Metamorphism of Siliceous Dolostone: An Example from the Alta Stock, Utah

Cameron Davidson and Bereket Haileab
Department of Geology, Carleton College
One North College Street, Northfield, Minnesota 55057

Introduction

This exercise is based on a suite of rocks from the contact metamorphic aureole of the Alta stock near Salt Lake City, Utah. The Alta stock is a Tertiary (~38 Ma) granodiorite that intruded Paleozoic dolostone containing sparse quartz and chert nodules (Cook and Bowman, 2000). Wonderful things happen when dolostone + quartz (chert) are intruded and heated up by crystallizing granites. The country rocks recrystallize in the solid state and new minerals grow at the expense of pre-existing minerals due to changes in temperature and fluid composition. By the end of this exercise you should be able to:

1. Identify mineral assemblages common to metamorphosed siliceous dolostones.
2. Determine appropriate chemical systems to describe and plot minerals.
3. Infer metamorphic reactions from progressive changes in mineral assemblages.
4. Identify metamorphic reactions responsible for producing isograds mapped in the field.
5. Understand how rock and fluid compositions control mineral assemblages.
6. Infer the temperature and fluid composition evolution of the Alta stock aureole based on T-X(CO_2)diagrams.

Specific skills you will practice in this exercise include:

1. Plotting mineral compositions on ternary diagrams.
2. Using the phase rule.
3. Using Schreinemaker's rules to construct a petrogenetic grid.

The Alta Stock Contact Aureole

The Alta stock contact aureole is well-developed in Paleozoic siliceous dolostones (Figs. 1&2). The photomicrographs shown in Figure 3 are taken from the different metamorphic zones defined by field isograds (Fig. 2). The isograds mark the first appearance of a given index mineral that defines the metamorphic zone. For example, as you walk north from the bottom of Figure 2, you pass over the talc (Tlc) isograd, which marks the first appearance of talc in these rocks.

Photomicrographs (plane and cross polarized light) from the different metamorphic zones are shown in Figure 3. Carefully examine the photomicrographs to get a feeling for the mineral assemblages and textures that define each zone.

I. Plotting Mineral Assemblages

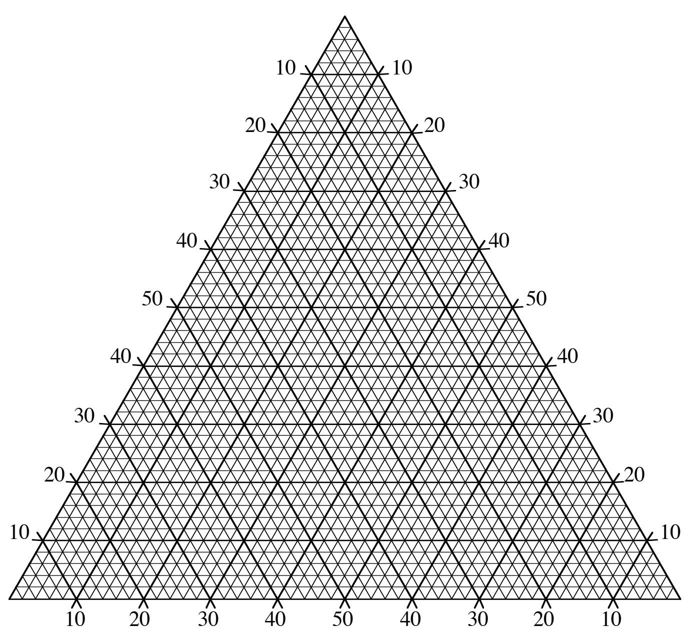
1. Fill in the table below by listing the minerals present in each metamorphic zone. Give the name of each mineral and its chemical composition in parentheses: e.g., Quartz (SiO_2).

Table 1. Metamorphic mineral assemblages from the Alta stock contact aureole

	Talc Zone	Tremolite Zone	Forsterite Zone	Periclase Zone
1.				
2.				
3.				
4.				
5.				

2. What components (use oxides) do you need to define all the minerals on your list?

3. If you eliminate the fluid species, you should be left with three components. On the ternary diagram below, put one component at each corner, and plot the positions of the minerals present in the contact aureole of the Alta stock.



II. Metamorphic Reactions

Now that you have a working chemography (mineral plot), you can use it to generate univariant reactions that might apply to these rocks.

4. Use the phase rule to determine the number of minerals present in these rocks for the following cases. Assume that the fluid species (H_2O and CO_2) are in excess and available.

Invariance:

Univariance:

Divariance:

5. Let's work our way up the temperature gradient in the aureole. Construct a chemography (based on what you did in question #3) that can be used to generate reactions to explain the occurrence of the talc and tremolite zones. Mineral coordinates do not need to be precise, but should preserve the important topological relationships between the minerals. On a separate piece of paper, neatly draw the topologies and list the reactions that give you the various topologies in an easy to follow format. Computer generated illustrations are welcome for this question.

6. Repeat question #5 for the forsterite and periclase zones. Note that in these rocks quartz is probably the limiting phase. That is, let's assume that all the quartz was consumed by the reactions you generated in #5.

7. Ultimately we will want to plot these reactions on a quantitative T-XCO_2 diagram so that we can constrain the temperature and fluid composition in the contact aureole. Now that you have the topologies and reactions, draw the Schreinemaker's bundle in T-XCO_2 space for #5 and #6. For #5, draw the bundle assuming that 1) Dol + Qtz is on the lower temperature side of reactions, 2) Tr + Cal is favored at high XCO_2, and 3) Tr + Dol is favored at low XCO_2. For #6, draw the bundle using your own geologic intuition. Draw each figure with T = y-axes and XCO_2 = x-axis.

III. Quantitative T-XCO_2 Diagrams

Reconstructions of stratigraphic thickness and geobarometery suggest that the Alta stock crystallized at a depth of 5-6 kilometers which corresponds to a pressure of about 150 MPa. Figure 4 is a T-XCO_2 diagram constructed for the system MgO-CaO-SiO_2-H_2O-CO_2 at P=150 MPa using TWQ (Berman, 1991). This diagram assumes that calcite and dolomite are in excess and that quartz is the limiting phase.

8. Compare the reactions and Schreinemaker's bundles you generated in Part II with Figure 4. Discuss and <u>explain</u> the similarities and differences.

9. Write a summary (as a narrative) of the metamorphic history experienced by the rocks that make up the contact aureole of the Alta stock. What reactions were responsible for the minerals we see in the contact aureole? At what temperature did these minerals form? What was the fluid composition during metamorphism? Was it everywhere the same? What was the origin of the fluids? When answering this question, be sure to study, use, and refer to the maps (Figs. 1&2), the thin sections (Fig. 3), and Figure 4.

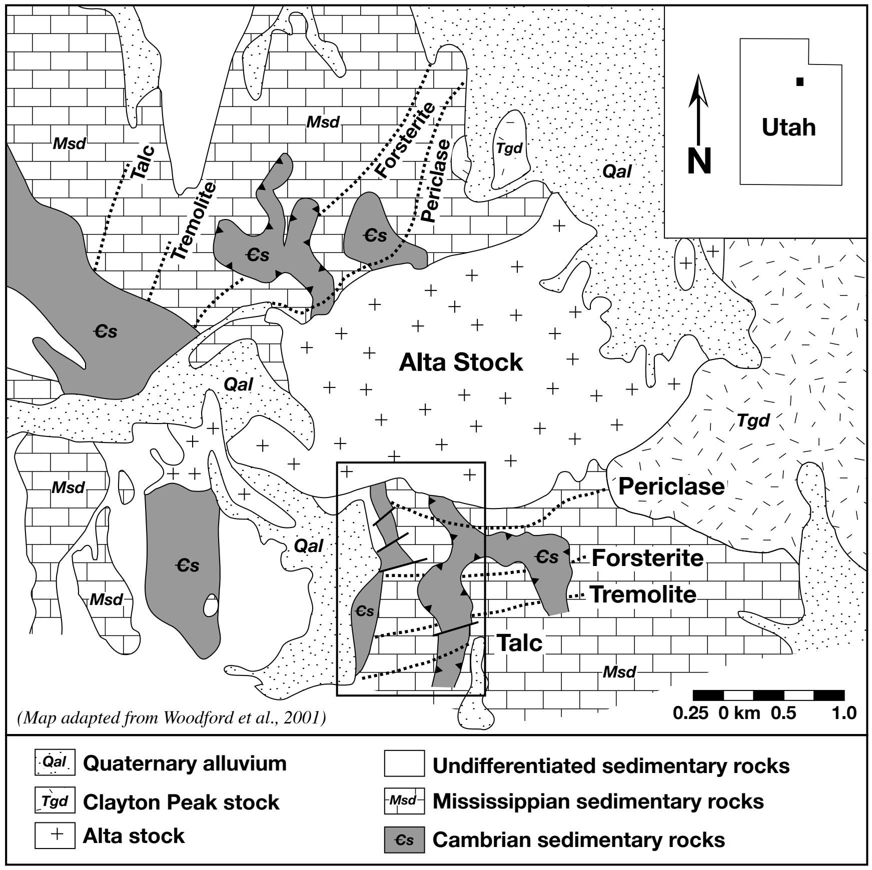


Figure 1. Geology of the Alta stock and contact aureole. The Cambrian and Mississippian sedimentary rocks are predominately composed of siliceous dolostone and limestone. Box shows area of detail shown in Fig. 2.

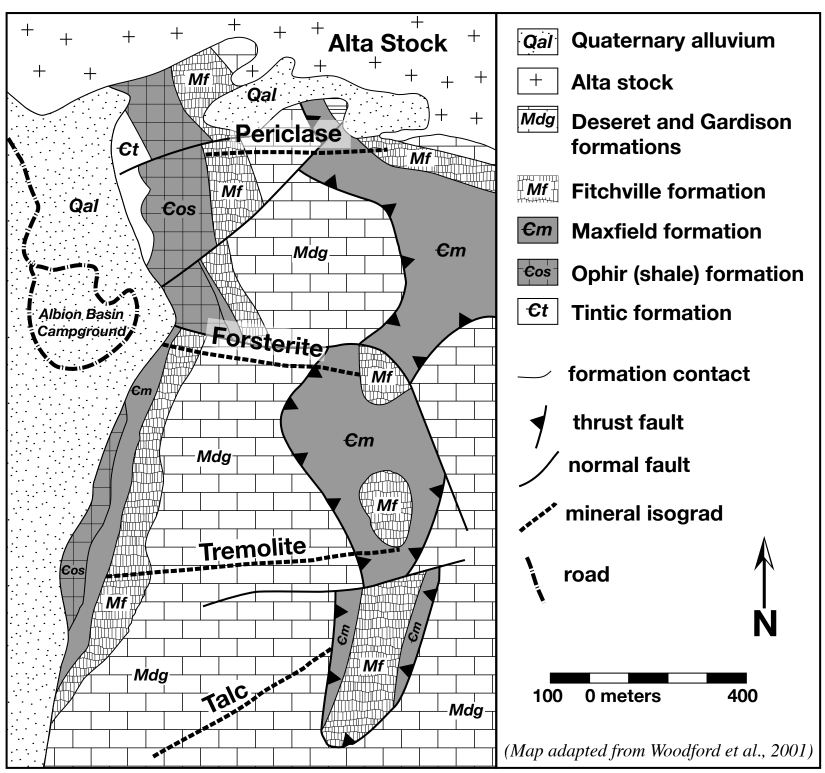


Figure 2. Detailed geologic map from the southern contact of the Alta stock where the samples for this exercise were collected.

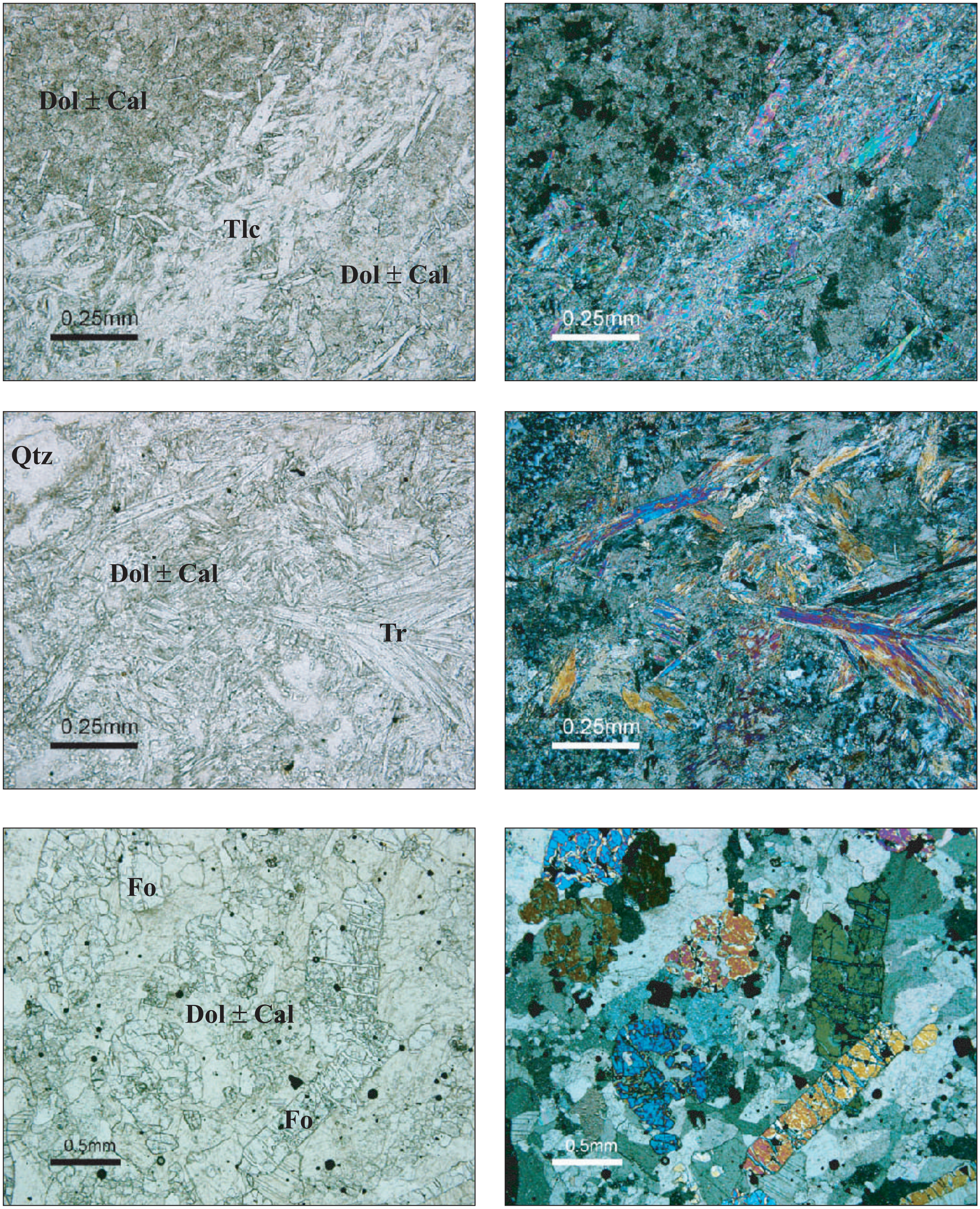


Figure 3. Photomicrographs from the contact aureole of the Alta stock. Plane polarized light on left and crossed plarized light on right. a) Talc zone. b) Tremolite zone. c) Forsterite zone. Note change in scale between b and c. Cal = calcite, Dol = dolomite, Fo = forsterite, Tlc = talc, Tr = tremolite, and Qtz = quartz.

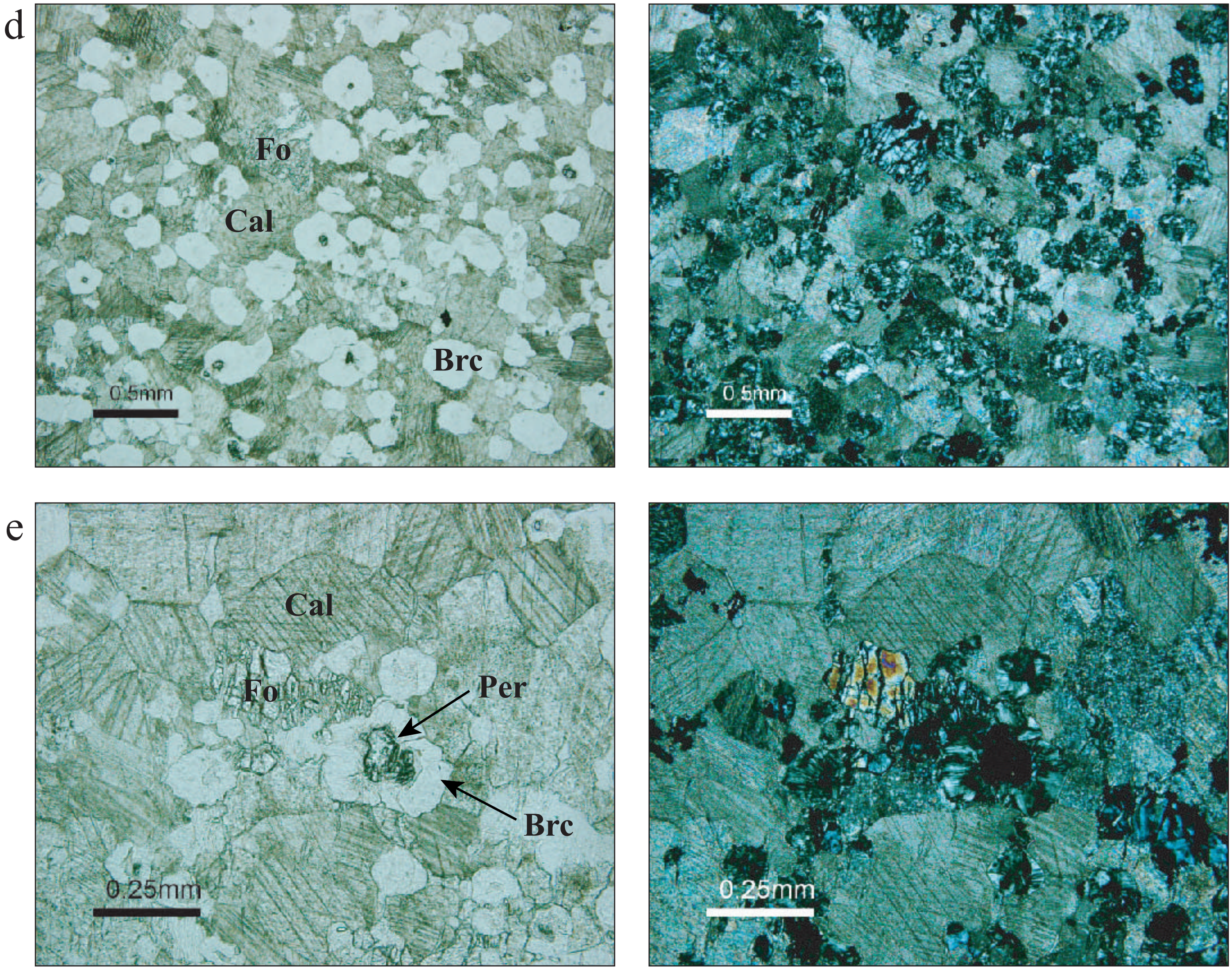


Figure 3 - continued. d) Periclase zone. Note brucite replacing periclase. e) Periclase zone. Magnified view of brucite replacing periclase. Brc = brucite, Di = diopside, Per = periclase.

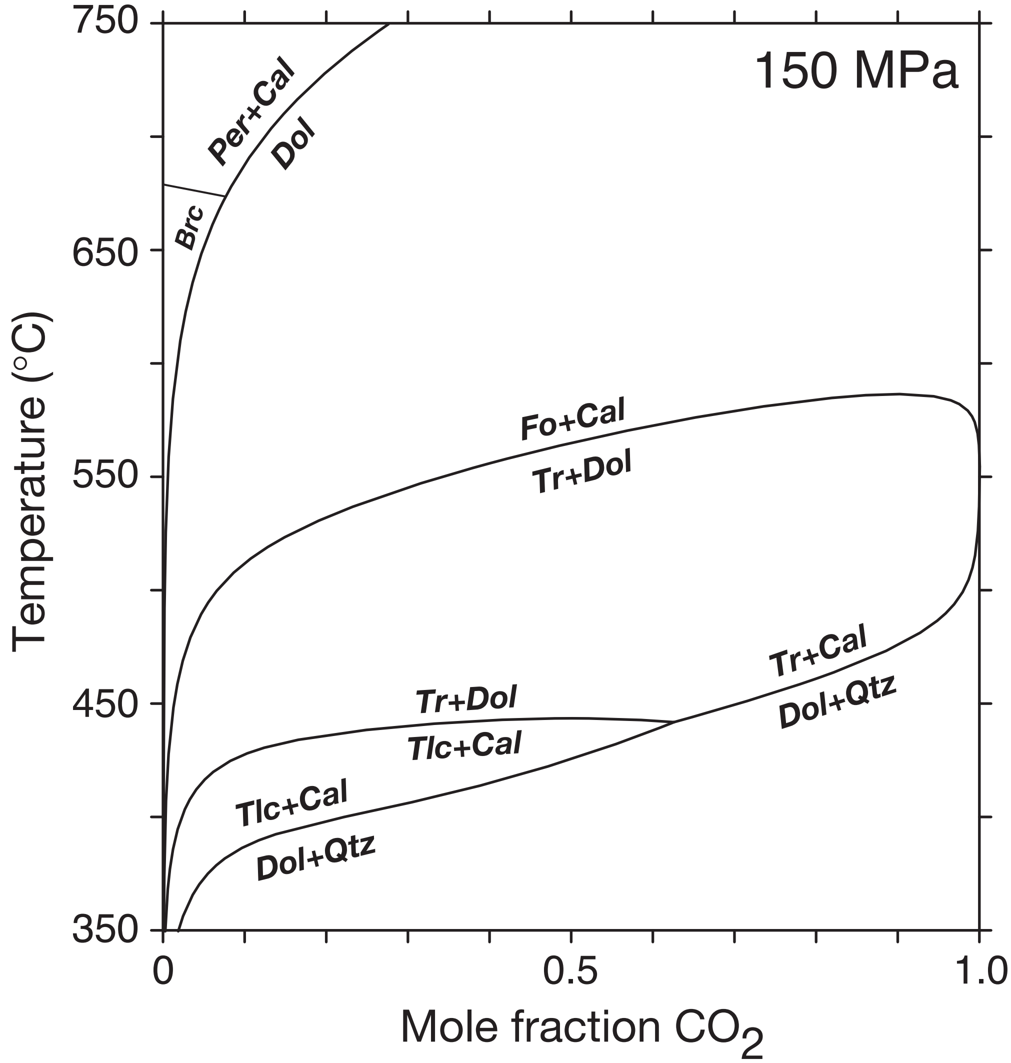


Figure 4. T-XCO_2 diagram constructed for the system MgO-CaO-SiO_2-H_2O-CO_2 at P=150 MPa.