

12.109 Lecture Notes
October 13, 2005

Basalts

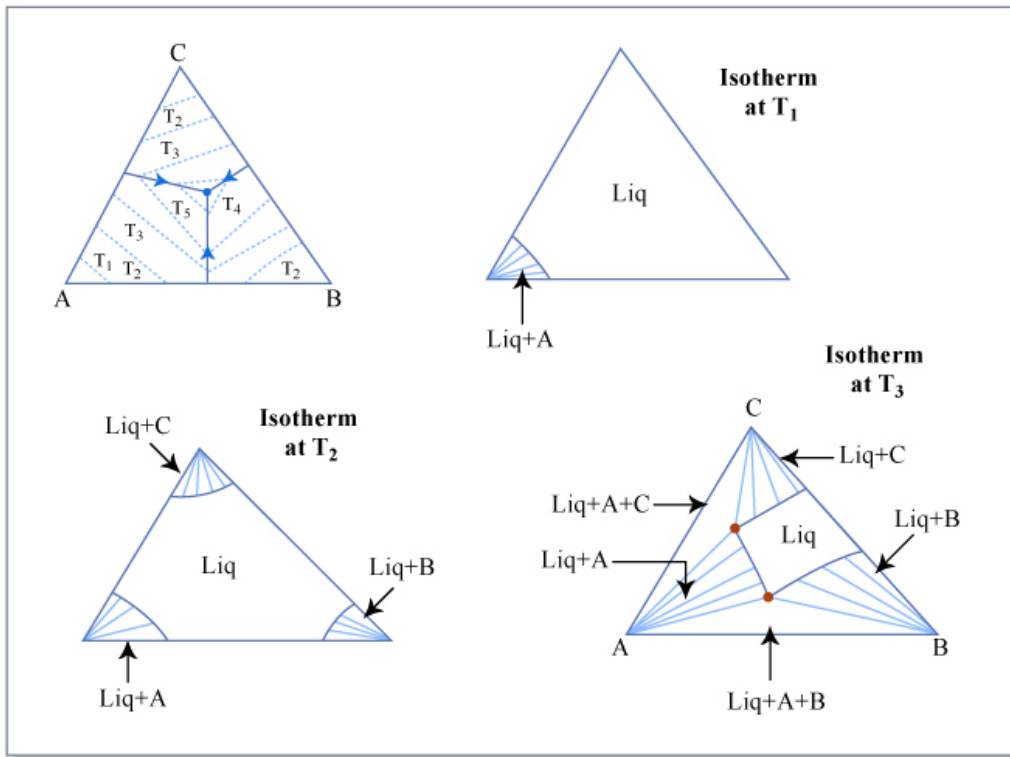
We first have to talk about ternary phase diagrams. These are an analog for the crystallization of basaltic melts. (see Hess ch. 7)

Ternary liquidus diagrams

These “hide” information about the subsolidus – only show liquidus data (liquid and coexisting crystals)

Analogous to topographical map with respect to temperature (contour lines are isotherms)

Example: 3 pure solids, A, B, C, eutectic behavior



Basalts can tell us about mantle melting conditions, i.e. temperature and pressure of melting. In a system of phases with a eutectic point, the eutectic composition records conditions of melt generation. It is a liquid in equilibrium with solids present in the residue at depth – liquid is multiply saturated with these phases at the conditions of melt generation.

The melting reaction doesn't just occur as a eutectic. For example, in the olivine-opx-qtz system, melting involves a reaction relation (peritectic).

In ternary phase diagrams, all crystalline phases are pure end members.

Primary phase volume – part of diagram where a single phase is the liquidus phases
Boundary curves or cotectics – where liquid is in equilibrium with 2 phases, arrows show direction of falling temperature

Ternary eutectic – 1 special liquid composition that coexists with all 3 solid phases, represents the lowest temperature on the diagram where liquid is stable

Temperature contours

For bulk composition X (where X is closest to A and closer to B than C), A is liquidus phase. A crystallizes out of liquid, liquid composition follows a path directly away from A. The liquid composition reaches the A + B boundary curve (cotectic) where A and B cocrystallize. The composition moves to the eutectic point as these two phases precipitate. At the eutectic composition, A, B, and C crystallize until all of the melt is used up.

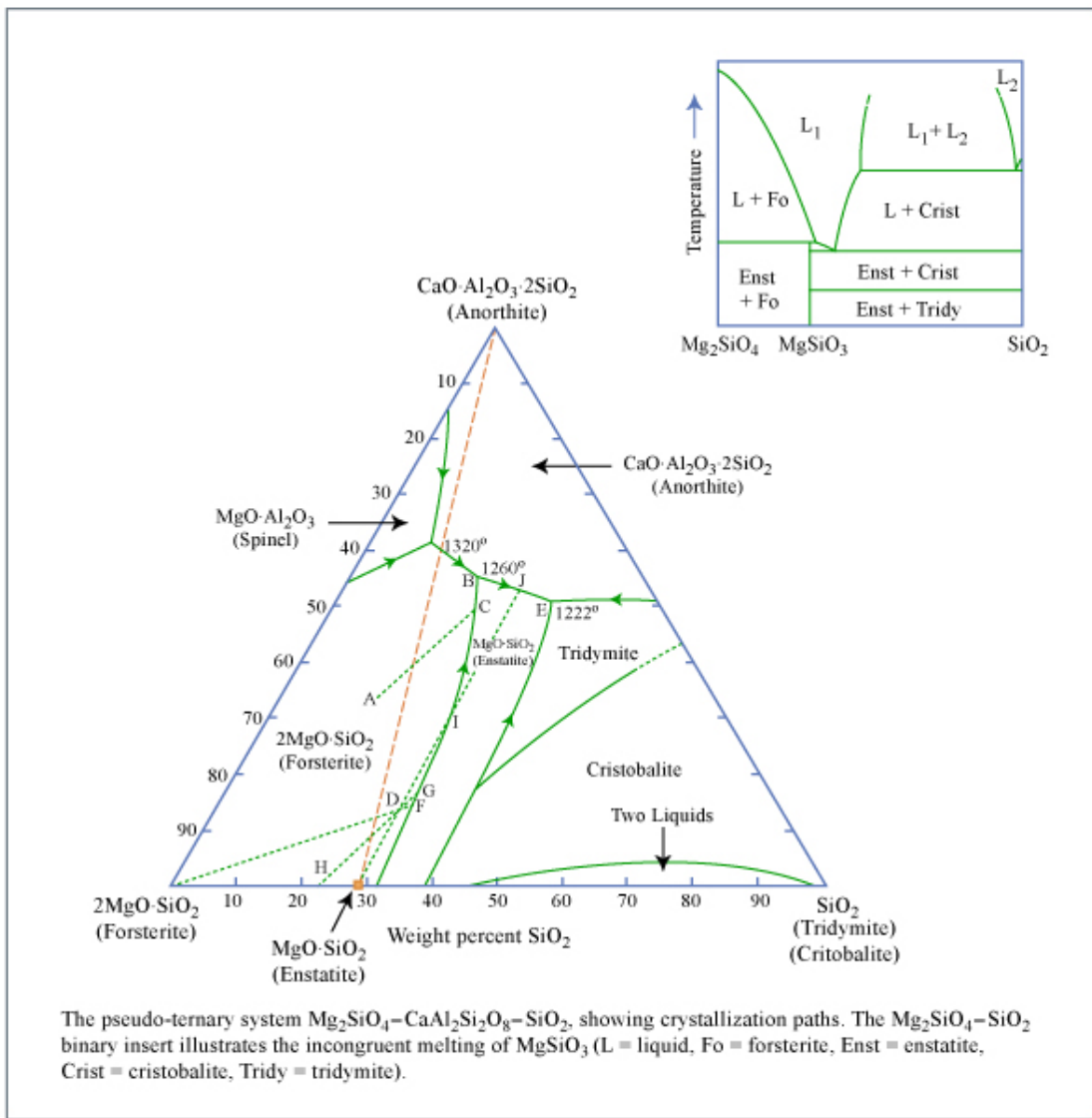
For every bulk composition on a diagram with a eutectic, the first melt (lowest T) has the composition of the eutectic.

Isothermal sections take a slice of the three dimensional ternary diagram for a single value of T. The challenge is to reconstruct information about the solids stable at this temperature.

Reaction boundaries – along these boundaries, one crystalline phase and the liquid react to form a second crystalline phase.

For example, $ol + l = opx$

This is the ternary equivalent of a reaction point or peritectic



Alkemade line – line between coexisting phases

When the liquid that coexists with three solids plots outside the compositional Alkemade triangle, the four phase point is a reaction point, NOT a eutectic point.

Reaction boundary

- 1) choose a point on the boundary
- 2) construct tangent line from pure phase point and project back to line between the two phases
- 3) if the tangent intersects outside of the line drawn between the two phases, it is a reaction boundary

reaction boundaries are depicted with double arrows facing lower T

from a point A in the Fo primary phase volume:

- 1) Fo is liquidus phase
- 2) Olivine crystallizes out, liquid composition moves away from A on an ol subtraction line
- 3) Liquid composition reaches Fo-En reaction boundary @ C
- 4) Fo and liquid react to form En, get Fo + En + l
- 5) @ B, Fo + l \rightarrow An + En
- 6) All l used up, left with Fo, An, En