p anomaly −159°C; magnetic anomaly −160°C. (Darken and Gurry, 1946.)
Fe_2O_3	Hematite, dissociates in air (1/5 atm O_2)1388°C; (1 atm O_2) 1457°C, to magnetite and O_2;orthobaric melting point is unknown, transition point 1030. (Greig and others, 1935; Darken and Gurry, 1946.) α, paramagnetic, isomorphous with corundum. γ, ferromagnetic, isomorphous with magnetite; produced on oxidation of magnetite, also on dehydration of γ FeOOH (Lepidocrocite).
Ga_2O_3	Melting point 1740°C; dimorphous: α, isomorphous with corundum; β, monoclinic, transition point 650°C.
GeO_2	Soluble, quartz type, melting point 1116°C±4°C. Insoluble, rutile type, labile, melting point 1086°C±5°C; transition point 1033°C±10°C; volatilizes above 1250°C.
H_2O	Water, melting point 0.000°C, boiling point 100.000°C (thermometric fixed points at 1 atm); orthobaric triple point 0.01°C (International 1948 Scale). Triple points of high pressure modifications: (1) I - III - L, 2047 atmosphere, −22.0°C (2) I - II - III, 2100 atmosphere, −34.7°C (3) II - III - V, 3397 atmosphere, −24−3°C (4) III - V - L, 3416 atmosphere, −17°C (5) V - VI - L, 6175 atmosphere, 0.16°C (6) VI - VII - L, 21678 atmosphere, 81.6°C (Bridgman, 1937). D_2O, heavy water melting point 3.82°C, boiling point 101.42°C(1 atm).
HfO_2	Hafnia, melting point 2810°C.
HgO	Montroydite, dissociates in air (1/5 atm O_2) 426°C, (1 atm O_2) 496°C.
La_2O_3	Melting point 2315°C±20°C; boiling point about 4200°C.
MgO	Periclase, melting point 2800°C.
MnO	Manganosite, melting point 1850°C;2 liquids with Mn;oxides to Mn_3O_4 in air below 1200°C; C_p anomaly −155°C.
Mn_3O_4	Hausmannite, stable in air below 1200°C;oxidizes in air to Mn_2O_3 below 877°C; melting point 1567°C; transition point, tetragonal to cubic, 1160°C. (Van Hook and Keith, 1958.)
Mn_2O_3	Braunite, dissociates in air (1/5 atm O_2) 877°C, (1 atm) 1090°C to Mn_2O_4 plus O_2; transition point 600°C.

MnO_2	Polianite, dissociates in air 530°C±50°C, in 1 atm O_2 565°C±50°C; C_p anomaly −181°C. Pyrolusite is partially hydrated, has structure like Polianite.
MoO_3	Molybdite, melting point 795°C with sublimation.
NiO	Bunsenite, melting point 1990°C.
Ni_3O_4	Dissociates to NiO and O_2 at less than 600°C.
Ni_2O_3	Unstable in anhydrous condition.
P_2O_5	(Tabular) melting point more than 570°C; (acicular) melting point 569°C; tends to remain glassy; sublimation point about 360°C; sublimation to glassy state, 400° to 500°C.
PbO	Massicot, melting point 886°C; transition point tetragonal to rhombic 488°C; volatilizes below 750°C.
Pb_3O_4	Minium, artificial dissociates (1 atm O_2) 601°C to $PbO+O_2$.
PbO_2	Plattnerite, artificial dissociation (1 atm O_2) 344°C to $Pb_3O_4+O_2$ when precipitated; 313°C when electrolytic.
SO_2	Melting point −75.46°C, boiling point −10.0°C.
SO_3	Melting point (prismatic icelike) 16° to 8°C; (low asbestoslike) 32.5°C; (high asbestoslike, at 2.29 atm) 62.2°C; sublimation point 44.8°C.
Sb_2O_3	Valentinite, rhombic, melting point 656°C, boiling point 1550°C. Senarmontite, cubic melting point 656°C. Transition point rhombic to cubic 557°C. Oxidizes in air to SbO_2 below 930°C.
SbO_2	Cervantite, melting point unknown; dissociates in free air to Sb_2O_3 liquid $+O_2$ at 930°C.
Sb_2O_5	Dissociates in air at 380°C to SbO_2+O_2.
SiO_2	Quartz melting point (metastable) about 1470°C; transition point low trigonal to high hexagonal 573°C±3°C; transition point Quartz-Tridymite 867°C±3°C; Tridymite, melting point (metastable) about 1670°C; transition point rhombic to low hexagonal 105°C, low hexagonal to high hexagonal 163°C; transition point Tridymite to Cristobalite 1470°C±10°C; Cristobalite, melting point 1713°C±10°C (Day and Sosman scale), 1723°C±10°C (International 1948 scale); transition point rhombic to cubic 200° to 270°C depending on thermal history. (Fenner, 1913; Greig, 1927a.)
SnO_2	Cassiterite, melting point 1127°C with decomposition; transition point 410°C.
SrO	Melting point 2430°C.
TeO_2	Tellurite, melting point 732.6°C, sublimation point above 450°C; droplets solidify vitreous.
ThO_2	Melting point 3050°C.
TiO_2	Rutile, melting point 1825°C. Anatase, artificial, by dehydrating TiO_2 gel at about 900°C transition to Rutile in presence of flux at or above 400°C without flux 915°C; α to β Anatase transition point 642°C; Brookite, transition in presence of flux to Rutile below 900°C; Decomposes to $Ti_2O_3+O_2$ above 1600°C.

UO_2 Melting point 2176°C.

V_2O_5 Melting point 690°C; liquid decomposes 1750°C.

WO_3 Tungstite, melting point 1473°C.

ZnO Zincite, artificial melting point 1975°C; sublimation point 1800°C.

ZrO_2 Baddeleyite, melting point 2690°C; transition point 625°C, 1000°C, 1900°C; boiling point about 4300°C.

OXIDE SYSTEMS INVOLVING Al_2O_3

BaO-Al_2O_3:-$3BaO \cdot Al_2O_3$, (3:1), eutectic with BaO, 1660°C; melting point 1750°C; eutectic with (1:1), 1710°C.

-$BaO \cdot Al_2O_3$, (1:1), Barium spinel, melting point 1830°C; eutectic with (1:6), 1790°C.

-$BaO \cdot 6Al_2O_3$ (1:6), melting point 1900°C; eutectic with Al_2O_3, 1890°C. (Toropov and Galakhov, 1952.)

BeO-Al_2O_3:-$BeO \cdot Al_2O_3$, (1:1), Chrysoberyl, eutectic with BeO, 1835°C; melting point 1870°C; eutectic with (1:3), 1850°C.

-$BeO \cdot 3Al_2O_3$, (1:3), melting point 1910°C; eutectic with Al_2O_3, 1890°C. (Lang and others, 1952; Foster and Royal, 1949.)

CaO-Al_2O_3:-$3CaO \cdot Al_2O_3$, (3:1), incongruent melting to CaO and liquid, 41 percent Al_2O_3, 1535°C; eutectic with (5:3), 50 percent Al_2O_3, 1395°C.

-$5CaO \cdot 3Al_2O_3$, (5:3), melting point 1455°C; eutectic with (1:1), 53 percent Al_2O_3, 1400°C.

-$CaO \cdot Al_2O_3$, (1:1), melting point 1600°C; eutectic with (3:5), 67 percent Al_2O_3, 1590°C.

-$3CaO \cdot 5Al_2O_3$, (3:5), composition is in question, may be CaO. $2Al_2O_3$, melting point 1720°C; eutectic with Al_2O_3, 76 percent Al_2O_3, 1700°C. (Rankin and Wright, 1915; Goldsmith, 1948.)

FeO-Al_2O_3:-$3FeO \cdot Al_2O_3$, (3:1), decomposes below liquidus to (1:1) and FeO, 1230°C.

-$FeO \cdot Al_2O_3$, (1:1), Hercynite, incongruent melting to Al_2O_3 and liquid, 12 percent Al_2O_3, 1440°C; eutectic with FeO, 7 percent Al_2O_3, 1305°C. (McIntosh and others, 1937.)

FeO-Fe_2O_3-Al_2O_3:-(Muan and Gee, 1956.)

Fe_2O_3-Al_2O_3:-$Fe_2O_3 \cdot Al_2O_3$, (1:1), is unstable below 1318°C relative to the phase assemblage: Hematite solid solution plus Corundum solid solution. (Muan, 1958a.)

Ga_2O_3-Al_2O_3:-$Ga_2O_3 \cdot Al_2O_3$, (1:1), decomposes below the liquidus to Ga_2O_3 solid solution, 825°C; α Al_2O_3 solid solution plus β Ga_2O_3 solid solution coexist in solvus, 800° to 2000°C; limits of homogeneity: α Al_2O_3 solid solution, 0 to 28 mole percent Ga_2O_3;β Ga_2O_3 solid solution, 34 to 100 mole percent Ga_2O_3 at 800°C; 31 to 100 mole percent Ga_2O_3 at 2000°C. α solid solution and β solid solution liquidus descends with a slope discontinuity in region of the solvus from melting point Al_2O_3, 2035°C, to melting point Ga_2O_3, 1740°C. (Hill and others, 1952.)

MgO-Al_2O_3:-$MgO \cdot Al_2O_3$, (1:1), Spinel, melting point 2135°C; eutectic with MgO, 45 percent MgO, 2030°C; eutectic with Al_2O_3, 5 percent MgO, 1860°C. Spinel solid solution coexists with Al_2O_3 and with liquid, solid solution limit 15 percent MgO, 1860°C. (Rankin and Merwin, 1916; Roy, R., and others, 1953.)

MnO-Al_2O_3:-$MnO \cdot Al_2O_3$, (1:1), incongruent melting to Al_2O_3 and liquid, 71 percent MnO, 1560°C; eutectic with MnO, 76 percent MnO, 1520°C. (Hay and others, 1934.)

PbO-Al_2O_3:-$PbO \cdot Al_2O_3$, (1:1), incongruent melting to Al_2O_3 and liquid, 91 percent PbO, 985°C; eutectic with 94 percent PbO, 865°C. (Geller and Bunting, 1943.)

TiO_2-Al_2O_3:-$TiO_2 \cdot Al_2O_3$, (1:1), melting point 1860°C; eutectic with TiO_2, 19.5 percent Al_2O_3, 1705°C; eutectic with Al_2O_3, 60 percent Al_2O_3, 1840°C; transition 1820°C. (Bunting, 1933; Lang and others, 1952; Wartenberg and Reusch, 1932.)

UO_2-Al_2O_3:-No compounds; eutectic, 75 percent Al_2O_3, 1930°C; UO_2+2 immiscible liquids, 51 to 75 percent Al_2O_3, 1930°C. (Lambertson and Mueller, 1953a.)

OXIDE SYSTEMS EXCLUSIVE OF Al_2O_3, B_2O_3, SiO_2.

BaO-MgO	No compounds; eutectic 41 percent MgO, 1500°C.
BaO-TiO_2	$BaO \cdot TiO_2$, (1:1), melting point 1612°C; transition point 112.7°C; (Rase and Roy, 1955a.)
BaO-ZrO_2	$BaO \cdot ZrO_2$, (1:1), melting point 2650°C; eutectic with BaO, 10 mole percent ZrO_2, 1440°C; eutectic with ZrO_2, 90 percent ZrO_2, 2050°C.
BeO-CaO	Eutectic, 44 percent CaO, 1470°C.
BeO-CeO_2	Minimum 1960°C, 25 percent CeO_2.
BeO-CoO	Minimum 1750°C, 65 percent BeO.
BeO-Cr_2O_3	Minimum 2210°C, 30 percent BeO.
BeO-Cu_2O	Eutectic 1200°C, about 1 percent BeO.
BeO-Fe_3O_4	Minimum 1580°C, 15 percent BeO.
BeO-La_2O_3	Minimum 1400°C, 25 percent BeO.
BeO-MgO	Minimum 1950°C, 48 percent BeO.
BeO-Mn_3O_4	Minimum 1540°C, 16 percent BeO.
BeO-NiO	Eutectic 1900°C, 12 percent BeO.
BeO-ThO_2	Minimum 2210°C, 20 percent BeO. All systems above with BeO by (Wartenberg, Reusch, and others, 1937).
BeO-TiO_2	Minimum 1670°C (eutectic?), 15 percent BeO, (Lang and others, 1952.)
BeO-ZrO_2	Eutectic 2200°C, 75 percent BeO. (Wartenberg, Reusch, and others, 1937.)
CaO-CeO_2	Minimum 1980°C, 30 percent CaO.
CaO-CoO	Eutectic 1420°C, 36 percent CaO.
CaO-Cu_2O	Eutectic 1140°C, 27 percent CaO.
CaO-Fe_2O_3	$2CaO \cdot Fe_2O_3$, (2:1), melting point 1449°C; eutectic with CaO, 42.0 percent CaO, 1438°C.
	$CaO \cdot Fe_2O_3$, (1:1), incongruent melting to (2:1) plus liquid, 24 percent CaO, 1216°C; eutectic with (1:2), 1 atm O_2, 21.5 percent CaO, 1206°C.

	$CaO \cdot 2Fe_2O_3$, (1:2), disproportionates to (1:1) plus Hematite below 1172°C; incongruent melting to Hematite solid solution plus liquid. 78.0 percent Fe_2O_3 (1 atm O_2) 1228°C. Magnetite plus Hematite plus liquid 81.5 percent Fe_2O_3, (1 atm O_2) 1430°C. (Phillips and Muan, 1958.)
CaO-Mn_3O_4	Minimum 1450°C, 15 percent CaO.
CaO-NiO	Eutectic 1750°C, 36 percent CaO.
CaO-SrO	Continuous solid solution.
CaO-ThO_2	Eutectic 2300°C, 24 percent CaO. All above systems with CaO by (Wartenberg, Reusch, and others, 1937.)
CaO-Cr_2O_3	Readily oxidized to chromate. (Ford and White, 1949.)
CaO-Fe_2O_3	$2CaO \cdot Fe_2O_3$, (2:1), incongruent melting to CaO and liquid 38 percent CaO, 1436°C. $CaO \cdot Fe_2O_3$, (1:1), incongruent melting to (2:1) and liquid 24.5 percent CaO, 1216°C; eutectic with Fe_2O_3, 7 percent CaO, 1205°C; not a true binary system because of dissociation of Fe_2O_3 to FeO. (Sosman and Merwin, 1916.)
CaO-MgO	Eutectic 2360°C, 66 percent CaO. (Rankin and Merwin, 1916.)
CaO-TiO_2	$CaTiO_3$, (1:1), Perovskite, melting point 1970°C; eutectic with TiO_2, 18 percent CaO, 1460°C; transition point 1260°C. $Ca_3Ti_2O_7$, (3:2), incongruent melting at 1750°C to (1:1) and liquid 60 percent CaO; eutectic with CaO, 63 percent CaO, 1695°C. (DeVries and others, 1954a); see also (Coughanour and others, 1954; Berezhnoy, 1950; Roth, 1958.)
CaO-ZrO_2	$CaZrO_3$, (1:1), melting point 2550°C; eutectic with ZrO_2 solid solution, 24 percent CaO, 2390°C; eutectic with CaO, 60 percent CaO, 2250°C. (Ruff and others, 1929.)
CeO_2-Cr_2O_3	$CeO_2 \cdot Cr_2O_3$ (?), melting point 2440°C; eutectic with Cr_2O_3 2240°C.
CeO_2-Fe_3O_4	Minimum 1510°C, 30 percent CeO_2.
CeO_2-MgO	Minimum 2250°C, 20 percent CeO_2.
CeO_2-Mn_3O_4	Minimum 1540°C, 20 percent CeO_2. For systems with CeO_2 above, see (Wartenberg and Eckhardt, 1937.)
CeO_2-ZrO_2	Two series solid states at liquidus; eutectic 2310°C. (Duwez and Odell, 1950.)
CoO-MgO	Continuous series solid solution. (Wartenberg and Prophet, 1932.)
CoO-ZrO_2	Minimum 1730°C. (Wartenberg and Gurr, 1931.)
Cr_2O_3-FeO	$FeCr_2O_4$, Chromite, melting point 1670°C.
Cr_2O_3-MgO	$MgCr_2O_4$, melting point 2200°C; eutectic with MgO 2100°C, 33 percent MgO; eutectic with Cr_2O_3 2100°C, 8 percent MgO. (Wilde and Rees, 1943.)
Cr_2O_3-ZrO_2	Minimum 2320°C. (Wartenberg and Gurr, 1931.)
Cu_2O-MgO	Eutectic 1120°C, 20 percent MgO. (Wartenberg and Prophet, 1932.)

CuO-PbO	Eutectic 698°C, 41 percent PbO.
FeO-MgO	Continuous series solid solution. (Bowen and Schairer, 1935.)
FeO-MnO	Two series solid solution, peritectic relation, 1430°C. (Hay and others, 1934.)
FeO-Mn_2O_3	$(Fe, Zn, Mn)O \cdot (Fe, Mn)_2O_3$, Franklinite, melting point above 1420°C.
FeO-TiO_2	$FeTiO_3$, (1:1), Ilmenite, natural melting point 1450°C; artificial melting point 1470°C; transition point 215°C; eutectic with TiO_2 1330°C, 68 percent TiO_2. Fe_2TiO_4, (2:1), Pseudobrookite, artificial melting point 1470°C; eutectic with (1:1) 1320°C; eutectic with FeO 1305°C, 5 percent TiO_2. (Grieve and White, 1939.)
Fe_2O_3-MgO	$Fe_2O_3 \cdot MgO$, Magnesioferrite, melting point 1750°C with loss of O_2. (Roberts and Merwin, 1931.)
Fe_2O_3-Mn_2O_3	Subliquidus limited solid state fields: Fe_2O_3, 0 to 14 percent Mn_2O_3 at 600°C, 0 to 19 percent Mn_2O_3 at 1050°C; Mn_2O_3, 71 to 100 percent Mn_2O_3 at 600°C, 36 to 100 percent Mn_2O_3 at 1000°C. (Mason, 1944.)
Fe_2O_3-ZrO_2	Minimum 1520°C. (Wartenberg and Gurr, 1931.)
K_2O-GeO_2	$K_2O \cdot GeO_2$, (1:1), melting point 842°C; eutectic with (1:2) 710°C, 63.6 percent GeO_2. $K_2O \cdot 2GeO_2$, (1:2), melting point 797°C, eutectic with (1:4) 789°C, 70.4 percent GeO_2. $K_2O \cdot 4GeO_2$, (1:4), melting point 1038°C; eutectic with GeO_2 1006°C, 85.1 percent GeO_2. (Schwarz, 1929.)
La_2O_3-MgO	$La_2O_3 \cdot MgO$, melting point 2030°C; eutectic with La_2O_3, 1970°C, 8 percent MgO; eutectic with MgO, 1990°C, 34 percent MgO.
La_2O_3-ZrO_2	$La_2O_3 \cdot 3ZrO_2$(?), incongruent melting point 2300°C; eutectic with La_2O_3 2080°C, 20 percent ZrO_2. (Wartenberg and Gurr, 1931.)
Li_2O-GeO_2	$2Li_2O \cdot GeO_2$, melting point 1298°C. $Li_2O \cdot GeO_2$, melting point 1239°C. (Schwarz, 1929.)
MgO-GeO_2	(Robbins and Levin, 1959.)
MgO-Mn_3O_4	Continuous liquidus without eutectic or minimum.
MgO-NiO	Continuous solid solution. (Wartenberg and Prophet, 1932.)
MgO-TiO_2	Mg_2TiO_4, melting point 1732°C. $MgTiO_3$, melting point 1630°C. $MgTi_2O_5$, melting point 1652°C. (Coughanour and DeProsse, 1953.)
MgO-ZrO_2	Two series solid solution, eutectic 2070°C; α-β ZrO_2 transition point 2550°C.
MnO-TiO_2	$MnTiO_3$, (1:1), Pyrophanite, incongruent melting to (2:1) and liquid, 60 percent TiO_2, 1360°C. Mn_2TiO_4, (2:1), melting point 1450°C, eutectic with MnO, 34 percent TiO_2, 1330°C. (Grieve and White, 1940.)

Mn_3O_4-ZrO_2	Minimum 1460°C. (Wartenberg and Gurr, 1931.)
Na_2O-GeO_2	Na_2GeO_3, (1:1), melting point 1083°C; eutectic with (1:2), 76 percent GeO_2, 778°C. $Na_2Ge_2O_5$, (1:2), melting point 799°C; eutectic with (1:4), 78.5 percent GeO_2, 789°C. $Na_2Ge_4O_9$, (1:4), melting point 1052°C; eutectic with GeO_2, 89 percent GeO_2, 1042°C. (Schwarz, 1929.)
Na_2O-TiO_2	Na_2TiO_3, melting point 1030°C. $Na_2Ti_2O_5$, melting point 985°C. $Na_2Ti_3O_7$, melting point 1128°C. (Washburn and Bunting, 1934.)
SnO_2-ZrO_2	SnO_2 volatilizes before fluxing occurs.
SrO-ZrO_2	$SrZrO_3$, melting point above 2700°C.
ThO_2-TiO_2	Minimum, 45 percent TiO_2, 1640°C. (Wartenberg and Eckhardt, 1937.)
ThO_2-ZrO_2	Continuous solid solution at liquidus probably; unmixing solvus, maximum about 2700°C, 50 mole percent ThO_2. (Ruff and others, 1929.)
TiO_2-ZrO_2	$ZrTiO_4$, incongruent melting to ZrO_2 solid solution and liquid, 55 percent TiO_2 1850°C, eutectic with TiO_2 solid solution, 70 percent TiO_2, 1760°C. (Brown and Duwez, 1954; Coughanour, Roth, and DeProsse, 1954; Sosman and Andrews, 1951.)
UO_2-CaO	$UO_2 \cdot CaO$ and $UO_2 \cdot 2CaO$, both decomposes below liquidus, 1850°C and 1790°C, respectively; eutectic UO_2 solid solution and CaO, 38 mole percent UO_2, 2080°C; solid solution limits at eutectic 55 to 100 mole percent UO_2. (Alberman and others, 1951.)
UO_2-MgO	No compounds; eutectic MgO and UO_2, 30 percent MgO, 2100°C; UO2 in equilibrium with 2 liquids, about 8 to 24 percent MgO, about 2200°C. (Lambertson and Mueller, 1953b.)
UO_2-ThO_2	Continuous series solid solution. (Lambertson, Mueller and Gunzel, 1953.)
UO_2-ZrO_2	Two series solid solutions meet at a eutectic, about 52 percent ZrO_2, 2540°C. Solvus for face-centered UO_2 solid solution and tetragonal. ZrO_2 solid solution, maximum about 1930°C, 52 mole percent ZrO_2. (Lambertson and Mueller, 1953c.)
ZnO-ZrO_2	Eutectic 1810°C; ZnO volatilizes. (Wartenberg and Gurr, 1931; Wartenberg and Eckhardt, 1937.)

SILICATE SYSTEMS, BINARY

Al_2O_3-SiO_2	$3Al_2O_3 \cdot 2SiO_2$, (3:2), Mullite, incongruent melting to Corundum plus liquid of 55 percent Al_2O_3, 1810°C; eutectic with Cristobalite 94.5 percent SiO_2, 1959°C. (Bowen and Greig, 1924; Schairer, 1942.) See figure 2.

	(3:2) melts congruently 1875°C; eutectic with Corundum 1860°C. (Toropov and Galakhov, 1951.) (3:2) forms solid solution to 79 percent Al_2O_3. (Toropov and Galakhov, 1958.) Liquidus relations of Bowen and Greig (1924) are confirmed, Mullite phase has range of homogeneity 72 to 78 percent Al_2O_3. (Trömel and others, 1957.) $Al_2O_3 \cdot SiO_2$, (1:1), Sillimanite, Andalusite, Kyanite, all decompose to Mullite and SiO_2; Kyanite between 1000°C and 1325°C; Andalusite between 1325°C and 1410°C; Sillimanite between 1345°C and 1550°C. (Greig, 1926.) Andalusite synthesis (Roy, D. M., 1954.) Kyanite-Sillimanite equilibrium curve 18,200 bars at 1000°C; 21,000 bars at 1300°C, with Kyanite field on the high pressure side of curve. (Clark and others, 1957.)
B_2O_3-SiO_2	No compounds, no liquid immiscibility, eutectic near 100 percent B_2O_3, 450°C.
BaO-SiO_2	Ba_2SiO_4, (2:1), melting point above 1700°C; eutectic with (1:1), 24.5 percent SiO_2, 1551°C. $BaSiO_3$, (1:1), melting point 1604°C; eutectic with (2:3), 40 percent SiO_2, 1437°C. $Ba_2Si_3O_8$, (2:3), melting point 1450°C; solid solution with (1:2). $BaSi_2O_5$, (1:2), Sanbornite, melting point 1420°C; solid solution with (2:3); eutectic with tridymite, 50 percent SiO_2, 1374°C. Cristobalite liquidus: no liquid immiscibility in contradistinction from systems of MgO, CaO and SrO with SiO_2. (Eskola, 1922; Glushkova, 1957; Greig, 1927a.)
BeO-SiO_2	Eutectic of BeO, SiO_2 and liquid, 95 percent SiO_2, 1670°C. Be_2SiO_4, (2:1), Phenacite, decomposes 1560°C, below eutectic of system. (Morgan and Hummel, 1949.)
CaO-SiO_2	Ca_3SiO_5 (3:1), disproportionates below the liquidus, to CaO and (2:1), 1900°C; unstable below 1250°C. Ca_2SiO_4, (2:1) melting point 2130°C; eutectic with CaO, 30.5 percent SiO_2, 2065°C; tetramorphous, α, α (Bredigite), transition point 1437°C; α, γ transition point 725°C; β, Larnite, is labile at 1 bar, stable above 137 bars; D. M. Roy (1958). Transition behavior is influenced by additions of Mg_2SiO_4, $Ca_3(PO_4)_2$ and other substances in solid solution (Bredig, 1950). For the influence of grain size and departures from stoichiometry upon α^1 to β, or α^1 to γ transitions, see Guinier and Yannaquis (1957). Transition of α^1 to γ results in about 10 percent volume increase. (Rankin and Wright, 1915; Roy, D. M., 1958; Bredig, 1950; Muan and Osborn, 1951.) $Ca_3Si_2O_7$, (3:2), incongruent melting to (2:1) and liquid, 44.5 percent SiO_2, 1475°C; eutectic with (1:1), 45.5 percent SiO_2, 1455°C. $CaSiO_3$, (1:1), melting point 1540°C; Wollastonite, monoclinic; transition at 1125°C to Pseudowollastonite, pseudohexagonal; eutectic with Tridymite, 63 percent SiO_2, 1436°C. Cristobalite liquidus, liquid immiscibility 72 to 99 percent SiO_2, 1698°C. (Rankin and Wright, 1915; Greig, 1927a.) See figure 3.

CoO-SiO_2	Co_2SiO_4, (2:1), melting point 1420°C; eutectic with CoO 1377°C. $CoSiO_3$, (1:1), may exist as incongruent melting phase, breaks up into SiO_2 and liquid at 1400°C; eutectic with (2:1), 1382°C. (Asanti and Kohlmeyer, 1951.) Cristobalite liquidus with liquid immiscibility 1725°C. (Greig, 1927b.)
Cr_2O_3-SiO_2	No compounds, eutectic 1710°C. Liquid immiscibility overlying field of Cr_2O_3, 5 to 95 percent Cr_2O_3, 2200°C. (Bunting, 1930b; Keith, 1954.)
Cu_2O-SiO_2	No compounds, eutectic with 8 percent SiO_2, 1060°C; liquid immisibility overlying Cristobalite, 36 to 95 percent SiO_2, 1690°C. (Berezhnoy and others, 1952.)
FeO-SiO_2	Fe_2SiO_4, (2:1), Fayalite, melting point 1205°C; eutectic with Wüstite, 24 percent SiO_2, 1177°C; eutectic with Tridymite 38 percent SiO_2, 1178°C. Cristobalite and two liquids, 58 to 97 percent SiO_2, 1690°C. (Bowen and Schairer, 1932; Greig, 1927b; Muan, 1958c.) See figure 4.
Fe_2O_3-SiO_2	No compounds; liquidus temperatures are not determined. Cristobalite and two immiscible liquids of very wide range. Eutectic probably near 100 percent SiO_2. At 1 atmosphere pressure of air, Fe_2O_3; dissociates to Fe_3O_4 and oxygen above 1388°C. (Bowen and others, 1930; Darken and Gurry, 1946; Greig, 1927b; Muan, 1958c.)
K_2O-SiO_2	K_2SiO_3, (1:1), melting point 976°C, transition point 725°C, transition point 750°C; eutectic with (1:2), 45.5 percent SiO_2, 780°C. $K_2Si_2O_5$, (1:2), melting point 1045°C; transition point 217°C, transition point 593°C; eutectic with (1:4), 67.6 percent SiO_2, 742°C. $K_2Si_4O_9$, (1:4), melting point 770°C; transition point 592°C; pressure lowers melting point 60°C per kilobars, raises transition point 28°C per kilobar; eutectic with Quartz 72.5 percent SiO_2, 769°C. (Kracek, Bowen, and Morey, 1937; Goranson and Kracek, 1932.)
Li_2O-SiO_2	Li_4SiO_4, (2:1), incongruent 1255°C; eutectic with (1:1), 55.3 percent SiO_2, 1024°C. Li_2SiO_3, (1:1), melting point 1201°C. $Li_2Si_2O_5$, (1:2), incongruent melting to (1:1) and liquid, 80.1 percent SiO2, 1033°C; eutectic with Tridymite, 82.2 percent SiO_2, 1028°C; transition point 936°C. (Jaeger and Klooster, 1914; Kracek, 1930b; Kracek, 1939.)
MgO-SiO_2	Mg_2SiO_4, (2:1), Forsterite, melting point 1890°C; eutectic with MgO, 36 percent SiO_2, 1850°C. $MgSiO_3$, (1:1), Enstatite, and its varieties, incongruent melting to (2:1), and liquid, 60.9 percent SiO_2, 1557°C; slow transition Protoenstatite to Enstatite, 1260°C; Protoenstatite - Clinoenstatite 700°C cooling, 1000 to 1100°C heating. (Foster, 1951b.) Cristobalite and immiscible liquids, 69 to 99 percent SiO_2, 1695°C. (Bowen and Anderson, 1914; Greig, 1927a.) See figure 5.

MnO-SiO_2	Controlled atmosphere in furnace to retain Mn in 2+ state. Mn_2SiO_4, (2:1), Tephroite, melting point 1345°C; eutectic with MnO, 25.5 percent SiO_2, 1317°C; eutectic with (1:1), 38.3 percent SiO_2, 1251°C. $MnSiO_3$, (1:1), Rhodonite, incongruent melting to Tridymite plus liquid, 44.5 percent SiO_2, 1291°C. Cristobalite plus 2 liquids, 55 to 99 percent SiO_2, 1705°C. (Glasser, 1958a), with references to earlier data.
Mn_3O_4-SiO_2	In air atmosphere (0.21 atmosphere O_2). System is a portion of Mn-Si-O. Mn_3O_4 (cubic) + Mn_3O_4 (tetragonal), 1160°C. Mn_3O_4 (tetragonal) + Mn_2O_3, 877°C. Mn_3O_4 (cubic) + Tephroite + liquid, 33 percent SiO_2, 1230°C. Mn_2SiO_4 Tephroite, + $MnSiO_3$ solid solution + liquid, 34 percent SiO_2, 1206°C. Mn_3O_4 (cubic) + Mn_2O_3 solid solution + $MnSiO_3$ solid solution 1168°C. $MnSiO_3$ solid solution + Tridymite + liquid, 42 percent SiO_2, 1272°C. Mn_2O_3 solid solution + $MnSiO_3$ solid solution + Tridymite, 1048°C. Cristobalite + 2 liquids, 55 to 99 percent SiO_2, 1700°C. (Muan, 1959.)
Na_2O-SiO_2	Na_4SiO_4, (2:1), incongruent melting point 1118°C; eutectic with (1:1), 43.1 percent SiO_2, 1022°C. Na_2SiO_3, (1:1), melting point 1089°C; eutectic with (1:2), 62.1 percent SiO_2, 837°C. $Na_2Si_2O_5$, (1:2), melting point 874°C; eutectic with Quartz, 74.2 percent SiO_2, 789°C; metastable eutectic with Tridymite, about 75 percent SiO_2, 770°C; 6 slowly inverting polymorphous phases A, B, C, D, E, F; rapid transition in A, 678°C, 707°C; rapid transition in E 549°C, 573°C, 593°C. (Morey and Bowen, 1925; Kracek, 1930a; d'Ans and Löffler, 1930; Kracek, Morey, and England, 1953.)
NiO-SiO_2	2 immiscible liquids, 1725°C; eutectic with SiO_2, 90 percent SiO_2. (Greig, 1927b.)
P_2O_5-SiO_2	Compounds $SiO_2 \cdot P_2O_5$ and $3SiO_2 \cdot P_2O_5$ crystallize rapidly, whereas the components tend to remain vitreous. (Huttner, 1908; Tamman, 1925.)
PbO-SiO_2	Pb_4SiO_6, (4:1), incongruent melting to PbO and liquid 6.7 percent SiO_2, 725°C; transition 120° to 155°C, transition 720°C; eutectic with (2:1), 8.2 percent SiO_2, 714°C. Pb_2SiO_4, (2:1), melting 743°C; eutectic with (1:1), 15.4 percent SiO_2, 716°C. $PbSiO_3$, (1:1), melting point 762; eutectic with Quartz, 29 percent SiO_2, 732°C. Cristobalite and immiscible liquid pair probable. (Geller and others, 1934.) $Pb_3Si_2O_7$, (3:2), Barysilite, natural melting point 690°C; artificial does not crystallize in 20 hours at 705°C. $PbSiO_3$, (1:1), natural melting point 764°C; eutectic with SiO_2, 26.9 percent SiO_2, 732°C.
Rb_2O-SiO_2	$Rb_2Si_2O_5$, (1:2), melting point 1115°C. $Rb_2Si_4O_9$, (1:4), melting point 957°C. (Kracek, 1933.)

$SnO-SiO_2$	No liquid immiscibility found at 80 and 90 percent SiO_2, at 1715°C and 1725°C, respectively. (Greig, 1927a.)
$SrO-SiO_2$	Sr_2SiO_4, (2:1), melting above 1700°C; eutectic with (1:1), 34.5 percent SiO_2, 1545°C. $SrSiO_3$, (1:1), melting point 1580°C; eutectic with Tridymite, 53.5 percent SiO_2, 1358°C. Cristobalite and two immiscible liquids, 70 to 97.5 percent SiO_2, 1692°C. (Eskola, 1922; Greig, 1927a.)
TiO_2-SiO_2	No compounds; eutectic of SiO_2 and Rutile, 10.5 percent TiO_2, 1550°C. Rutile and 2 immiscible liquids, 19 to 93 percent TiO_2, 1780°C. Rutile, TiO_2, melting point 1830°C. (DeVries, Roy, and Osborn, 1954b.)
$ZnO-SiO_2$	Zn_2SiO_4, (2:1), Willemite, melting point 1512°C; eutectic with ZnO, 22.5 percent SiO_2, 1507°C; eutectic with Tridymite, 50.9 percent SiO_2, 1432°C. Cristobalite and 2 immiscible liquids, 65 to 98 percent SiO_2, 1695°C. (Bunting, 1930a.)
ZrO_2-SiO_2	$ZrSiO_4$, (1:1), Zircon, decomposes to oxides below liquidus, 1540°C. Eutectic with SiO_2, ZrO_2 and liquid 1670°C. (Curtis and Sowman, 1953.)

SILICATE SYSTEMS, TERNARY

$Al_2O_3-BaO-SiO_2$	$BaO \cdot Al_2O_3 \cdot 2SiO_2$, (1:1:2), Celsian, monoclinic; Paracelsian, orthorhombic, topazlike; (Spencer, 1942); melting above 1700°C. $3BaO \cdot 3Al_2O_3 \cdot 2SiO_2$, (3:3:2), decomposes below liquidus, (Toropov, Galakhov and Bondar, 1954, 1955.) Field boundaries and melting relations for (1:1:2) and mullite, silica and Ba silicates. (Thomas, 1950.)
$Al_2O_3-CaO-SiO_2$	$CaO \cdot Al_2O_3 \cdot 2SiO_2$, (1:1:2), Anorthite, melting point 1550°C. $2CaO \cdot Al_2O_3 \cdot SiO_2$, (2:1:1), melting point 1590°C. Melting relations and field boundaries for (1:1:2), (2:1:1) and adjoining binary and unary compounds have been determined. (Rankin and Wright, 1915; Greig, 1927a; Goldsmith, 1948; Langenberg and Chipman, 1956.) For ternary equilibrium diagram, see figure 6.
$Al_2O_3-FeO-SiO_2$	$2FeO \cdot 2Al_2O_3 \cdot 5SiO_2$ (2:2:5), Iron Cordierite, incongruent melting to Mullite and liquid 1210°C. $3FeO \cdot Al_2O_3 \cdot 3SiO_2$, (3:1:3), Almandine, dry could not be crystalized; natural (3:1:3) decomposes 900°C. For ternary equilibrium diagram, see figure 7. Lowest ternary eutectic. (Fe Cordierite, Tridymite, Fayalite), 1083°C. (Schairer and Yagi, 1952; Langenberg and Chipman, 1956.)
$Al_2O_3-Fe_2O_3-SiO_2$	Ternary diagram giving equilibrium phases at 1000°C; solid solution with a gap, solid solution Al_2O_3 and solid solution Fe_2O_3. (Nowotny and Funk, 1951; see also Muan, 1958a.)

Al_2O_3-K_2O-SiO_2	$K_2O \cdot Al_2O_3 \cdot SiO_2$, (1:1:1) in octahedra prepared with aid of fluxes, melts well above 1700°C. $K_2O \cdot Al_2O_3 \cdot 2SiO_2$, (1:1:2); low temperature hexagonal; similar to natural Kaliophilite below 900°C; above 1000°C orthorhombic; hexagonal Kalsilite is formed only in presence of some Na_2O, between 650°C and 1200°C. (Rigby and Richardson, 1947.) Hexagonal Kalsilite is phase stable below 840°C, a second high orthorhombic modification in some melts with $NaAlSiO_4$ present. (Tuttle and Smith, 1953.) Melts above 1700°C; eutectic with (1:1:4), 1615°C. $K_2O \cdot Al_2O_3 \cdot 4SiO_2$, (1:1:4), Leucite, melting point 1686°C; cubic above (603°C) 627°C. $K_2O \cdot Al_2O_3 \cdot 6SiO_2$, (1:1:6), Potash feldspar, incongruent melting to (1:1:4) and liquid, 1150°C; eutectic with SiO_2 990°C. For ternary equilibrium diagram, see figure 8; lowest ternary eutectic with Potash feldspar, $K_2Si_4O_9$, $K_2Si_2O_5$, 695°C. (Schairer, 1955; Schairer and Bowen, 1947b See figure 8.
Al_2O_3-Li_2O-SiO_2	$Li_2O \cdot Al_2O_3 \cdot 2SiO_2$, (1:1:2), Eucryptite, melting point 1405°C; α-β transition point 970°C; transition point lowered by solid solution with (1:1:4) to about 900°C; interrupted series solid solution at liquidus with (1:1:4); transition point about 1410°C. $Li_2O \cdot Al_2O_3 \cdot 4SiO_2$, (1:1:4), Spodumene, melting point 1425°C; α-β transition point 510°C; transition point lowered in solid solution by (1:1:2) to 485°C, by (1:1:8) to 460°C; solid solution with excess SiO_2 at liquidus; eutectic with Tridymite, 1356°C. $Li_2O \cdot Al_2O_3 \cdot 8SiO_2$ (1;1:8), Petalite, decomposes below liquidus to Quartz and (1:1:4), 680°C. (Roy, Rustum, and Osborn, 1949; Roy, Rustum, Roy, D. M. and others, 1950; Krishna-Murthy and Hummel, 1954; Hatch, 1943.)
Al_2O_3-MgO-SiO_2	$2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$, (2:2:5), Cordierite, incongruent melting to Mullite and liquid, 1460°C. $4MgO \cdot 5Al_2O_3 \cdot 2SiO_2$, (4:5:2), Sapphirine, incongruent melting to $MgO \cdot Al_2O_3$, Spinel, and liquid, 1482°C. For ternary equilibrium diagram see figure 9; lowest ternary eutectic with $MgO \cdot SiO_2$, Tridymite and Cordierite, 1345°C. (Rankin and Merwin, 1918; Bowen and Greig, 1924; Greig, 1927a; Schairer, 1942; Foster, 1950, 1951a; Keith and Schairer, 1952.)
Al_2O_3-MnO-SiO_2	$2MnO \cdot 2Al_2O_3 \cdot 5SiO_2$, (2:2:5), Manganese Cordierite, incongruent melting to mullite and liquid about 1168°C. $3MnO \cdot 3Al_2O_3 \cdot 3SiO_2$, (3:1:3), Spessartite, melting above 1200°C. Partial study of system at the liquidus. (Snow, 1943.)
Al_2O_3-Na_2O-SiO_2	$Na_2O \cdot Al_2O_3 \cdot 2SiO_2$, (1:1:2), Nepheline, hexagonal, low temperature; Carnegieite, cubic, high temperature; transition point 1248°C pure, solid solution of Albite raises transition point to 1280°C, solid solution of Na_2SiO_3 lowers transition point to 1163°C; Carnegieite, melting point 1526°C; ternary eutectic of Na_2SiO_3, $Na_2Si_2O_5$ and 1:1:2, 760°C.

	$NaO \cdot Al_2O_3 \cdot 4SiO_2$, (1:1:4), Jadeite, no sharp melting point at 1 atmosphere; decomposes to glass as low as 800°C; the glass devitrifies to a mixture of (1:1:2) and (1:1:6) in solid solution. Thermochemical data indicates that Jadeite should be formed by reaction Albite + Nepheline = 2 Jadeite at 25°C and 1 atmosphere. The stability of Jadeite is favored by increased pressure. At higher temperatures increasingly higher pressures are required, reaching 17,000 atmospheres at 927°C. (Kracek, Neuvonen, and Burley, 1951; Kelley and others, 1953.) Synthesis of Jadeite has been accomplished by above reaction at pressures and temperatures related by $P=(1000+18.5t)$ kg per cm^2. (Robertson and others, 1957.) $Na_2O \cdot Al_2O_3 \cdot 6SiO_2$, (1:1:6), Albite, melting point 1118°C, ternary eutectic with Quartz, $Na_2Si_2O_5$, 740°C. For ternary equilibrium diagram see figure 10; lowest ternary eutectic with $Na_2Si_2O_5$, Albite and Nepheline 732°C. (Schairer and Bowen, 1956.)
Al_2O_3-PbO-SiO_2	$4PbO \cdot Al_2O_3 \cdot 2SiO_2$, (4:1:2), incongruent melting to an unidentified compound and liquid, 837°C. $8PbO \cdot Al_2O_3 \cdot 4SiO_2$, (8:1:4), incongruent melting at (4:1:2) and liquid, 735°C. $6PbO \cdot Al_2O_3 \cdot 6SiO_2$, (6:1:6), melting point 811°C. Detailed study of high PbO compositions in the ternary system. (Geller and Bunting, 1943.)
Al_2O_3-TiO_2-SiO_2	No ternary compounds; fields of mullite and corundum, $TiAl_2O_5$, rutile and cristobalite; ternary eutectic of cristobalite, Rutile and $TiAl_2O_5$, about 1480°C. (Agamawi and White, 1951.)
Al_2O_3-ZnO-SiO_2	No ternary compounds; fields of ZnO, Zn_2SiO_4, Cristobalite, $ZnAl_2O_4$, mullite and corundum; lowest ternary eutectic Zn_2SiO_4, cristobalite and $ZnAl_2O_4$, 1305°C. (Bunting, 1932.)
B_2O_3-BaO-SiO_2	$3BaO \cdot 3B_2O_3 \cdot 2SiO_2$, (3:3:2), melting point 1009°C. Field of 2 liquids extends from BaO-B_2O_3 boundary far towards BaO-SiO_2 boundary over fields of $BaO \cdot 4B_2O_3$, Tridymite, and Cristobalite. Lowest ternary eutectic with $BaO \cdot 4B_2O_3$, $BaO \cdot 2B_2O_3$ and Tridymite, 810°C. (Levin and Ugrinic, 1953; Levin and Cleek, 1958.)
B_2O_3-CaO-SiO_2	$CaO \cdot B_2O_3 \cdot 2SiO_2$, (1:1:2), Danburite, decomposes to 2 liquids 996° to 1002°C. $5CaO \cdot B_2O_3 \cdot SiO_2$, (5:1:1), melting point 1419°C. Field of 2 liquids extends completely across the system from CaO-B_2O_3 to CaO-SiO_2, overlying fields of $CaO. 2B_2O_3$, (1:1:2), and SiO_2. (Flint and Wells, 1936; Morey and Ingerson, 1937.)
B_2O_3-Li_2O-SiO_2	$Li_2B_2O_4$-Li_2SiO_3, eutectic, 22 percent Li_2SiO_3, 803°C. (Klooster, 1910a, b.)
B_2O_3-Na_2O-SiO_2	$Na_2O \cdot B_2O_3 \cdot 2SiO_2$, (1:1:2), melts above 730°C; extent of field of (1:1:2) could not be determined owing to reluctance to crystallize. No liquid immiscibility in the system. (Morey, 1951.)

B_2O_3-PbO-SiO_2	$5PbO\cdot B_2O_3\cdot SiO_2$, (5:1:1), incongruent melting to 2PbO. SiO_2 and liquid about 550°C. Liquid immiscibility extends into system from PbO-B_2O_3 to part overlying fields of $PbO\cdot 2B_2O_3$ and SiO_2. (Geller and Bunting, 1939.)
B_2O_3-ZnO-SiO_2	No ternary compounds. Liquid immiscibility area extends completely across system from ZnO-SiO_2 to ZnO-B_2O_3 boundaries. It partly overlies fields of $ZnO\cdot B_2O_3$, $5ZnO\cdot 2B_2O_3$, Zn_2SiO_4 and SiO_2. (Ingerson, Morey and Tuttle, 1948.)
BaO-CaO-SiO_2	The binary join $CaSiO_3$-$BaSiO_3$: $2CaO\cdot BaO\cdot 3SiO_2$(2:1:3) incongruent melting to $CaSiO_3$ and liquid 52 percent $BaSiO_3$, 1320°C. (Eskola, 1922.)
BaO-Na_2O-SiO_2	The binary join $Na_2Si_2O_5$-$BaSi_2O_5$: eutectic, 33 percent $BaSi_2O_5$, 797°C. (Greene and Morgan, 1941.)
BaO-TiO_2-SiO_2	The binary join $BaTiO_3$-SiO_2: $BaO\cdot TiO_2SiO_2$, (1:1:1), melting point 1400°C; eutectic with $BaTiO_3$, 32 percent SiO_2, 1260°C; eutectic with (1:1:2), 67 percent SiO_2, 1246°C. $BaO\cdot TiO_2.2SiO_2$, (1:1:2), melting point 1250°C; eutectic with SiO_2, 70 percent SiO_2, 1245°C. $BaO\cdot TiO_2\cdot 3SiO_3$, (1:1:3), decomposes below liquidus to (1:1:2) and Tridymite, 965°C. Cubic to hexagonal $BaTiO_3$ transition point raised to 1575°C by limited solid solution. (Rase and Roy, 1955a, b.)
CaO-FeO-SiO_2	$CaO\cdot FeO\cdot SiO_2$, (1:1:1), Ca-Fe Olivine, melting point 1208°C. The join $CaSiO_3$-(1:1:1), forms the only binary system within the ternary; eutectic at 20 percent $CaSiO_3$, 1203°C. $2CaO\cdot FeO\cdot 2SiO_2$, (2:1:2), Fe Akermanite, stable only below 775°C; decomposes into (1:1:1) and $CaSiO_3$ 775°C. $CaO\cdot FeO\cdot 2SiO_2$, (1:1:2), Hedenbergite, stable only below 965°C; decomposes into $CaSiO_3$ solid solution; melting relations are ternary, there being no crystalline $FeSiO_3$, but mixtures 0 to 72 percent $FeSiO_3$ behave in binary manner(Bowen, Schairer, and Posnjak, 1933, p. 217.) No ternary eutectic in System, but the field of Ca-Fe olivines which are solid solution of variable orthosilicate composition, has a minimum along the boundary with wollastonite solid solution about 1100°C. Courses of crystallization of Wollastonite solid solution and Ca-Fe Olivines solid solution are outlined(Bowen, Schairer, and Posnjak, 1933, figures 9-25.) For ternary diagram, see figure 11. (Bowen, Schairer, and Posnjak, 1933; Allen and Snow, 1955.)
CaO-Fe_2O_3-SiO_2	Partial study of system outlines fields in $CaSiO_3$, $Ca_3Si_2O_7$, Ca_2SiO_4, and CaO. Extent of 2 liquid region from Fe_2O_3-SiO_2 towards CaO-SiO_2 boundary was not determined. (Burdick, 1940; Greig, 1927b; Iwasé and Nisioka, 1938; Phillips and Muan, 1958.)

$CaO-K_2O-SiO_2$	$2CaO \cdot K_2O \cdot 9SiO_2$, (2:1:9), incongruent melting to β $CaSiO_3$ and liquid 1050°C; eutectic with $K_2O \cdot 4SiO_2$ 730°C; ternary eutectic with $K_2O \cdot 4SiO_2$ and Quartz 720°C; ternary eutectic with $K_2O \cdot 2SiO_2$ and $K_2O \cdot 4SiO_2$ 720°C. $CaO \cdot 4K_2O \cdot 10SiO_2$, (1:4:10) melting point 946°C. $CaO \cdot 2K_2O \cdot 6SiO_2$, (1:2:6), melting point 959°C. β $CaO \cdot K_2O \cdot 6SiO_2$, (3:1:6), incongruent melting to β $CaSiO_3$ and liquid 1020°C; dimorphous, transition point 985°C. $CaO \cdot 2K_2O \cdot 3SiO_2$, (1:2:3), incongruent melting to (1:1:1) and liquid 1005°C; eutectic with $K_2O \cdot SiO_2$ 900°C; eutectic with $K_2O \cdot 2SiO_2$ 900°C; eutectic with (1:4:10), 895°C; eutectic with (1:2:6) 895°C; ternary eutectic with $K_2O \cdot SiO_2$, and $K_2O \cdot 2SiO_2$, 770°C. $CaO \cdot K_2O \cdot SiO_2$, (1:1:1), melting point 1630°C. Region of good glasses: fields of (2:1:9) and of (3:1:6), composition limits 2 to 15 percent CaO, 67 to 73 percent SiO_2. (Morey, Kracek, and Bowen, 1930.)
$CaO-Li_2O-SiO_2$	The binary join Li_4SiO_4-Ca_2SiO_4, $6Li_2O \cdot 4CaO \cdot 5SiO_2$, (6:4:5), melting point 1108°C; eutectic with Li_4SiO_4 1090°C; eutectic with (4:6:5), 1065°C. $4Li_2O \cdot 6CaO \cdot 5SiO_2$, (4:6:5), melting point 1090°C; eutectic with Ca_2SiO_4, 1050°C. (Schwarz, 1921; Wallace, 1909.)
$CaO-MgO-SiO_2$	$CaO \cdot MgO \cdot 2SiO_2$, (1:1:2), Diopside, melting point 1391°C; forms continuous solid state with $MgO \cdot SiO_2$. $2CaO \cdot MgO \cdot 2SiO_2$, (2:1:2), Akermanite, melting point 1454°C; low temperature limit of stability was studied in hydrothermal experiments: mixtures of oxides in ratio (2:1:2) yielded $CaSiO_3$ as Wollastonite and CaO. $MgO \cdot SiO_2$ as Monticellite when heated below 700°C to 750°C at pressures up to 4000 bars. Above 750°C Akermanite was formed. Results have bearing on the problem of the petrogenetic grid of the Bowen (1940) decarbonation series: (Harker and Tuttle, 1956.) $CaO \cdot MgO \cdot SiO_2$, (1:1:1), Monticellite, incongruent meltint to MgO plus liquid, 1503°C. $3CaO \cdot MgO \cdot 2SiO_2$, (3:1:2), Merwinite, incongruent melting to Ca_2SiO_4 plus liquid, 1575°C. For ternary diagram, see figure 12. (Ferguson and Merwin, 1919; Greig, 1927a; Ricker and Osborn, 1954; Bowen, 1914; Schairer and Bowen, 1942; Osborn, 1943; Bredig, 1950; Atlas, 1952.)
$CaO-MnO-SiO_2$	$CaSiO_3$-$MnSiO_3$, Wollastonite-Rhodonite, isodimorphous series solid solution; α-β $CaSiO_3$ transition point raised to 1374°C. (Voos, 1935.) Ca_2SiO_4-Mn_2SiO_4, Tephroite, solid solution with a minimum, 15 mole percent Tephroite, 1170°C; Glauchochroite, $CaMnSiO_4$, is interpreted as equimolar solid solution (Kallenberg, 1914; Tokody, 1928.)
$CaO-Na_2O-SiO_2$	$CaO \cdot 2Na_2O \cdot 3SiO_2$, (1:2:3), incongruent melting to (2:1:3) and liquid 1141°C; eutectic with $Na_2O \cdot SiO_2$, 1060°C. $2CaO \cdot Na_2O \cdot 3SiO_2$, (2:1:3), melting point 1284°C; eutectic with $Na_2O \cdot 2SiO_2$, 862°C. $3CaO \cdot Na_2O \cdot 6SiO_2$, (3:1:6), Devitrite, incongruent melting to β $CaSiO_3$ and liquid 1047°C.

	Region of good glasses: field of Devitrite and adjoining regions, 5 to 15 percent CaO, 67 to 74 percent SiO_2. Lowest ternary eutectic with Devitrite, Quartz, $Na_2O\cdot 2SiO_2$, 725°C. (Morey and Bowen, 1925; Morey, 1930.)
$CaO-P_2O_5-SiO_2$	$7CaO\cdot P_2O_5\cdot 2SiO_2$, (7:1:2), Nagelschmidtite, melting point indefinite;interpreted as series of solid solution of $Ca_3(PO_4)_2$ in Ca_2SiO_4 rather than as a compound by Bredig (1943, 1950); phase found in phosphate slag is biaxial positive, parallel extinction, $\alpha = 1.652$, $\gamma = 1.661$, G = 3.035. $5CaO\cdot P_2O_5\cdot SiO_2$, (5:1:1), Silicocarnotite, decomposes 1300°C to solid solution phases; compound has solid solution range of composition; biaxial, 2V nearly 90°, $\alpha = 1.632$, $\beta = 1.636$, $\gamma = 1.640$. $Ca_2SiO_4-Ca_3(PO_4)_2$ system, two series solid solution at liquidus, transition point 1900°C; Ca_2SiO_4 rich and $Ca_3(PO_4)_2$ rich solid solution with gap below liquidus; below 1300°C, (5:1:1), solid solution separate from the two series;transitions in Ca_2SiO_4 and in $Ca_3(PO_4)_2$ are lowered by solid solution. (Bredig, 1950.) $Ca_3(PO_4)_2-SiO_2$ system, eutectic of $Ca_3(PO_4)_2$, Cristobalite and liquid, about 8 percent SiO_2, 1540°C; Cristobalite and 2 liquids, 12.5 to about 95 percent SiO_2, about 1680°C. (Trömel and others, 1948.) Liquid immiscibility area extends from $CaO-SiO_2$, 1698°C, far towards $CaO-P_2O_5$. (Barrett and McCaughey, 1942; Greig, 1927a; Tromel, 1932, 1943; Bredig, 1943, 1950; St. Pierre, 1953; Trömel and others, 1948; Hill, Faust, and Reynolds, 1944.)
$CaO-SrO-SiO_2$	The binary join $CaSiO_3-SrSiO_3$, solid solution series with a minimum, 56 percent $SrSiO_3$, 1475°C. (Eskola, 1922.)
$CaO-TiO_2-SiO_2$	$CaTiSiO_5$, (1:1:1), Titanite (Sphene), melting point 1382°C; eutectic with $CaTiO_3$, 1375°C; eutectic with Tridymite, 1373°C; eutectic with $CaSiO_3$, 1373°C; eutectic with TiO_2, Rutile, 1375°C. Liquid immiscible region extends from $CaO-SiO_2$ to $CaO-TiO_2$ boundary, in part overlying the fields of Cristobalite and Rutile. (DeVries, Roy, and Osborn, 1953, 1955; Berezhnoi, 1950; Iwasé and Fukusima, 1936; Iwasé and Nisioka, 1936.)
$CaO-ZnO-SiO_2$	$2CaO\cdot ZnO\cdot 2SiO_2$, (2:1:2), melting point 1425°C; ternary eutectic with Tridymite and Zn_2SiO_4, 1170°C; eutectic with Zn_2SiO_4 and ZnO, 1259°C; eutectic with ZnO and Ca_2SiO_4, 1345°C; eutectic with $CaSiO_3$ and $Ca_3Si_2O_7$, 1365°C; with $CaSiO_3$ and Tridymite, 1223°C. Liquid immiscible region extends from $CaO-SiO_2$ to $ZnO-SiO_2$, in part overlying the field of Cristobalite. (Segnit, 1954.)
$Cr_2O_3-MgO-SiO_2$	No ternary compounds; lowest temperatures are near $MgO-SiO_2$ binary;lowest ternary eutectic with $MgSiO_3$, SiO_2, $MgCr_2O_4$, with about 2 percent Cr_2O_3 added to eutectic of $MgSiO_3$ and SiO_2, 1546°C.

	Liquid immiscible region extends from $MgO-SiO_2$ to $MgO-Cr_2O_3$, partly overlying fields of Cr_2O_3, $MgCr_2O_4$ (Picrochromite) and Cristobalite. Field of $MgCr_2O_4$, Picrochromite, separates field of MgO, Periclase, from that of 2 liquids. (Keith, 1954.)
$FeO-Fe_2O_3-SiO_2$	Two-liquid region overlying Cristobalite across system near SiO_2 corner. (Greig, 1927b.) Ternary eutectic of Fayalite, Grunerite and Fe_2O_3, 40FeO, $20Fe_2O_3$, $40SiO_2$. (Hallimond and Whiteley, 1919); this eutectic is not possible because $FeSiO_3$ does not crystallize in binary system $FeO-SiO_3$. (Bowen, Schairer and Posnjak, 1933.) 1600°C section of system (Gurry and Darken, 1950.)
$FeO-K_2O-SiO_2$	$K_2O \cdot FeO \cdot 5SiO_2$, (1:1:5), melting point 900°C. $K_2O \cdot FeO \cdot 3SiO_2$, (1:1:3), melting point 900°C. Two-liquid region over Cristobalite along $FeO-SiO_2$ boundary, (Roedder, 1952.)
$FeO-MgO-SiO_2$	No ternary compounds. $Fe_2SiO_4-Mg_2SiO_4$, the Olivine series solid solution. The join $FeSiO_3-MgSiO_3$, this is not a binary system because $FeSiO_3$ is not a crystalline compound;the $MgSiO_3$ end is composed of solid solution series of orthopyroxene and clinopyroxenes. No ternary eutectic in system. Low temperatures on liquidus lie on $FeO-SiO_2$ boundary of composition triangle. Reaction point Pyroxene ($MgSiO_3$), Olivine, Tridymite, liquid, 1305°C. Reaction point Pyroxene, Cristobalite, Tridymite, liquid, 1470°C. 2 liquid region extends from $FeO-SiO_2$ to $MgO-SiO_2$ overlying Cristobalite near SiO_2 corner. For ternary diagram, see figure 13. (Bowen and Schairer, 1935.)
$FeO-MnO-SiO_2$	No ternary compounds, no ternary eutectic, low temperature on liquidus lie at $FeO-SiO_2$ binary. $Fe_2SiO_4-Mn_2SiO_4$ join, the Knebelite series solid solution. (Fayalite-Tephroite series.) $FeSiO_3-MnSiO_3$ join is not a binary system, because $FeSiO_3$ is not a crystalline compound; $MnSiO_3$ end is comprised of Rhodonite series solid solution. FeO-MnO; two series solid solution with a transition point 1430°C; liquidus slopes down to boundary with the Knebelite series solid solution. Two immiscible liquids region near SiO_2 corner extends completely from $FeO-SiO_2$ join to $MnO-SiO_2$ join, overlying Cristobalite field. (Hay, White and McIntosh, 1935; Maddocks, 1935; White, 1943.)
$FeO-Na_2O-SiO_2$	Na_2FeSiO_4, (1:1:1), melting point 976°C; reaction point with Na_2SiO_3, $Na_2Si_2O_5$ and liquid 724°C; reaction point with FeO, $Na_2Si_2O_5$ and liquid 720°C. Liquid immiscible along $FeO-SiO_2$ border. Lowest ternary eutectic with Fayalite, $Na_2Si_2O_5$, SiO_2 and liquid below 500°C. (Carter and Ibrahim, 1952.)

Fe_2O_3-K_2O-SiO_2	$K_2O\cdot Fe_2O_3\cdot 6SiO_2$, (1:1:6), Iron Orthoclase, incongruent melting to (1:1:4) and liquid 920°C. $K_2O\cdot Fe_2O_3\cdot 4SiO_2$, (1:1:4), Iron Leucite, incongruent melting to Fe_2O_3 and liquid 1050°C. (Faust, 1936.)
Fe_2O_3-Na_2O-SiO_2	$Na_2O\cdot Fe_2O_3\cdot 4SiO_2$, (1:1:4), Acmite, incongruent melting to Fe_2O_3 and liquid, 990°C; eutectic with $Na_2Si_2O_5$, 810°C; eutectic with (5:1:8), 817°C. $5Na_2O\cdot Fe_2O_3\cdot 8SiO_2$, (5:1:8), melting point 838°C; eutectic with Na_2SiO_3, 837°C, eutectic with Fe_2O_3, 816°C. $6Na_2O\cdot 4Fe_2O_3\cdot 5SiO_2$, (6:4:5), melting point above 1091°C. $2Na_2O\cdot Fe_2O_3\cdot SiO_2$, (2:1:1), melting point above 1145°C. Liquid immiscible along Fe_2O_3-SiO_2 border. (Bowen, Schairer, and Willems, 1930.)
K_2O-Li_2O-SiO_2	$K_2O\cdot Li_2O\cdot 4SiO_2$, (1:1:4), melting point (870°C ?) 820°C. $2K_2O\cdot Li_2O\cdot 6SiO_2$, (2:1:6), melting point 815°C. $5K_2O\cdot Li_2O\cdot 6SiO_2$, (5:1:6), melting point (880°C ?) 857°C. $5K_2O\cdot 2Li_2O\cdot 7SiO_2$, (5:2:7), melting point (900°C ?) 880°C. $5K_2O\cdot Li_2O\cdot 4SiO_2$, (5:1:4), melting point (830°C ?). The phase diagram is dominated by fields of $Li_2O\cdot SiO_2$ and SiO_2. Modified from Sheybany (1948).
K_2O-MgO-SiO_2	$K_2O\cdot 5MgO\cdot 12SiO_2$, (1:5:12), incongruent melting to $MgSiO_3$ and liquid, 1174°C. $K_2O\cdot MgO\cdot 5SiO_2$, (1:1:5), melting point 1089°C; eutectic with $K_2Si_4O_9$, 730°C; eutectic with Tridymite, 963°C; eutectic with Mg_2SiO_4, 1053°C. $K_2O\cdot MgO\cdot 3SiO_2$, (1:1:3), melting point 1134°C; eutectic with $K_2Si_2O_5$, 933°C; eutectic with (1:1:5), 1030°C; eutectic with Mg_2SiO_4, 1131°C. $K_2O\cdot MgO\cdot SiO_2$, (1:1:1), melting point 1650°C; eutectic with K_2SiO_3, 950°C; eutectic with $K_2Si_2O_5$, 910°C; eutectic with (1:1:3), 1110°C. Liquid immiscible along MgO-SiO_2 border, overlying Cristobalite. (Roedder, 1951b.)
K_2O-Na_2O-SiO_2	No ternary compounds in portion of system K_2SiO_3-Na_2SiO_3-SiO_2. K_2SiO_3-Na_2SiO_3 join, eutectic 745°C. $K_2Si_2O_5$-$Na_2Si_2O_5$ join, limited series solid solution of $K_2Si_2O_5$;solid solution $Na_2Si_2O_5$, a minimum at 705°C; solid solution $Na_2Si_2O_5$, transition point at 742°C at the liquidus. Eutectic $Na_2Si_2O_5$, $K_2Si_2O_5$, Quartz and liquid 540°C. Modified from Kracek (1932).
K_2O-PbO-SiO_2	$K_2O\cdot PbO\cdot 4SiO_2$, (1:1:4), melting point 757°C. $K_2O\cdot 4PbO\cdot 8SiO_2$, (1:4:8), melting point 779°C. $K_2O\cdot 2PbO\cdot 2SiO_2$, (1:2:2), melting point 918°C. $2K_2O\cdot PbO\cdot 3SiO_2$, (2:1:3), incongruent melting to (1:2:2) and liquid, 806°C. (Geller and Bunting, 1936.)
K_2O-ZnO-SiO_2	$K_2O\cdot ZnO\cdot SiO_2$, (1:1:1), field of stability and melting point were not determined. Field of Willemite intrudes between those of ZnO and SiO_2. (Ingerson and others, 1948.)
Li_2O-MgO-SiO_2	(Krishna-Murthy and Hummel, 1955.)

$Li_2O-Na_2O-SiO_2$	The join Na_2SiO_3-Li_2SiO_3, continuous series solid solution from Na_2SiO_3 to $NaLiSiO_3$, with a liquidus minimum, 38.5 percent Li_2SiO_3, 845°C. $NaLiSiO_3$, (1:1:2), incongruent melting to Li_2SiO_3 solid solution and liquid, 847°C. The join $Na_2Si_2O_5$-$Li_2Si_2O_5$ is not binary at liquidus because of incongruent melting of $Li_2Si_2O_5$. Lowest ternary eutectic $Na_2Si_2O_5$, $Li_2Si_2O_5$ and Quartz, 637°C. (Kracek, 1939a, b.)
$Li_2O-ZrO_2-SiO_2$	$4Li_2O \cdot 3ZrO_2 \cdot 5SiO_2$, (4:3:5), melting point 1152°C. (Schwarz, 1921.)
$MgO-TiO_2-SiO_2$	Incomplete study. Liquidus has a minimum below 1500°C. (Berezhnoi, 1950; Massazza and Sirchia, 1958.)
$MgO-ZrO_2-SiO_2$	Compatibility triangles outlined. (Foster, 1951b.)
$MnO-TiO_2-SiO_2$	$MnSiO_3$-$MnTiO_3$, eutectic, 22.3 mole percent $MnTiO_3$, 1120°C; solid solution limit 38 to 100 mole percent $MnTiO_3$. (Smolensku, 1912.)
$Na_2O-PbO-SiO_2$	$Na_2O \cdot 2PbO \cdot SiO_2$, (1:2:1), melting point 840°C; transition point 790°C; β decomposes to PbO and Na_2SiO_3, 590°C. $Na_2O \cdot 3PbO \cdot 6SiO_2$, (1:3:6). $Na_2O \cdot 2PbO \cdot 3SiO_2$, (1:2:3), melting point 615°C. $Na_2O \cdot 3PbO \cdot 7SiO_2$, (1:3:7). $3Na_2O \cdot 3PbO \cdot 11SiO_2$, (3:3:11). (Krakau and others, 1937; Grebenshchikov, 1949.)
$Na_2O-P_2O_5-SiO_2$	$5Na_2O \cdot P_2O_5 \cdot 4SiO_2$, (5:1:4), incongruent melting to (9:2:6) and liquid, 953°C. $9Na_2O \cdot 2P_2O_5 \cdot 6SiO_2$, (9:2:6), melting point 1100°C. $15Na_2O \cdot 5P_2O_5 \cdot 6SiO_2$, (15:5:6), incongruent melting to (9:2:6) and liquid, 987°C. Two liquids over Cristobalite in SiO_2-P_2O_5 rich region. (Turkdogan and Maddocks, 1952.)
$Na_2O-ZrO_2-SiO_2$	Na_2O-SiO_2 rich portion of system investigated to 1100°C, disclosing fields of Na_4SiO_4, $Na_6Si_2O_7$, Na_2SiO_3, Na_2ZrO_3, Na_2ZrSiO_5 and $Na_4Zr_2Si_3O_{12}$. (d'Ans and Löffler, 1930.)
$TiO_2-Ti_2O_3-SiO_2$	Exploratory study. (Roy, Rustum, and others, 1952.)
$TiO_2-ZrO_2-SiO_2$	No ternary compounds. Ternary eutectic SiO_2, TiO_2, ZrO_2 and liquid, 1500°C. (Sowman and Andrews, 1951; McTaggart and Andrews, 1957.)

Additional References

$Al_2O_3-B_2O_3-SiO_2$	Dietzel and Scholze (1955).
$Al_2O_3-SrO-SiO_2$	Dear (1957).
$B_2O_3-P_2O_5-SiO_2$	Horn and Hummel (1955).
$CaO-CaF_2-SiO_2$	$3CaO \cdot CaF_2 \cdot 2SiO_2$, Cuspidine, Brisi (1957).
$CaO-Cr_2O_3-SiO_2$	Glasser and Osborn (1958).

MgO-MnO-SiO_2	Glasser (1958b).
PbO-P_2O_5-SiO_2	Paetsch and Dietzel (1956).
SrO-ZrO_2-SiO_2	Dear (1958).

SILICATE SYSTEMS, QUATERNARY AND HIGHER

Al_2O_3-CaO-Cr_2O_3-MgO-SiO_2	7 percent R_2O_3 plane (75MgO·Al_2O_3, 25MgO.Cr_2O_3) parallel to the CaO-MgO-SiO_2 base. 7 percent R_2O_3 plane (50MgO·Al_2O_3, 50MgO.Cr_2O_3) parallel to the CaO-MgO-SiO_2 base. (Berry, Allen and Snow, 1950; also Warshaw and Keith, 1954.)
Al_2O_3-CaO-FeO-SiO_2	Study of several joins in the quaternary system: (a) FeO-Al_2O_3-$CaAl_2Si_2O_8$, Anorthite; (b) FeO-SiO_2-$CaAl_2Si_2O_8$, see figure 14; (c) FeO-$CaSiO_3$-$CaAl_2Si_2O_8$; (d) FeO-$CaSiO_3$-$Ca_2Al_2SiO_7$, Gehlinite; (e) FeO-$Ca_2Al_2SiO_7$-$CaAl_2Si_2O_8$; (f) FeO-$Ca_2Al_2SiO_7$; (g) FeO-Ca_2SiO_4-$Ca_2Al_2SiO_7$; (h) $Ca_2Al_2SiO_7$-$Ca_2FeSi_2O_7$, Iron Akermanite. (Schairer, 1942; Muan and Osborn, 1951.)
Al_2O_3-CaO-Fe_2O_3-SiO_2	0, 2, 5, 10 and 20 percent Fe_2O_3 planes parallel to base CaO-Ca_2SiO_4-5CaO·$3Al_2O_3$. (Lea and Parker, 1934; Swayze, 1946a, b.)
Al_2O_3-CaO-Fe_2O_3-MgO-SiO_2	CaO-5CaO·$3Al_2O_3$-2CaO·Fe_2O_3-Ca_2SiO_4;modified by 5 percent MgO. (Swayze, 1946a, b.)
Al_2O_3-CaO-K_2O-SiO_2	CaO-5CaO·$3Al_2O_3$-K_2O·23CaO·$12SiO_2$;(Taylor, 1942.) $KAlSi_2O_6$, Leucite-$CaAl_2Si_2O_8$, Anorthite-SiO_2; see figure 15. (Schairer and Bowen, 1947a, b.)
Al_2O_3-CaO-K_2O-MgO-SiO_2	$KAlSi_2O_6$, Leucite-$CaMgSi_2O_6$, Diopside-SiO_2; see figure 16. $KAlSi_2O_6$-$CaMgSi_2O_6$ binary section. (Bowen and Schairer, 1929; Bowen, 1937.)
Al_2O_3-CaO-K_2O-Na_2O-SiO_2	$NaAlSi_3O_8$, Albite-$KAlSi_3O_8$ Potash Feldspar-$CaAl_2Si_2O_8$ Anorthite; see figure 17. (Franco and Schairer, 1951.)
Al_2O_3-CaO-MgO-SiO_2	CaO-MgO-5CaO·$3Al_2O_3$-Ca_2SiO_4, with 0 and 5 percent MgO. (McMurdie and Insley, 1936.) SiO_2-Mg_2SiO_4, Forsterite-$CaAl_2Si_2O_8$, Anorthite. See figure 18. (Andersen, 1915.) $CaSiO_3$-$CaMgSi_2O_6$, Diopside-$CaAl_2Si_2O_8$Anorthite. (Osborn, 1942.) $Ca_2Al_2SiO_7$, Gehlinite-$Ca_2MgSi_2O_7$, Akermanite, binary solid solution. (Osborn and Schairer, 1941; Ferguson and Buddington, 1920.) $CaSiO_3$-$Ca_2Al_2SiO_7$-$Ca_2MgSi_2O_7$. (Osborn and Schairer, 1941.)

	$CaMgSi_2O_6$, Diopside-$CaAl_2Si_2O_8$, Anorthite-Mg_2SiO_4, Forsterite; see figure 19. (Osborn and Tait, 1952.) MgO-Ca_2SiO_4-$MgO\cdot Al_2O_3$, Spinel. (Prince, 1951.) $MgO\cdot Al_2O_3$-Ca_2SiO_4-$Ca_2Al_2SiO_7$, Gehlinite, (Prince, 1951.) MgO-Al_2O_3-Ca_2SiO_4. (Prince, 1951.) 10 percent MgO plane. (Prince, 1954.) $CaAl_2Si_2O_8$, Anorthite-$Ca_2MgSi_2O_7$, Akermanite. (DeWys and Foster, 1956;Prince, 1954.)
Al_2O_3-CaO-MgO-Na_2O-SiO_2	$NaAlSi_3O_8$, Albite-$CaAl_2Si_2O_8$, Anorthite-$CaMgSi_2O_6$, Diopside; see figure 20. (Bowen, 1915.) $CaMgSi_2O_6$-$NaAlSiO_4$, Nepheline, Carnegieite. (Bowen, 1922.) $CaMgSi_2O_6$-$NaAlSiO_4$-$NaAlSi_3O_8$, Albite, a portion of $CaMgSi_2O_6$-$NaAlSiO_4$-SiO_2. (Yoder, 1950, and from the unpublished work of Schairer.)
Al_2O_3-CaO-Na_2O-SiO_2	Na_2SiO_3-$CaSiO_3$-$NaAlSiO_4$, Nepheline-$CaAl_2Si_2O_8$, Anorthite. (Spivak, 1944.) $CaSiO_3$-$NaAlSiO_4$-$CaAl_2Si_2O_8$. (Gummer, 1943.)
Al_2O_3-CaO-Na_2O-P_2O_5-SiO_2	(Melent'ev and Ol'shanskiy, 1952.)
Al_2O_3-CaO-Na_2O-TiO_2-SiO_2	$NaAlSi_3O_8$, Albite-$CaAl_2Si_2O_8$, Anorthite-$CaTiSiO_5$, Titanite. (Prince, 1943.)
Al_2O_3-FeO-Fe_2O_3-SiO_2	(Muan, 1957a, 1958b.)
Al_2O_3-CaO-P_2O_5-SiO_2	$Ca_3(PO_4)_2$-Al_2O_3-SiO_2. (St. Pierre, 1953; Hartmann and Haegermann, 1953.)
Al_2O_3-CaO-TiO_2-SiO_2	$CaSiO_3$-$CaAl_2Si_2O_8$, Anorthite-$CaTiSiO_5$, Titanite. (Iwase and Nisioka, 1936.)
Al_2O_3-FeO-Fe_2O_3-SiO_2	Projection of the curved surface bounding mixtures that form 2 liquid layers, onto the FeO-Fe_2O_3-SiO_2 base. (Greig, 1927b; Muan, 1957a, b, 1958a, b, c); Muan and Gee, 1956.)
Al_2O_3-FeO-Na_2O-SiO_2	FeO-SiO_2-$NaAlSiO_4$, Nepheline. See figure 21. (Bowen, 1937.)
Al_2O_3-FeO-K_2O-SiO_2	$KAlSi_2O_6$, Leucite-Fe_2SiO_4, Fayalite-SiO_2. See figure 22. (Roedder, 1951a.)
Al_2O_3-K_2O-MgO-SiO_2	$KAlSi_2O_6$, Leucite-Mg_2SiO_4, Forsterite-SiO_2 ternary system. See figure 23. Mg_2SiO_4-$KAlSi_2O_6$-$Mg_2Al_4Si_5O_{18}$, Cordierite. $KAlSi_2O_6$-$Mg_2Al_4Si_5O_{18}$-SiO_2. $MgSiO_3$-$KAlSi_2O_6$-$Mg_2Al_4Si_5O_{18}$. $Mg_2Al_4Si_5O_{18}$-$KAlSi_3O_8$, Potash Feldspar-$3Al_2O_3\cdot 2SiO_2$, Mullite. (Schairer, 1954, 1955.)

Al_2O_3-K_2O-Na_2O-SiO_2	$NaAlSiO_4$, Nepheline, Carnegieite-$KAlSiO_4$, Kaliophilite, Kalsilite-SiO_2. See figure 24. (Schairer, 1950.) $NaAlSiO_4$-$KAlSiO_4$; Nephelite-Carnegieite transition point is raised by solid solution from 1248° to 1404°C; Nephelite solid solution - Kaliophilite transition point is raised from 1540° to 1580°C. (Bowen, 1917.) $KAlSi_3O_8$-$NaAlSi_3O_8$. (Schairer, 1950); Structure study (Smith and Tuttle, 1957.)
Al_2O_3-Li_2O-MgO-SiO_2	$Mg_2Al_4Si_5O_{18}$, Cordierite-$LiAlSi_2O_6$, Spodumene. (Karkhanavala and Hummel, 1953; Prokopowitz and Hummel, 1956.)
Al_2O_3-MgO-ZrO_2-SiO_2	No quaternary compounds. (Herold and Smothers, 1954.)
Al_2O_3-MnO-Y_2O_3-SiO_2	$Mn_3Al_2Si_3O_{12}$, Spessartite-$Y_6Al_{10}O_{24}$, Yttrogarnet; system illustrates complete substitution of Al for Si. (Yoder and Keith, 1951.)
B_2O_3-CaO-Na_2O-SiO_2	Effects of additions of 1 and 5 percent B_2O_3 on the liquidus for Devitrite, $Na_2Ca_3Si_6O_{16}$. (Morey, 1932.)
CaO-FeO-MgO-SiO_2	$CaSiO_3$-$CaMgSiO_4$, Monticellite-FeO, fields of Magnesiowustite, Olivine Melilite and Ca SiO_3, Pseudowollastonite; all fields except $CaSiO_3$ are solid solution. (Schairer and Osborn, 1950.)
CaO-Fe_2O_3-MgO-SiO_2	(Rait, 1949.)
CaO-MgO-MnO-TiO_2-SiO_2	$CaMgSi_2O_6$, Diopside-$MnTiO_3$; (Iwase and Nisioka, 1938.)
CaO-MgO-TiO_2-SiO_2	(Berezhnoy, 1950; Iwase and Nisioka, 1938; Nisioka, 1935.)
CaO-MnO-SiO_2-SiO_2	(Iwase and Nisioka, 1936.)
FeO-Fe_2O_3-MgO-SiO_2	(Muan and Osborn, 1956.)

Additional Systems

Al_2O_3-CaO-P_2O_5-SiO_2	$Ca_3(PO_4)_2$-$CaAl_2Si_2O_8$, Anorthite-SiO_2 section. (St. Pierre, 1956.)
CaO-MgO-P_2O_5-SiO_2-CaF_2	$3Ca_3(PO_4)_2 \cdot CaF_2$-$MgSiO_3$-$SiO_2$ section. (Bobrownicki and Swiecki, 1955.)
CaO-MgO-P_2O_5-SiO_2	$Ca_3(PO_4)_2$-$MgSiO_3$-SiO_2 section. (Sata, 1958.)
MgO-Fe_2O_3-TiO_2-SiO_2	(Rao, 1957.)

SILICATES, MISCELLANEOUS

$CaSiO_3$-CaF_2	Eutectic, 47 mole percent CaF_2, 1128°C. (Karandeeff, 1910; Boak and Olander, 1955.)

FeO-FeS-SiO_2	FeS-SiO_2, liquid immiscible, 5 to 95 percent SiO_2 over Cristobalite, 1690°C. FeO-FeS, eutectic 36 percent FeO, 920°C. Ternary eutectic FeO, Fe_2SiO_4, FeS, below 920°C. (Ol'shanskiy, 1950.)
NaF-Na_2O-SiO_2	Na_2SiO_3-NaF, eutectic, 39 mole percent NaF, 795°C. (Booth and others, 1933.)
CaO-Na_2O-SO_3-SiO_2	SiO_2-Na_2SiO_3-$CaSiO_3$-Na_2SO_4-$CaSO_4$, solubility relations at 1200°C. Na_2SiO_3-Na_2SO_4, eutectic 7 percent Na_2SO_4, 868°C. (Kordes and others, 1951.)
Na_2SiO_3-Na_2WO_4	Na_2SiO_3 in equilibrium with 2 liquids, 14 to 99 percent Na_2SiO_3, 1080°C; eutectic near 100 percent Na_2WO_4, 696°C. (Tammann, 1925.)

CARBONATES

Ag_2CO_3	Dissociates (1 atm CO_2) 219°C. (Drake and Benton, 1934; Watanabe, 1933; Centnerszwer, and Krustinsons, 1926.)
$CaCO_3$	Witherite, melting point (90 atm CO_2) 1740°C; dissociates 0.068 atm CO_2, 1204°C; transition points 806°C, 968°C. (Dutoit, 1927; Finkelstein, 1906; Lander, 1949, 1951a.)
$BaCO_3 \cdot BaO$	(Finkelstein, 1906); existence disproved by Lander (1951.)
$BaK_2(CO_3)_2$	Melting point 800°C. (Le Chatelier, 1887.)
$CaNa_2(CO_3)_2$	Melting point 740°C. (Le Chatelier, 1887.)
$CaCO_3$-$CaCO_3$	Melting diagram. (Boeke, 1913.)
$BeCO_3 \cdot 4H_2O$	Decomposes with loss of H_2O, 100°C.
$CaCO_3$	Calcite, melting point (1038) bars CO_2), 1339°C; eutectic of $CaCO_3$, CaO plus liquid (40 bars CO_2), 50 mole percent CaO, 1240°C; dissociates (1 atm CO_2), 897°C; dissociation pressure at higher temperature, $\log P(\text{bars } CO_2) = \frac{-11,355}{T(°K)} - 5.388 \log T(°K) + 26.244$. Heat of dissociation calculated 39.44 kcal per mol at 898.6°C and 35.79 kcal per mol at 1240°C; transition point 970°C found by Boeke (1912) may not exist. (Smyth and Adams, 1923; Johnston, 1910; Boeke, 1912; Harker and Tuttle (1955) observed higher pressure, lower temperatures in dissociates. Aragonite metastable at room temperature and above, inverts to Calcite about 425°C at 1 atmosphere pressure; reversible transition point Calcite-Aragonite P(bars) = 16 T (°C) + 1400, MacDonald (1956); P(bars) = 17 T (°C) + 3600, Clark (1957); agrees with value calculated for 1 bar pressure, −195°C (79°K) from Jamieson (1953). Vaterite, transition to Calcite from 430° to 440°C.

$CaCO_3$-K_2CO_3	(Kröger and others, 1943.)
$CaCO_3$-Na_2CO_3-K_2CO_3	1 atm CO_2 isotherms. (Niggli, 1919.)
$CaK_2(CO_3)_2$	Melting point 814°C.
$CaCO_3$-Li_2O	(Eitel and Skaliks, 1929.)
$CaNa_2(CO_3)_2$	Melting or decomposition, (54.2 atm CO_2), 812°C; eutectic with (Na_2, Ca) CO_3 solid solution, 38 percent $CaCO_3$, 805°C. (Eitel, 1925; Niggli, 1916.)
(Ca, Fe, Mg, Mn)CO_3	Ankerite, dissociates in two steps,610° to 770°C and 900°C.
CaO-MgO-CO_2	CaO· MgO· $(CO_2)_2$, Dolomite, dissociates to $CaCO_3$, MgO, CO_2 at 1 atm CO_2, about 500°C; to CaO, MgO, CO_2 at 890°C. High CO_2 pressure equilibrium was measured for dissociation of Dolomite to Magnesian Calcite+ MgO+CO_2 to 20, 000 psi(1378 bars)875°C,Graf and Goldsmith (1955), revised in Graf and Goldsmith (1958);measured to 40, 000 psi(2756 bars), 940°C. (Harker and Tuttle, 1955.) Magnesian Calcite, solid solution of Mg in Calcite. Excess Ca solid solution in Dolomite. Solid solution Ca in Magnesite, determined up to 900°C at pressure high enough to prevent dissociation. Details given in Graf and Goldsmith (1955) and Harker and Tuttle (1955).
$CaCO_3$· $NaAlSiO_4$	Cancrinite, artificial, incongruent melting to Nepheline and liquid, (107 atm CO_2), 1253°C.(Eitel,1925).
CaO-MnO-CO_2	A complete series of solid solution exists from Ca CO_3 to $MnCO_3$ at temperatures above 550°C and pressures sufficient to prevent dissociation. (75.9 bars at 550°C rising to 1550 bars at 750°C for dissociation of $MnCO_3$). Unmixing of these solid solutions is observed in the $MnCO_3$-rich region below 550°C. One limb of the solvus approaches the 1:1 composition, the other limb 80 mole percent $MnCO_3$, as temperature falls to 450°C. Below 400°C no equilibrium is attained either in hydrothermal runs or in presence of Li_2CO_3 as flux. Kutnahorite, $CaMn(CO_3)_2$, is a phase in which the random arrangement of Ca ions and Mn ions of the solid solution is replaced by an ordered one with Ca and Mn in alternate layers of the lattice. This phase becomes disordered at temperatures above 450°C. The heat of dissociation of $MnCO_3$ is calculated to be 26.0±0.4 kcal per mol. (Goldsmith and Graf, 1957.)
$CaCO_3$· $2Ca_2SiO_4$	Spurrite, incongruent melting to Ca_2SiO_4 plus liquid, (122 atm CO_2), 1380°C. Artificial differs from natural mineral. Transition natural to artificial (120 atm CO_2), 1200°C., (Eitel, 1923.)

	Mixture $5CaCO_3 \cdot 2SiO_2$ crystallized readily to Spurrite at 172 bars CO_2, 950°C; equilibrium values along $P(CO_2)-T$ curve were measured from 25 to 310 bars, 700° to 1000°C. Tilleyite, $2CaCO_3 \cdot Ca_3Si_2O_7$, did not crystallize in above experiments. (Tuttle and Harker, 1957.)
$CdCO_3$	Otavite, dissociation,(1 atm CO_2),344°C. (Andrussov, 1925; Centnerszwer, 1930; Jander, 1928.)
$CoCO_3$	Spherocobaltite, dissociation to basic carbonates. (Krustinsons, 1933.)
$CuCO_3$	Appears to be unstable relative to CuO and CO_2. (Maier, 1929; Kelley and Anderson, 1935.)
$Cu_3(OH)_2(CO_3)_2$	Azurite, decomposes about 200°C.
$FeCO_3$	Siderite,dissociation(1 atm CO_2)450°C. (Fleissner, 1925; Friedrich and Smith, 1912.)
K_2CO_3	Melting point 895°C, 422°C; vapor pressure of liquid 0.047 atmosphere at 1400°C. (Howarth and Turner, 1931.)
$K_2CO_3-Li_2CO_3$	(Eitel and Skaliks, 1929.)
$K_2CO_3-Na_2CO_3$	(Reisman, 1959.)
Li_2CO_3	Melting point 735°C, 401°C; vapor pressure of liquid 0.177 atmosphere at 1100°C. (Howarth and Turner, 1931.)
$LiNaCO_3$	Melting point 514°C; eutectic with Na_2CO_3, 61 percent Na_2CO_3, 510°C; eutectic with Li_2CO_3, 44 percent Li_2CO_3, 510°C. (Eitel and Shaliks, 1929.)
$MgCO_3$	Magnesite, conflicting data on dissociation, dissociates to basic carbonates, (Centnerszwer and Bruzs, 1925); basic carbonates disproved on X-ray evidence, (Huttig and Frankenstein, 1930); most consistent dissociation pressure measurements by Marc and Simek (1913); (1 atm CO_2), 404°C. (Kelley and Anderson, 1935.) High temperature and pressure equilibrium studied up to 40,000 psi (2750 bars), about 900°C by Harker and Tuttle (1955).
$MgCO_3 \cdot 3H_2O$	Nesquehonite, prepared by treating $MgCl_2$ solution at 14°C with K_2CO_3 solution. Loses $1H_2O$ over H_2SO_4 at room temperature; dried at 100°C, 150°C, 200°C with increasing loss of H_2O and some CO_2. (Menzel, Bruckner, Schultz, 1930.)
$MgNa_2(CO_3)_2$	Melting point at 124 atm CO_2, 677°C. (Eitel and Skaliks, 1929.)
$MnCO_3$	Rhodochrosite,dissociates 1 atm CO_2, 369°C. (Krustinsons, 1932, 1933.) Dissociation curve to high pressure CO_2 from 375° to 575°C is given by $\log P(\text{bars}) = \frac{5740}{T(°K)} + 8.852$, and from 575° to 775°C by

$$\log P(\text{bars}) = \frac{-10,320}{T(^\circ K)} - 11.910 \log T(^\circ K) + 49.127.$$

The calculated heat of dissociation is 26.0±0.4 kcal per mol. (Goldsmith and Graf, 1957.)

Na_2CO_3	Melting point 851°C; transition points 361°C, 489°C; vapor pressure of liquid 0.085 atmosphere, 1400°C. (Howarth and Turner, 1930.)
Na_2CO_3-Na_2S	Eutectic 38 percent Na_2S, 756°C. (Tammann and Oelsen, 1930.)
$PbCO_3$	Cerrusite, dissociates to basic carbonates. (Centnerszwer, Falk and Awerbach, 1925; Bružs, 1926; Colson, 1905, 1909.) 1 atm CO_2, 293°C. Kelley and Anderson, 1935; Peretti, 1957.)
$2PbCO_3 \cdot PbO \cdot H_2O$	Hydrocerrusite, decomposes below 400°C.
$SrCO_3$	Strontianite, melting point (60 atm CO_2), 1497°C; dissociate, 0.152 atm CO_2, 1091°C; transition rhombic to trigonal, 925°C. (Dutoit, 1927; Lander, 1951a; Rossini and others, 1952.)
$ZnCO_3$	Smithsonite, sluggish dissociation (1 atm CO_2), varies from 300° to 400°C. (Centnerszwer, 1930; Friedrich, 1911.)
	$P(CO_2)$-T curve passes through 689 bars at 310°C, 2067 bars at 410°C, and 3445 bars at 460°C. (Harker and Hutta, 1956.)

SYSTEM, MISCELLANEOUS

In this section are included references not elsewhere covered, for systems of oxides and other substances of interest in synthetic studies.

(a) Three oxides:

Al_2O_3-BeO-MgO	(Geller, Yavorsky, Steierman, and Creamer, 1946.)
Al_2O_3-BeO-ThO_2	- - - - - - - - - - - - - - do - - - - - - - - - - - - -
Al_2O_3-BeO-TiO_2	(Lang, Fillmore, and Maxwell, 1952.)
Al_2O_3-BeO-ZrO_2	(Geller, Yavorsky, Steierman, and Creamer, 1946.)
Al_2O_3-CaO-Cr_2O_3	(Vasenin, 1939.)
Al_2O_3-CaO-Fe_2O_3	(Hansen, Brownmiller, and Bogue, 1928; McMurdie, 1937; Swayze, 1946a, b.)
Al_2O_3-CaO-K_2O	Al_2O_3-$3CaO \cdot Al_2O_3$-$K_2O \cdot Al_2O_3$ (Brownmiller, 1935.)
Al_2O_3-CaO-P_2O_5	(Stone, Egan, and Lehr, 1956; St. Pierre, 1956.)
Al_2O_3-Cr_2O_3-MgO	(Wilde and Rees, 1943.)
Al_2O_3-FeO-MnO	(Hay, McIntosh, Rait, and White, 1937.)
Al_2O_3-MgO-ZrO_2	(Salldau and Zhirmova, 1945.)
BeO-CeO_2-ZrO_2	(Ruff, Ebert and Loerpabel, 1932; Lang, Roth, and Fillmore, 1954.)
BeO-Cr_2O_3-ZrO_2	(Lang, Roth, and Fillmore, 1954.)

(a) Three oxides Continued:

BeO-MgO-ThO_2	(Lang, Maxwell, and Geller, 1949.)
BeO-MgO-ZrO_2	- - - - - - - - - do - - - - - - - - -
BeO-TiO_2-ZrO_2	(Lang, Roth,and Fillmore, 1954.)
Bi_2O_3-MoO_3-PbO	(Zambonini, 1920.)
Bi_2O_3-PbO-WO_3	- - - - do - - - - -
CaO-Cr_2O_3-MgO	(Ford and Rees, 1949.)
CaO-Fe-Fe_2O_3	(Martin and Vogel, 1932; White, 1943.)
CaO-FeO-Fe_2O_3	(Krings and Shackmann, 1935;White, 1938; Gurry and Darken, 1950.)
CaO-Fe_2O_3-Fe_3O_4	(Burdese and Brisi, 1952.)
CaO-MgO-SnO_2	(Coughanour and others, 1955.)
CaO-MgO-TiO_2	- - - - - - - - do - - - - - - - -
CaO-ThO_2-Z_2O_2	(Ruff, Ebert, and Loerpabel, 1932.)
Cr_2O_3-MoO_3-PbO	(Jaeger and Germs, 1921.)
Cr_2O_3-PbO-WO_3	- - - - - - do - - - - - - -
FeO-Fe_2O_3-MgO	(Roberts and Merwin, 1931.)
FeO-Fe_2O_3-Mn_xO_y	(Gurry and Darken, 1950.)
FeO-MnO-TiO_2	(Grieve and White, 1940.)
MgO-SnO_2-TiO_2	(Coughanour and others, 1955.)
MgO-ThO_2-ZrO_2	(Ruff, Ebert, and Loerpabel, 1932.)
PbO-TiO_2-V_2O_5	(Belyayev and Nesterova,1952.)

(b) Four or more oxides:

Al_2O_3-CaO-Fe_2O_3-K_2O	(Taylor, 1938.)
Al_2O_3-CaO-Fe_2O_3-Na_2O	(Eubank and Bogue, 1948.)
Al_2O_3-CaO-Fe_2O_3-MgO	(Rait, 1949.)
BaO-Na_2O-Nb_2O_3-TiO_2	(Roy, Rustum, and others, 1953.)
CaO-MgO-SnO_2-TiO_2	(Coughanour and others, 1955.)

(c) Phosphates:

P_2O_5	(Hill, Faust, and Hendricks, 1943.)
CaO-P_2O_5	(Trömel, 1943; Hill, Faust,and Reynolds,1944.)
CaO-FeO-P_2O_5	(Oelsen and Maetz, 1941.)
CaO-Na_2O-P_2O_5	CaP_2O_6-$Na_2P_2O_6$. (Morey, 1952.)
Fe_2O_3-P_2O_5	(Wentrup, 1936.)
K_2O-Li_2O-P_2O_5	KPO_3-$LiPO_3$(Bergmann and Sholokovich, 1953.)
K_2O-P_2O_5-SO_3	K_2SO_4-$K_2P_2O_6$. (Bergmann and Sholokovich, 1953.)

(c) Phosphates Continued:

Li_2O-P_2O_5-SO_3	$Li_2P_2O_6$-Li_2SO_4. (Bergmann and Sholokhovich, 1953.)
Na_2O-P_2O_5	(Turkdogan and Maddocks, 1952; Morey and Ingerson, 1944.)
Al_2O_3-CaO-Na_2O-P_2O_5-SiO_2	(Melent'ev and Ol'shanskiy, 1952.)

(d) Sulfates:

CuO-K_2O-Na_2O-SO_3	(Bellanca and Carapezza, 1951.)
K_2SO_4-$CaSO_4$	- - - - - - - - do - - - - - - - -
K_2SO_4-Li_2SO_4	(Nacken, 1907.)
K_2O-PbO-SO_3-WO_3	(Belyayev and Nesterova, 1952.)
Li_2SO_4-$MgSO_4$	(Rea, 1938.)
Li_2SO_4-Na_2SO_4	(Nacken, 1907.)
Na_2SO_4-$CuSO_4$	(Bellanca and Carapezza, 1951.)
Na_2O-PbO-SO_3-WO_3	(Belyayev, 1952.)
PbO-$PbSO_4$	(Jaeger and Germs, 1921.)
$PbSO_4$-$PbCrO_4$	- - - - - - - do - - - - - -
$PbSO_4$-$PbMoO_4$	- - - - - - - do - - - - - -
$PbSO_4$-$PbWO_4$	- - - - - - - do - - - - - -

(e) Fluorides of interest for model systems:

BeF_2-NaF	(Thilo and Schröder, 1951; Roy, D.M., and others, 1953.)
BeF_2-PbF_2	(Roy, D. M., and others, 1954.)
KF-MgF_2	(DeVries and Roy, 1953.)
KF-ThF_4	(Asker and others, 1952.)
LiF-MgF_2	(Bergmann and Dergunov, 1941; Counts and others, 1953.)

(f) Oxides, halides:

Al_2O_3-CaF_2	(Pascal, 1913.)
Al_2O_3-CaF_2-CaO	(Eitel, 1938a, b.)
Al_2O_3-CaF_2-Na_3AlF_6	(Pascal, 1913.)
Al_2O_3-Na_3AlF_6	(Pascal, 1913; Drossbach, 1936.)
CaF_2-CaO	(Eitel, 1938b.)
CaF_2-CaO-Ca_2SiO_4	- - - - do - - - -
$CaCO_3$-Na_2CO_3-Na_2Cl_2	(Niggli, 1916.)

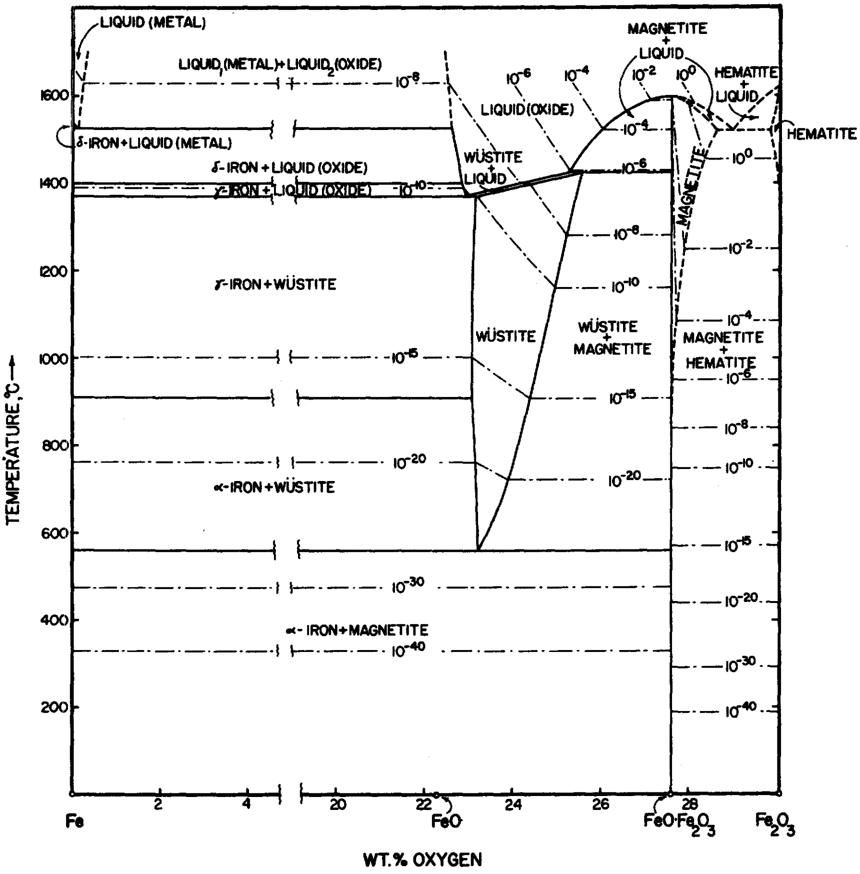

Figure 1.— The system: Fe-O. From Muan (1958d), reprinted by permission of the American Journal of Science;data are mainly from Darken and Gurry (1945, 1946). Solid lines are boundary curves separating phase areas labelled in the diagram; dash-dot curves are oxygen isobars in atmospheres. Boundary curves in the upper part of the figure are dashed where experimental data are lacking; in the upper right corner, dashed curves are inferred for oxygen pressures greater than 1 atmosphere.

3.11 " 16
Fig 2

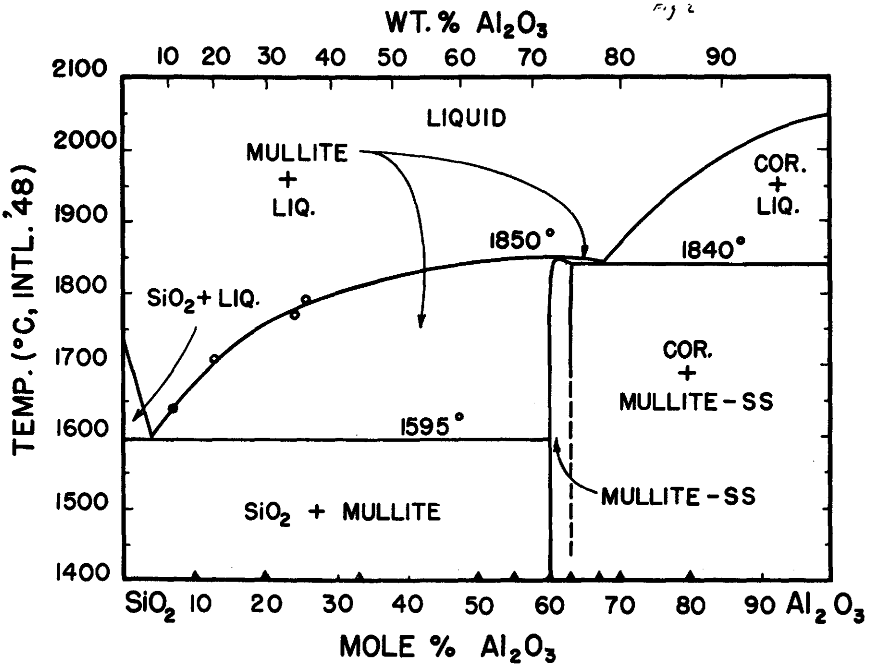

Figure 2.— The system: SiO_2-Al_2O_3. From Shigeo Aramaki and Rustum Roy (written communication, 1959), showing the incongruent melting of mullite.

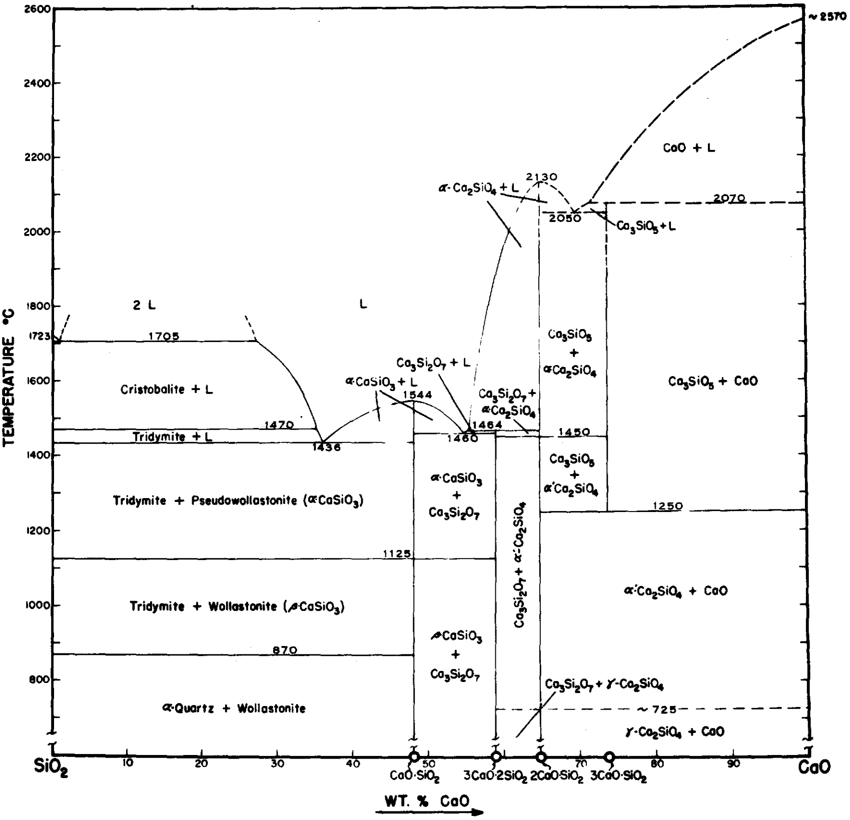

Figure 3.— The system: SiO_2-CaO. From Phillips and Muan (1958) reprinted by permission of the American Ceramic Society. Composite diagram based on Rankin and Wright (1915), Greig (1927a), Glasser and Osborn (1958), D. M. Roy (1958), and Welch and Gutt (1959).

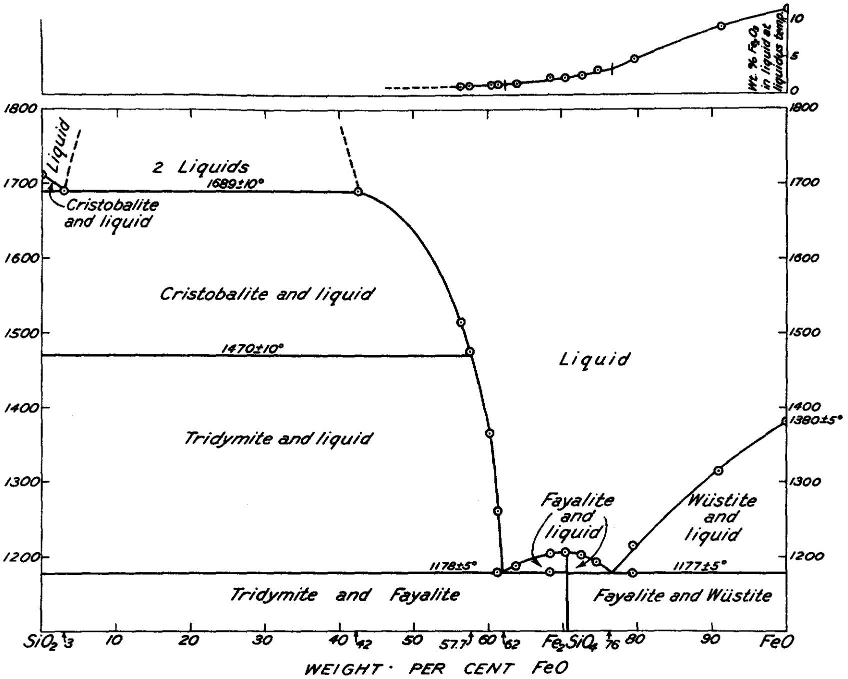

Figure 4.— The system: SiO_2-FeO. From Bowen and Schairer (1932); reprinted by permission of the American Journal of Science. The system is binary only when small amounts of Fe_2O_3 in the liquids are disregarded.

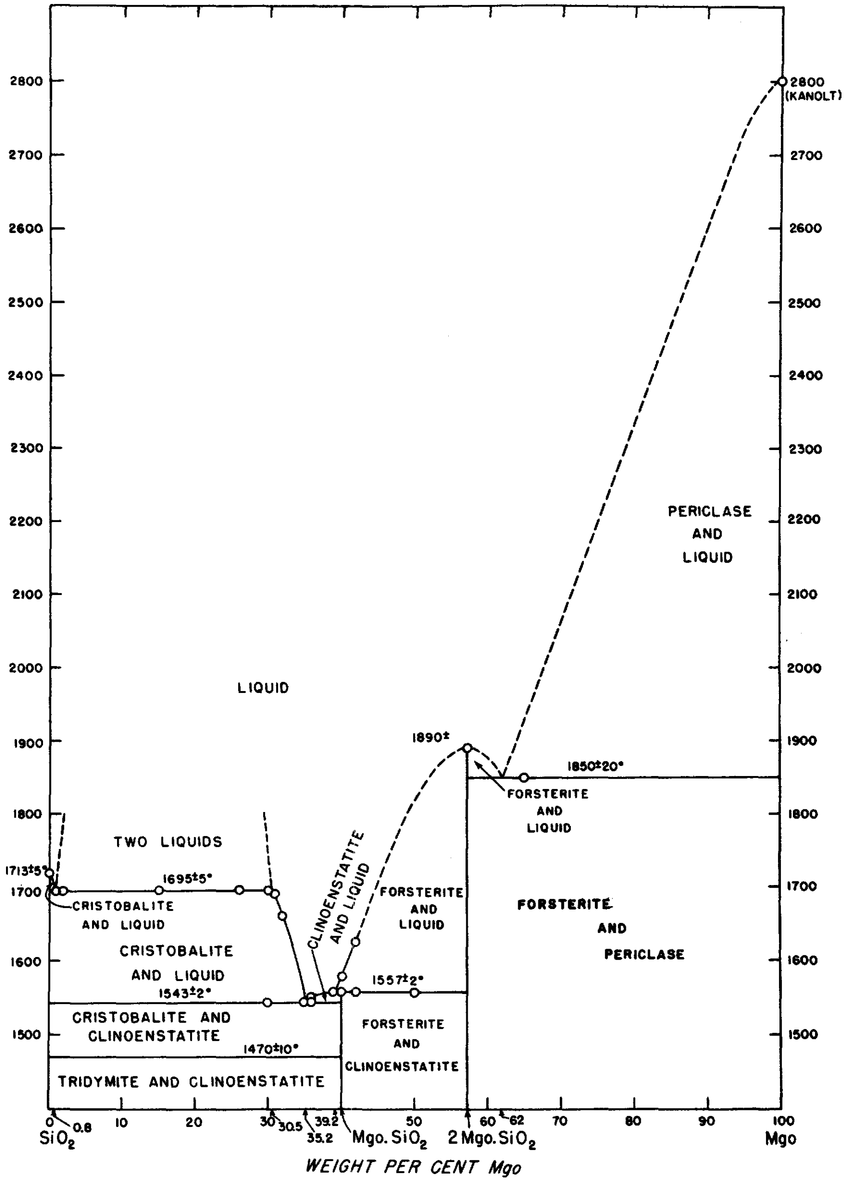

Figure 5.— The system: SiO_2-MgO. From J. W. Greig (written communication, 1958); based on Bowen and Andersen (1914) and Greig (1927a).

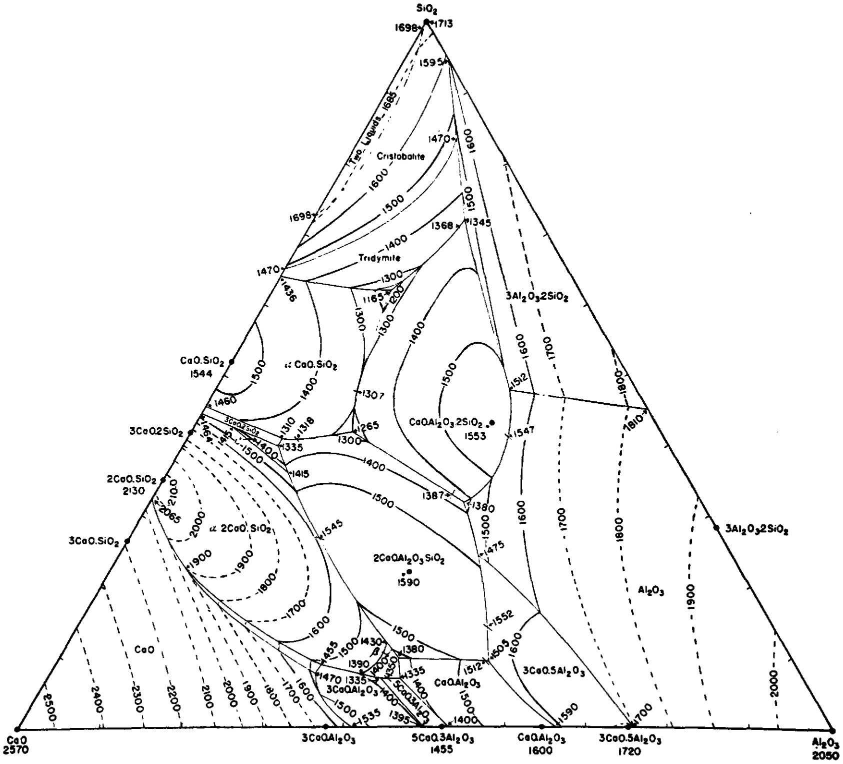

Figure 6.— The system: $CaO-Al_2O_3-SiO_2$. From Greig (1927a) with data from Rankin and Wright (1915). Goldsmith (1948) suggested that the compound designated 3 CaO• 5 Al_2O_3 is probably CaO• 2 Al_2O_3.

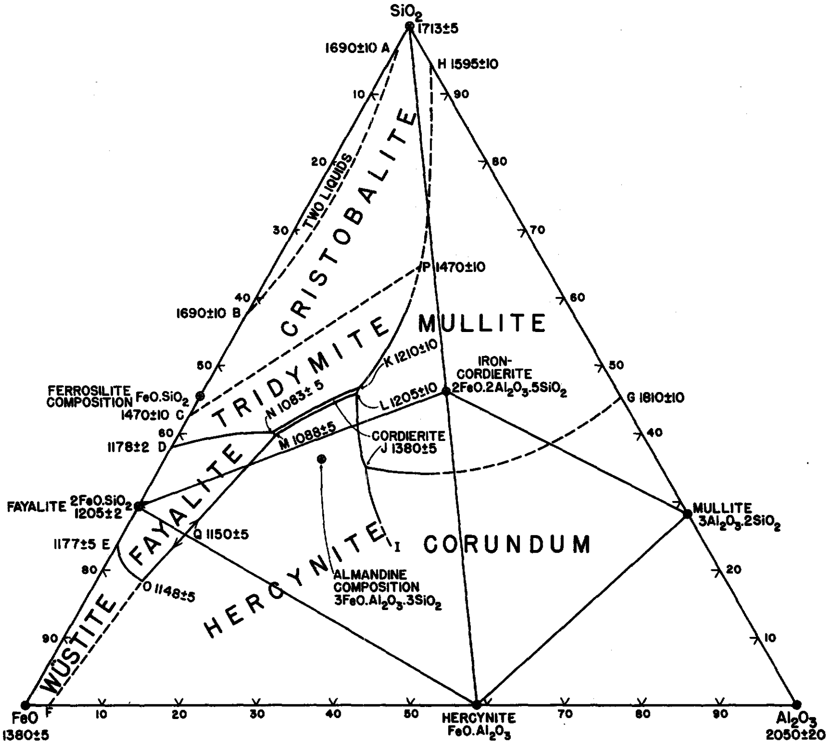

Figure 7.— The system: FeO-Al_2O_3. From Schairer and Yagi (1952); reprinted by permission of the American Journal of Science. The system is ternary only when a small content of Fe_2O_3 in the liquids is disregarded.

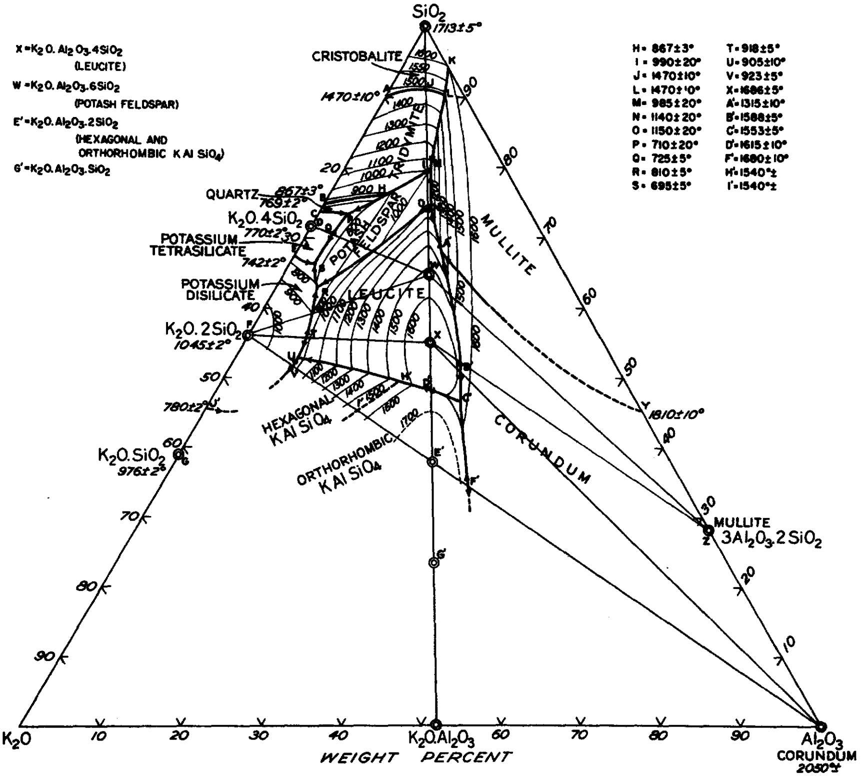

Figure 8.— The system: $K_2O-Al_2O_3-SiO_2$. From Schairer and Bowen (1955); reprinted by permission of the American Journal of Science.

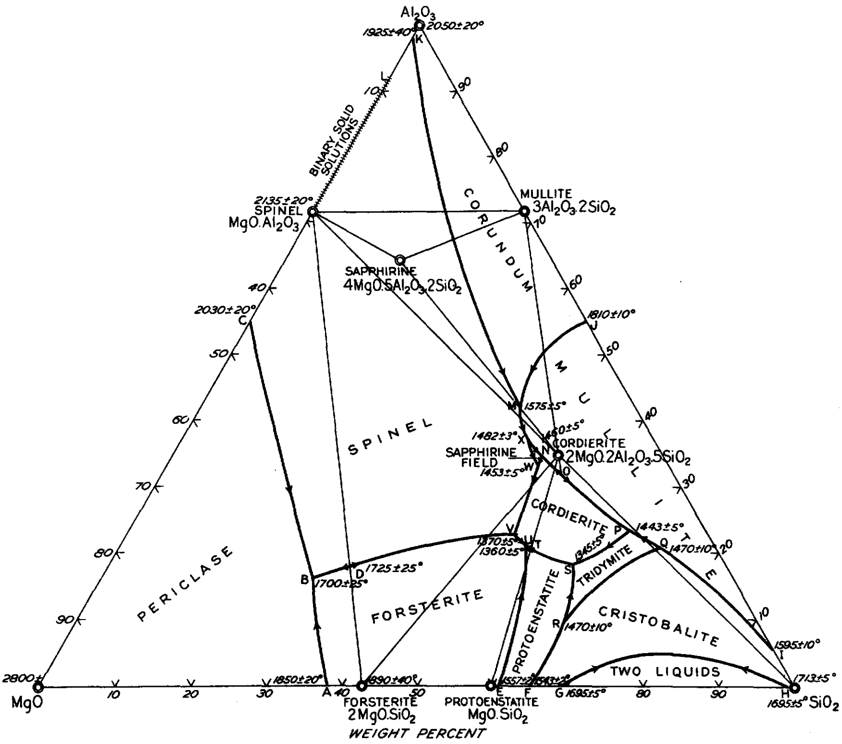

Figure 9.– The system: MgO-Al_2O_3-SiO_2. From Keith and Schairer (1952); reprinted by permission of the Journal of Geology; copyright, 1952, by the University of Chicago. Composite diagram based on Rankin and Merwin (1918), Bowen and Greig (1924), Greig (1927a), Schairer (1942), and Foster (1950).

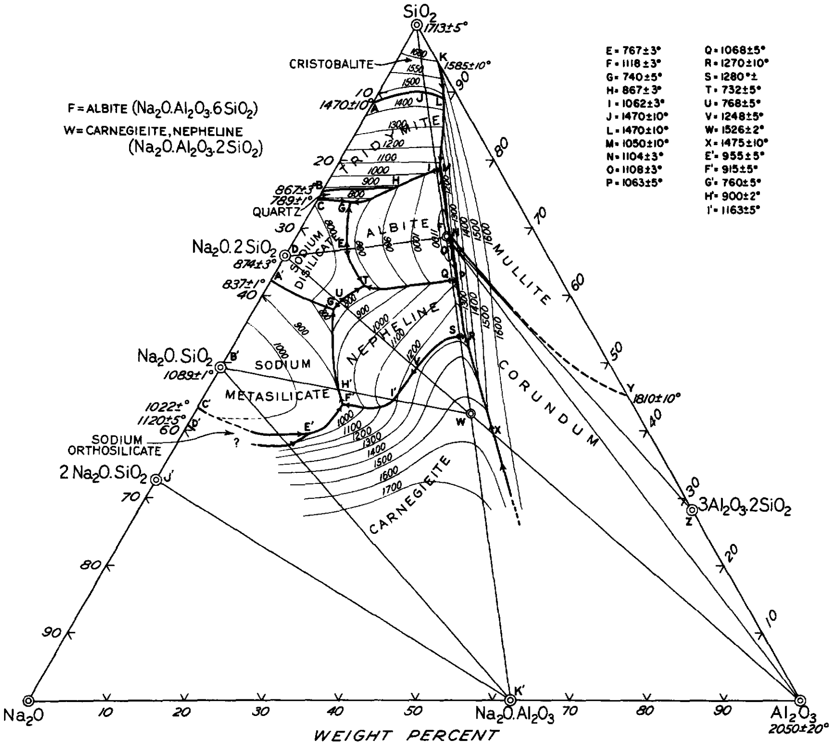

Figure 10.— The system: Na_2O-Al_2O_3-SiO_2. From Schairer and Bowen (1956); reprinted by permission of the American Journal of Science.

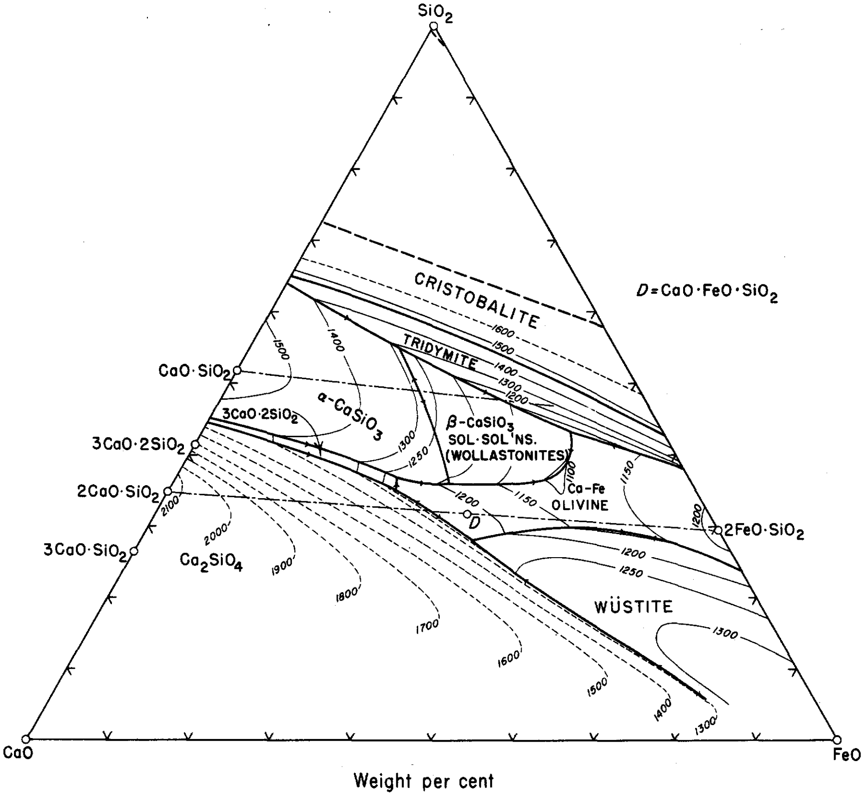

Figure 11.— The system: $CaO-FeO-SiO_2$. From S. P. Clark, Jr. (written communication, 1962), modified from Bowen, Schairer and Posnjak (1933). Estimated field boundaries are shown by broken lines. The system is ternary only if a small content of Fe_2O_3 in the liquids are disregarded.

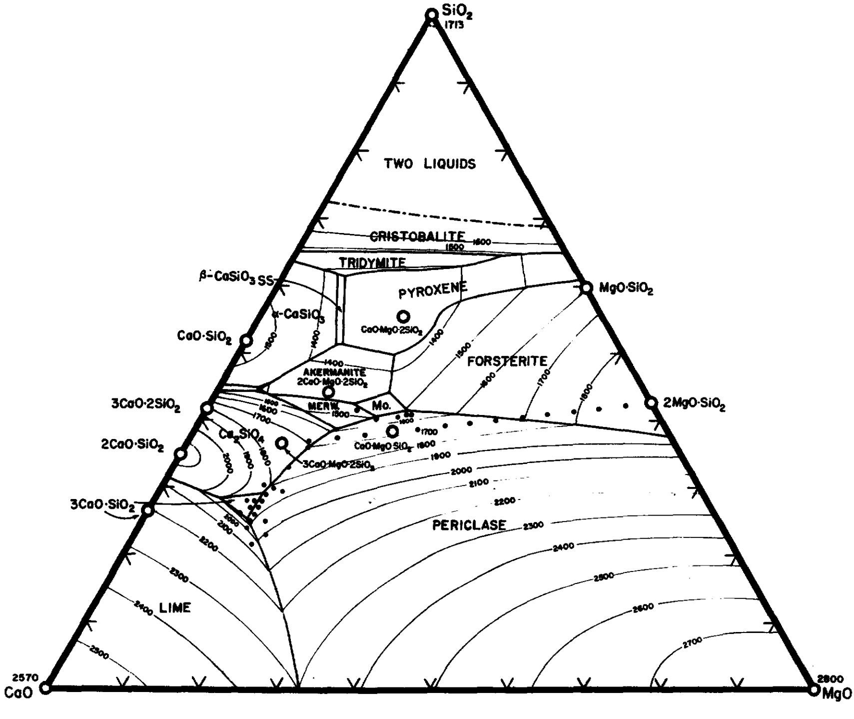

Figure 12.— The system: CaO-MgO-SiO2. From Ricker and Osborn (1954); reprinted by permission of the American Ceramic Society. Composite diagram based on Ferguson and Merwin (1919), Greig (1927a), Bowen (1914), Osborn (1942), and Bredig (1950).

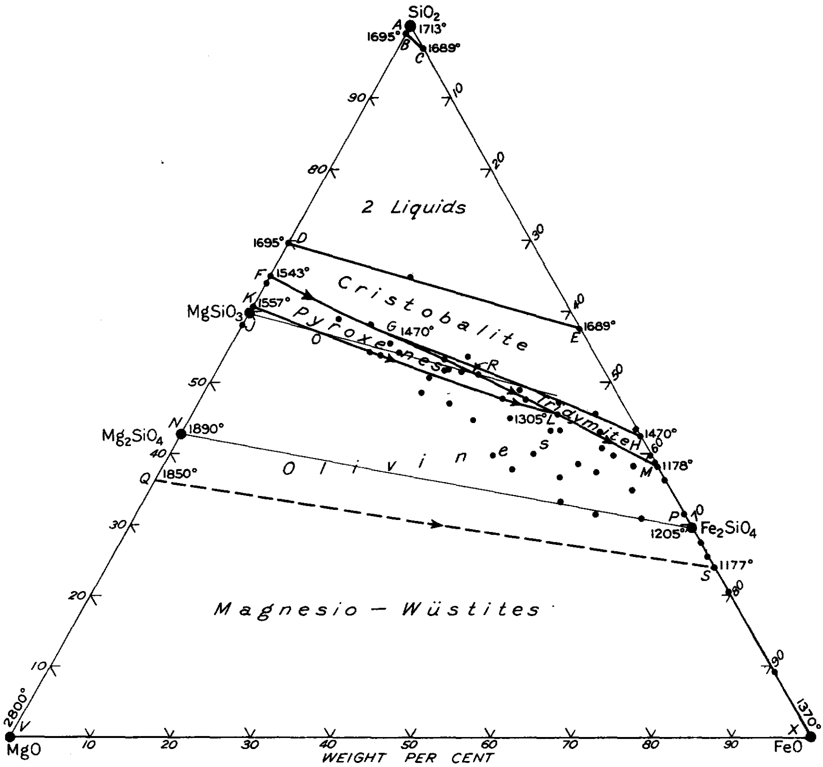

Figure 13.— The system: MgO-FeO-SiO_2. From Bowen and Schairer (1935); reprinted by permission of the American Journal of Science. The system is ternary only if a small content of Fe_2O_3 in the liquids is disregarded.

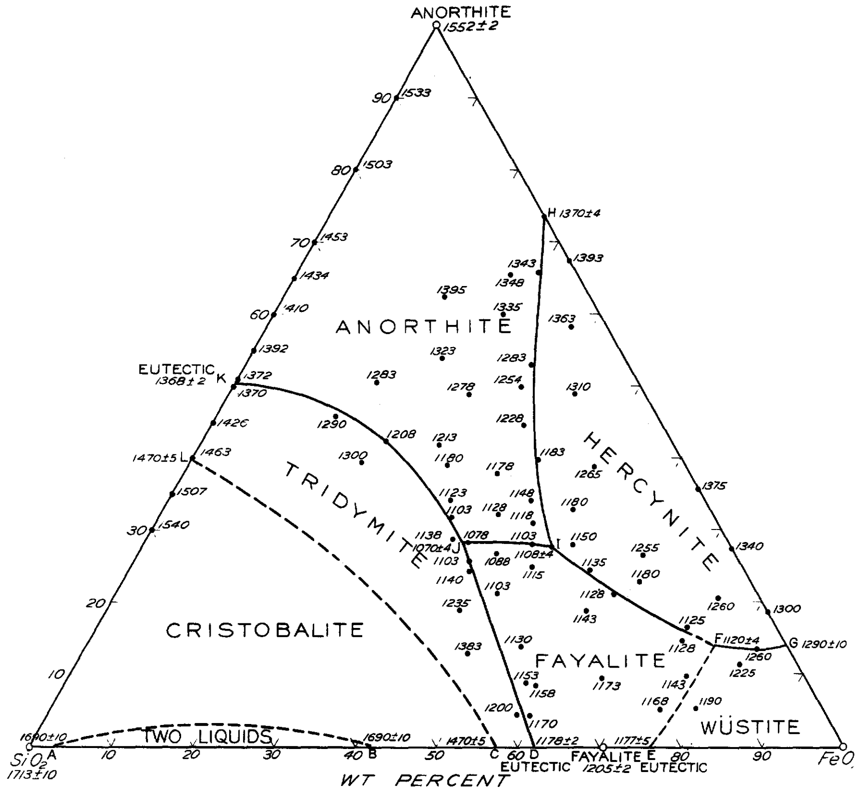

Figure 14.— The system: Al_2O_3-CaO-FeO-SiO_2; the join plane: SiO_2-FeO-$CaAl_2Si_2O_8$, Anorthite. From Schairer (1942); reprinted by permission of the American Ceramic Society. The join is not ternary in the field of hercynite, $FeAl_2O_4$.

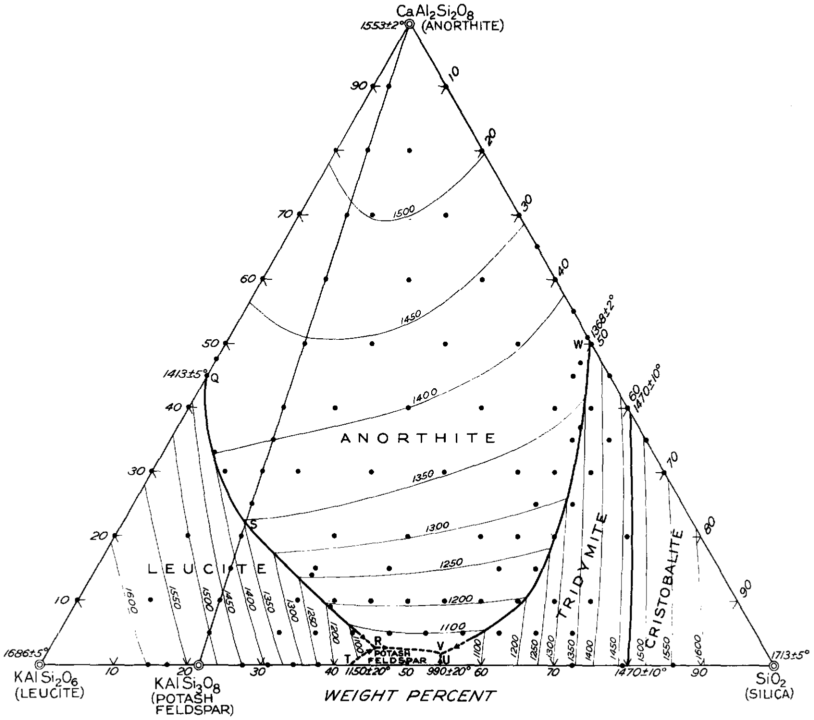

Figure 15.– The system: Al_2O_3-CaO-K_2O-SiO_2; the ternary section: $KAlSi_2O_6$, Leucite-SiO_2-$CaAl_2Si_2O_8$, Anorthite. From Schairer and Bowen (1947a); reprinted by permission of Commission Géologie de Finlande.

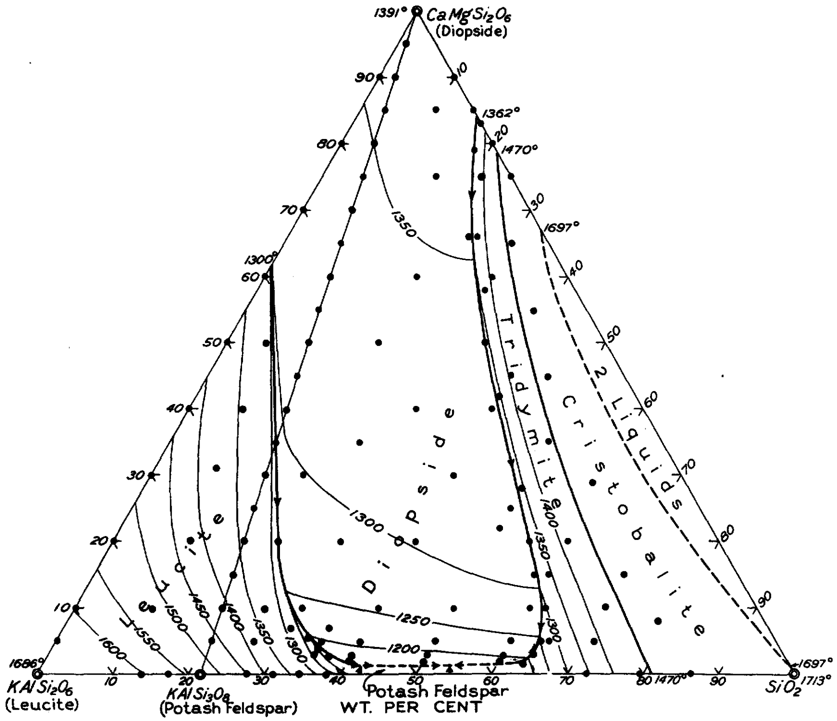

Figure 16.— The system: Al_2O_3-CaO-K_2O-MgO-SiO_2; the ternary section; $KAlSi_2O_6$, Leucite-SiO_2-$CaMgSi_2O_6$, Diopside. From Schairer and Bowen (1938); reprinted by permission of the American Journal of Science.

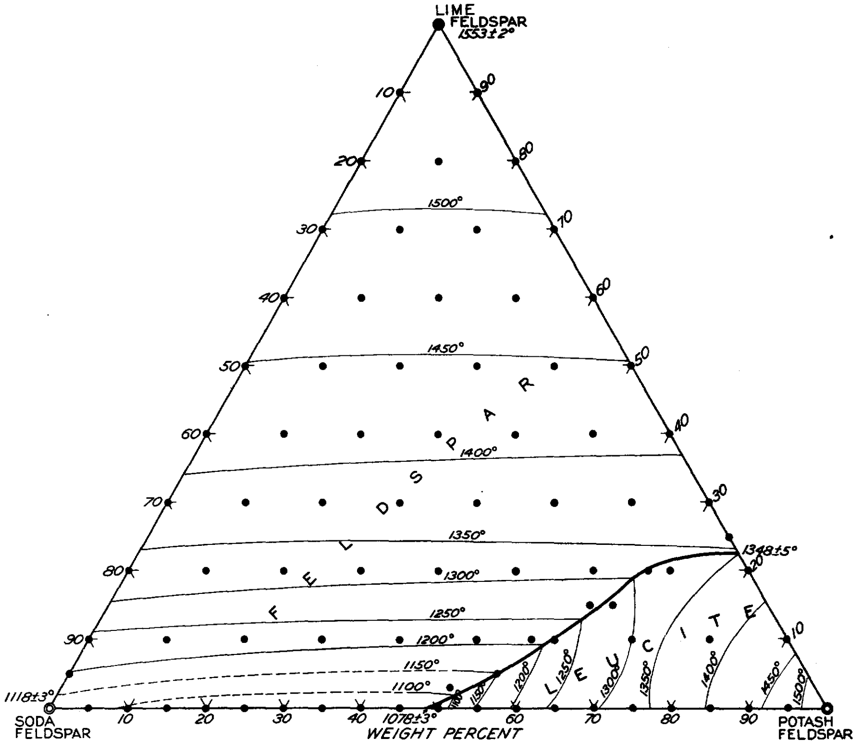

Figure 17.– The system: Al_2O_3-CaO-K_2O-Na_2O-SiO_2: the ternary section: $NaAlSi_3O_8$, Soda feldspar-$KAlSi_3O_8$, Potash feldspar-$CaAl_2Si_2O_8$, Lime feldspar. From Franco and Schairer (1951); reprinted by permission of the Journal of Geology; copyright, 1951, by the University of Chicago.

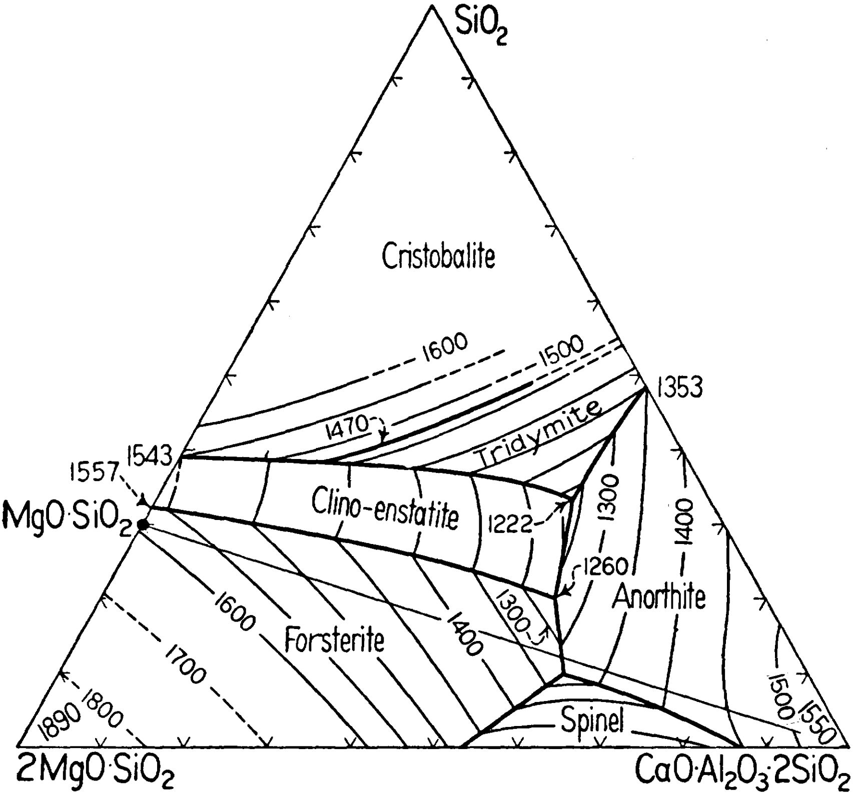

Figure 18.— The system: Al_2O_3-CaO-MgO-SiO_2: the join plane: Mg_2SiO_4, Forsterite-SiO_2-$CaAl_2Si_2O_8$, Anorthite. From Andersen (1915); reprinted by permission of the American Journal of Science. The join fails to be ternary in the field of spinel, $MgAl_2O_4$.

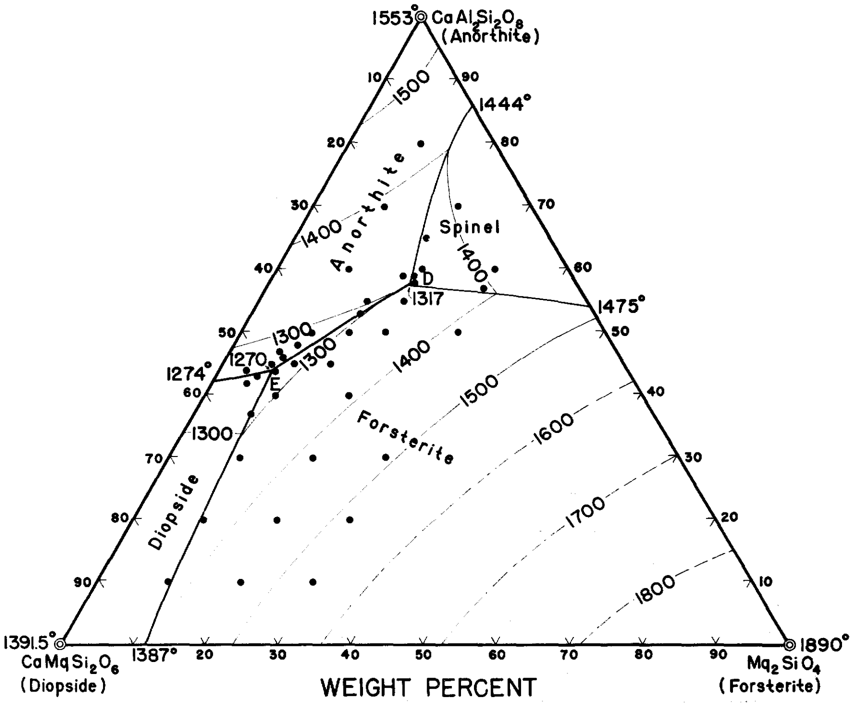

Figure 19.— The system: Al_2O_3-CaO-MgO-SiO_2: the ternary section: $CaMgSi_2O_6$, Diopside-Mg_2SiO_4, Forsterite-$CaAl_2Si_2O_8$, Anorthite. From Osborn and Tait (1952); reprinted by permission of the American Journal of Science.

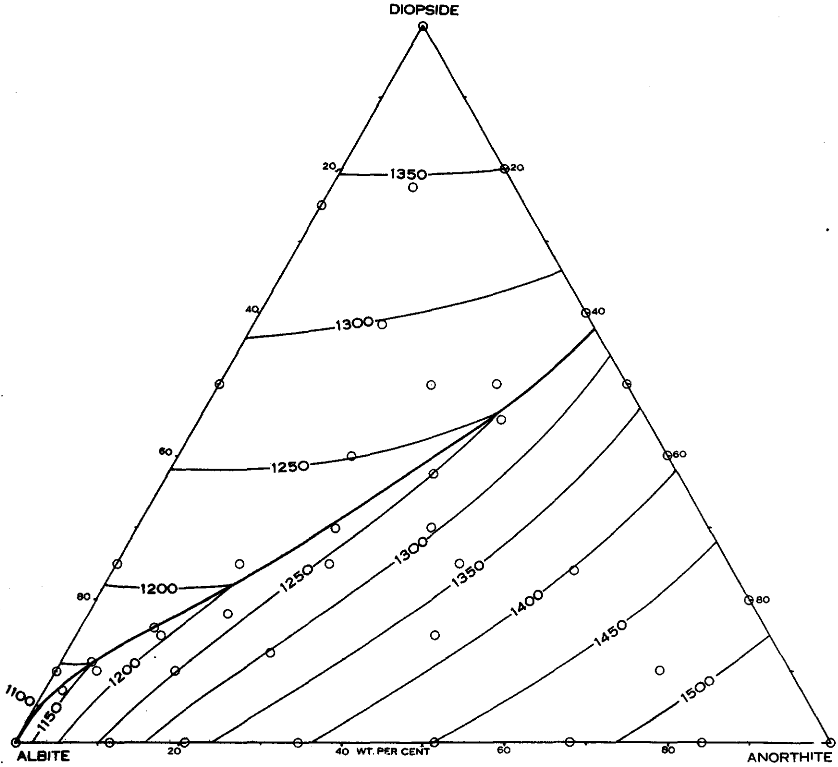

Figure 20.— The system: Al_2O_3-CaO-MgO-Na_2O-SiO_2; the ternary section: $NaAlSi_3O_8$, Albite-$CaAl_2Si_2O_8$, Anorthite-$CaMgSi_2O_6$, Diopside. From Bowen (1915); reprinted by permission of the American Journal of Science.

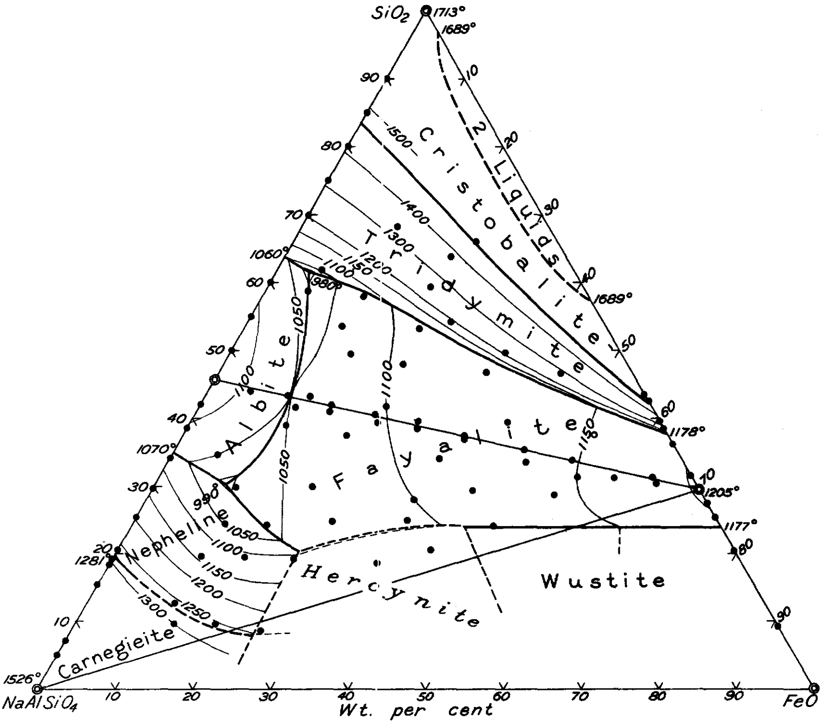

Figure 21.— The system: Al_2O_3-FeO-Na_2O-SiO_2: the join plane: $NaAlSiO_4$, Nepheline, Carnegieite-FeO-SiO_2. From Bowen (1937); reprinted by permission of the American Journal of Science. The join is not ternary in the field of hercynite, $FeAl_2O_4$.

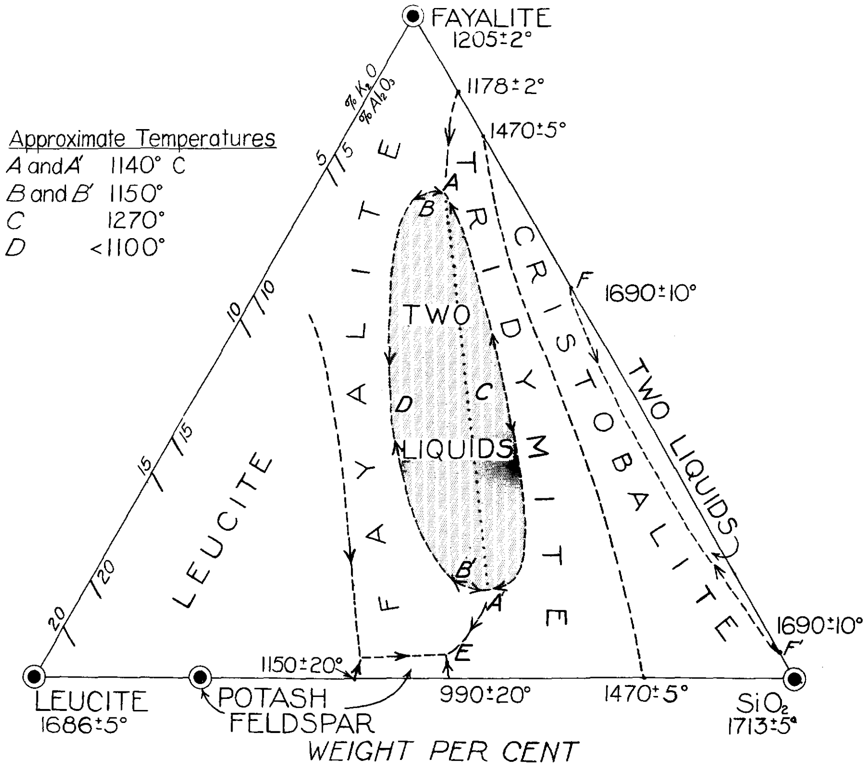

Figure 22.— The system: Al_2O_3-FeO-K_2O-SiO_2: the ternary section: $KAlSi_2O_6$, Leucite-SiO_2-Fe_2SiO_4, Fayalite. From Roedder (1951a); reprinted by permission of the Mineralogical Society of America. The section is ternary only when small contents of Fe_2O_3 in the liquids are disregarded.

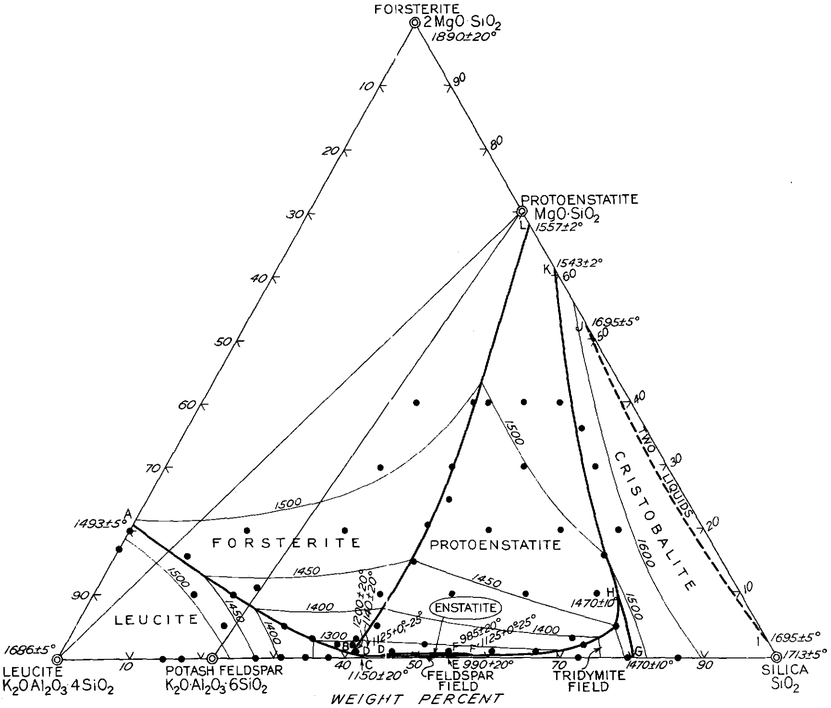

Figure 23.— The system: Al_2O_3-K_2O-MgO-SiO_2: the ternary section: $KAlSi_2O_6$, Leucite-SiO_2-Mg_2SiO_4, Forsterite. From Schairer (1954); reprinted by permission of the American Ceramic Society. The fields of $MgSiO_3$, Enstatite, and of $KAlSi_3O_8$, Potash Feldspar, are so narrow they could not be shown in the diagram without some exaggeration.

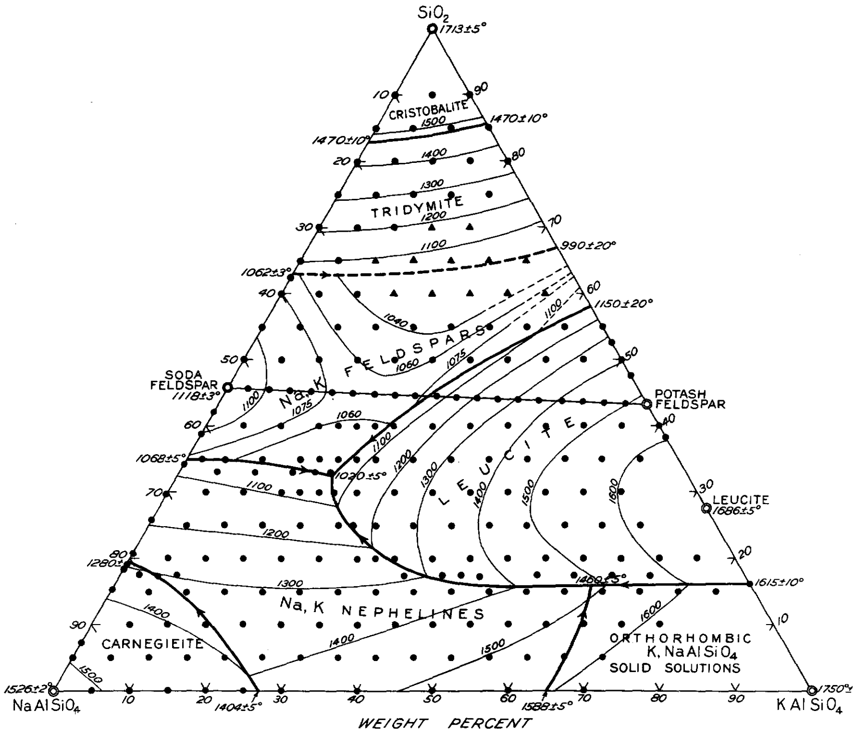

Figure 24.— The system: Al_2O_3-K_2O-Na_2O-SiO_2: the ternary section: $NaAlSiO_4$, Nepheline, Carnegieite-$KAlSiO_4$, Kalsilite, Kaliophillite-SiO_2. From Schairer (1950); reprinted by permission of the Journal of Geology; copyright, 1950, by the University of Chicago.

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