CRYSTALLIZATION OF ANGRITES, CAIs and Ca-Al CHONDRULES: FASSAITE-SPINEL LIQUIDI IN CMAST. Allan H. Treiman, Geology, Boston University, Boston MA 02215

Once-molten objects containing fassaite pyroxene (Al-Ti augite) and spinel are common among early solar system materials: angrite achondrites [1], CAIs and relations [2,3], and Ca-Al chondrules [4]. Experiments on the liquidus in CaO-MgO-Al_2O_3-SiO_2+-TiO_2 (CMAS+-T) confirm recent studies of CMAS and show that: TiO_2 causes the fassaite-spinel liquidus field to enlarge so as to make the fas-sp-ol-plag-liq invariant point a eutectic; TiO_2can enter fassaite as $MgTiAl_2O_6$ component; and TiO_2 can be nearly compatible in fassaite.

Experiments are 1-bar crystallizations from melt: glass beads were remelted at 1350°C, cooled at 20°C/hr, and held at T for 1-3 days. Temperatures are referenced to an NBS-traceable S-type thermocouple. Chemical analyses are by EMP-WDS.

Experiments here confirm recent studies in CMAS [5,6] as shown in the figure, a portion of the spinel-saturated liquidus in SPinel-FOrsterite- ANorthite-GEhlenite projection [7]. Invariant points Q (liq+ol+plag=sp+fas), S (liq+ol=sp+fas+mel) and R (liq=sp+fas+mel+plag) are found at similar T and compositions (Table) to [5,6]. Pyroxene compositions project on the Di-CaTs join, with minimal enstatite or Ca-eskola's ($Ca_{0.5}MgAlSiO_6$) components.

Experiments in progress have outlined the effects of TiO_2 .on the fassaite-spinel liquidus. Ti substitution in plagioclase and spinel is insignificant. Pyroxenes here contain 1-2.5% TiO_2 and (ignoring Ti) project on the sp-Di-CaTs join [7]. This suggests that Ti is held as $MgTiAl_2O_6$ component (=sp+TiO_2), and not $CaTiAl_2O_6$. The near-equilibrium pyroxenes of [8] also can contain significant $MgTiAl_2O_6$.

Compared to CMAS, the fas+sp liquidus field in CMAST is enlarged and its centroid shifted to lower AN content. For melts with ¿2.5% TiO_2, point Q is a quaternary eutectic, poorer in GE component than the Di-CaTs-SP join (up and right in the Figure). $D^{Ti}_{fas/liq}$ is 0.7-1.0, greater than in basaltic systems.

The effects of TiO_2 on phase relations may be explained by formation of M^{2+}-Ti^{4+} oxide complexes (M=Ca,Mg) in silicate melts [9]. Formation of these complexes draws non-bonding oxygens from the melt's aluminosilicate tetrahedra, inducing them to polymerize. Thus, polymerized solids (plag, pyroxene) are stabilized, and their liquidus fields enlarge. Clustering of Mg and Ti in the melt may favor the $MgTiAl_2O_6$ component in fassaite.

Phase relationships in spinel-saturated CMAST liquids will vary according to melt and pyroxene compositions. Point Q will be eutectic (liq=sp+ol+plag+fas) for melts with more than ~2.5% TiO_2 (either original Ti content or enriched through fractional crystallization) or for systems with fassaite that is rich in $CaTiAl_2O_6$ component [e.g. 7]. If fassaite compositions or phase boundaries shift so that the fas-SP join approaches or crosses the fas-sp liquidus field (as in [7]), reaction and co-crystallization relations will shift rapidly and may yield complex textures.

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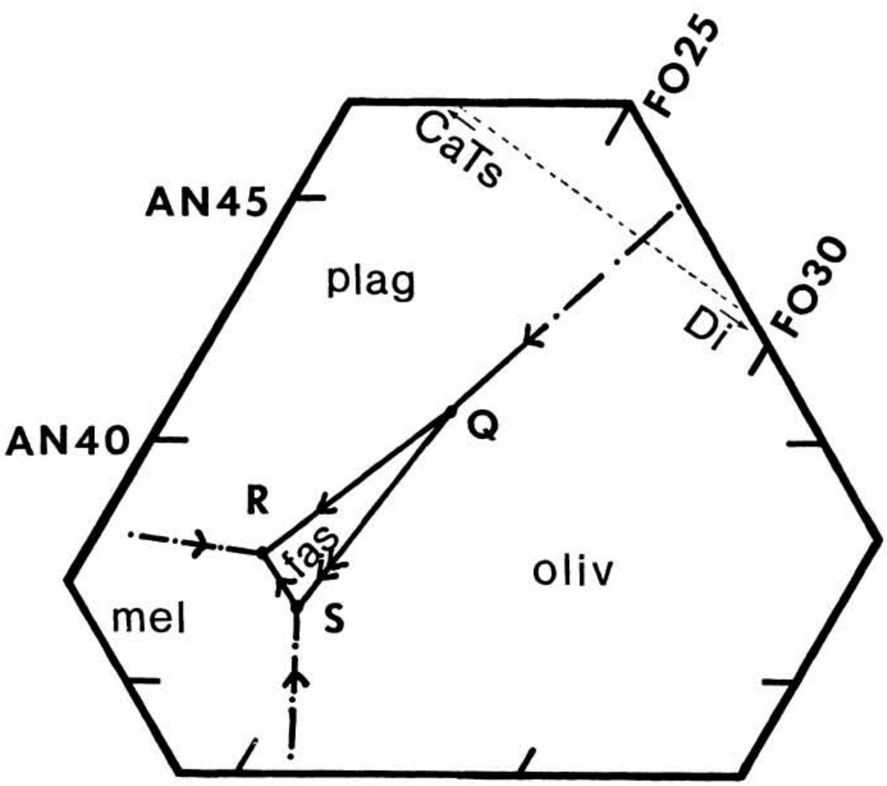
TABLE

Point	Q	S*	R
T(°C)	1244	1235	1233
SiO_2	42.91	42.69	42.73
Al_2O_3	17.60	17.72	18.90
MgO	11.18	10.57	10.05
CaO	26.56	28.70	28.91
Total	98.26	99.68	100.68

*approximate composition.

FIGURE: Invariant points and temperatures (°C) in on spinel-saturated liquidus surface in CMAS. Compositions calculated to ANorthite, GEhlenite, FOrsterite, and SPinel components [7], and projected from SPinel.



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