FOURTH QUARTERLY TECHNICAL PROGRESS REPORT

For the period January, February, March 1966

DEVELOPMENT OF TECHNOLOGICAL CONCEPTS LEADING TO BENEFICIAL USE OF LUNAR MAGMA PRODUCTS

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ACTIVITY LAST QUARTER AND NEW DATA

During the fourth quarter, 93 new determinations have been made of the solid-liquid phase transformations of igneous rocks from temperatures of 500°C to 1500°C. This brings the total number of determinations through this fourth quarter to 381, which is 1.65 determinations per working day.

As we had hoped at the time this research project was started, we have accumulated some data and ideas which can be correlated into a working hypothesis on the behaviour of natural igneous rocks. We can write this hypothesis as follows:

1. The genesis of igneous rocks or of their essential minerals is effected and controlled not only by the environmental conditions and processes, but also by the associated accessory minerals and minor constituents and by the kinetics of their association with the essential minerals. This introduces a time dependence in all phase transformations and texture transformations that involve natural igneous rocks and non-equilibrium processes. This time dependence is exemplified by the temperature time diagrams for basalt and gabbro (Figure 1a, 1b).

2. The combined number of essential minerals, accessory minerals and minor constituents in a rock make it into a complex multicomponent system which is difficult or impossible to analyze on a typical physico-chemical phase diagram.

3. Changes displayed by the igneous rocks or their essential minerals are characteristic of not only the environmental conditions and processes but also of the nature and abundance of the accessories and minor constituents. Hence examination of the genetic state of the essential minerals gives a clue to the genetic history of the total rock including the accessory minerals and minor constituents. The rock can be treated as a binary or ternary system on the basis of the essentials and the influence of the rest of the components included as subscripts. This characteristic property of the igneous rocks is exemplified by the genesis diagram

for gabbro which was shown in the last quarterly report, and it is repeated for the Bruderheim meteorite (Figure 2).

4. Serpentine. Petrographic and x-ray diffraction examination of the new experimental products reconfirm the previous observation reported last quarter that with increased pressure and temperature the original mineral antigorite loses water and transforms into forsterite; then, at still higher pressure and temperature the forsterite gains silica and breaks into enstatite plus some enriched iron-magnesium oxides. The additional data we are acquiring now is directed towards determination of the boundaries between the above phases. The x-ray diffraction analysis gives a fairly accurate estimate of the ratio of the crystalline phases. As to our attempt to make quantitative determinations based on x-ray diffraction it appears that the absolute peak heights are too sensitive to even traces of pyrophyllite, and the error in intensity reading is as much as 1 to 4 times their correct height. Comparing stay time at pressure and temperature for 5 minutes vs. stay time for 15 minutes shows coarser recrystallization at 15 minutes, as expected. We are trying now to use Differential Thermal Analysis techniques to determine the transformations in situ.

5. Granodiorite. X-ray diffraction examination of the experimental products shows the existence of two high pressure phases above 30 kilobars: jadeite and coesite. These experiments were all kept under the high pressure temperature conditions some for only one minute and some for five minutes and yet the time was enough for a clear development of coesite. We are trying to derive enough data to determine the kinetics of coesite formation in a complex association (granodiorite) vs. existing data on the genesis in pure silica.

6. Bruderheim Meteorite. New and old experiments on the phase transformation were reexamined in terms of 10 genetic states and a genetic diagram was prepared (Figure 2). This diagram shows the existence of four areas: solidus area, liquid transition area, glass quench area (the quench product is only glass with no recrystallization), and a crystal quench area (the quench product is only crystalline with no glass). We are trying to define these areas accurately and determine whether this can be plotted for all igneous rocks.

PLANNED ACTIVITY FOR NEXT QUARTER

We will determine the possibility of developing genetic diagrams for all the rocks examined thus far, and elaborate on the examination of time dependence.

We will try to determine the serpentine transformation curves into forsterite and enstatite and try to develop ideas on the kinetics and thermodynamics of these transformations.

We will try to determine whether the natural rock association in granodiorite has a real effect on the rate of transformation of quartz into coesite. If the answer is yes, we will search for other catalytic effects which might occur in a natural rock.

We will begin to determine the solid liquid transformations in a peridotite rock and compare with our previous determinations on dunite.

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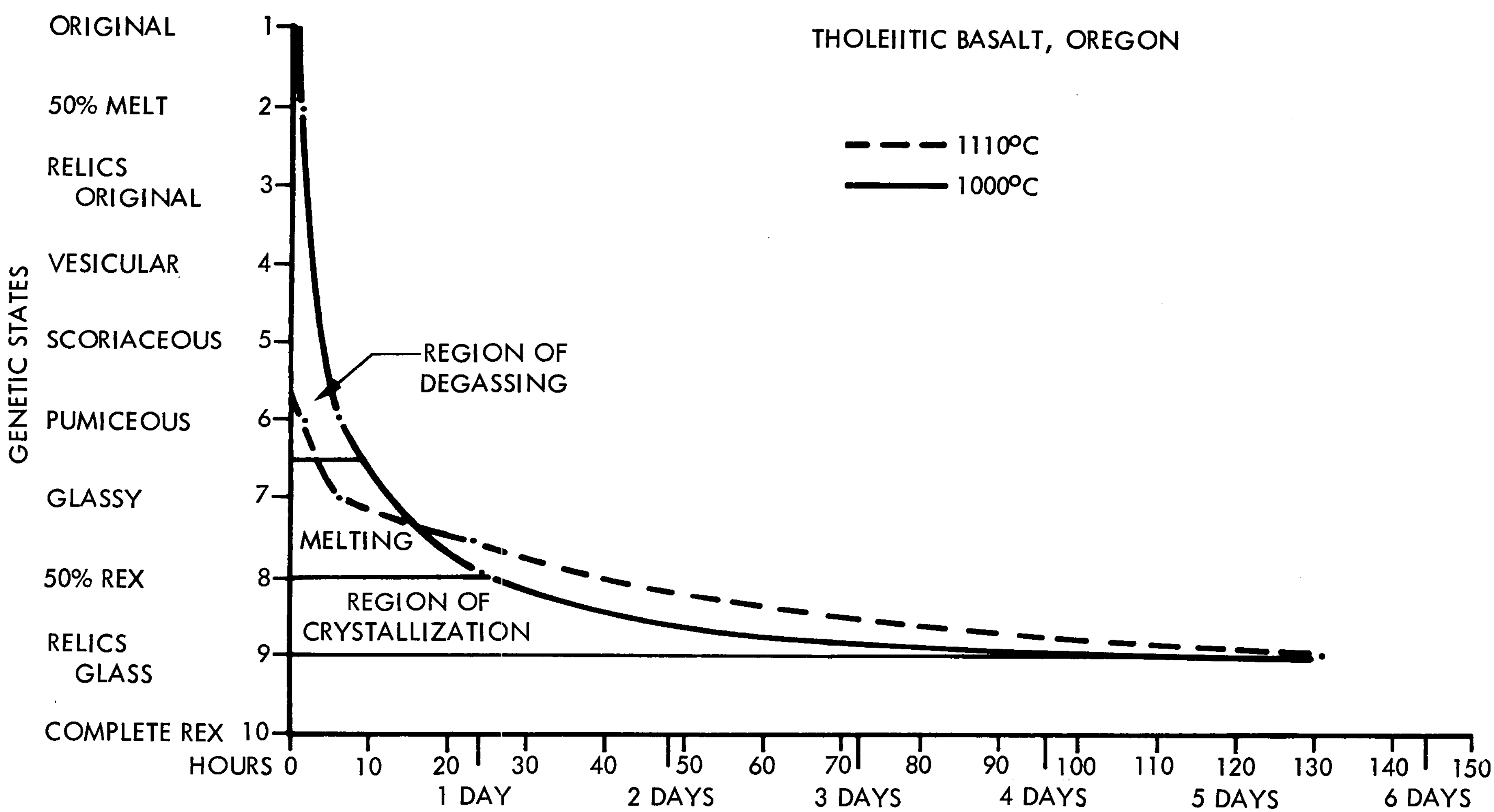

Figure 1a. Time Dependence of Genetic States at 1 atm

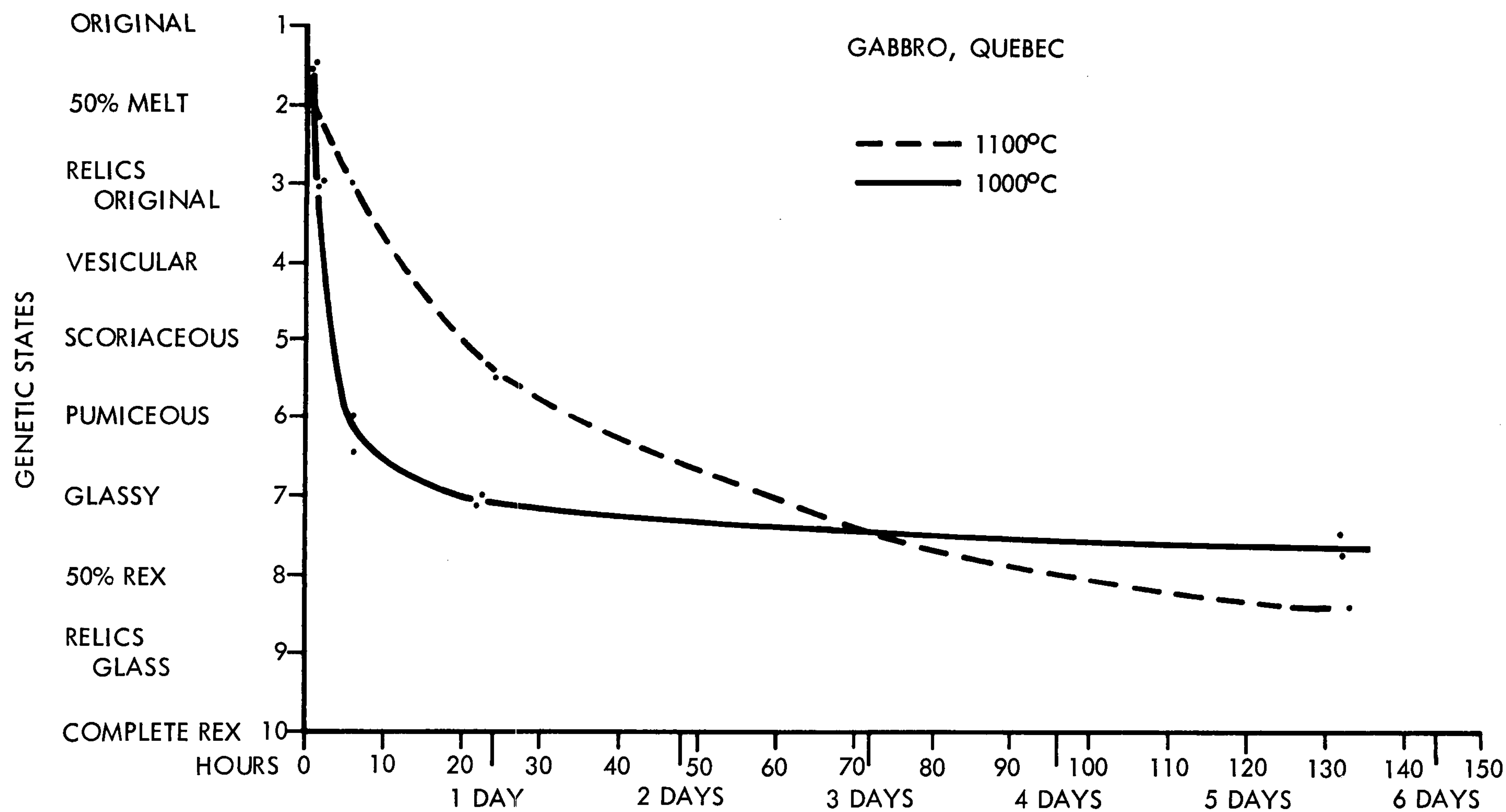

Figure 1b. Time Dependence of Genetic States at 1 atm

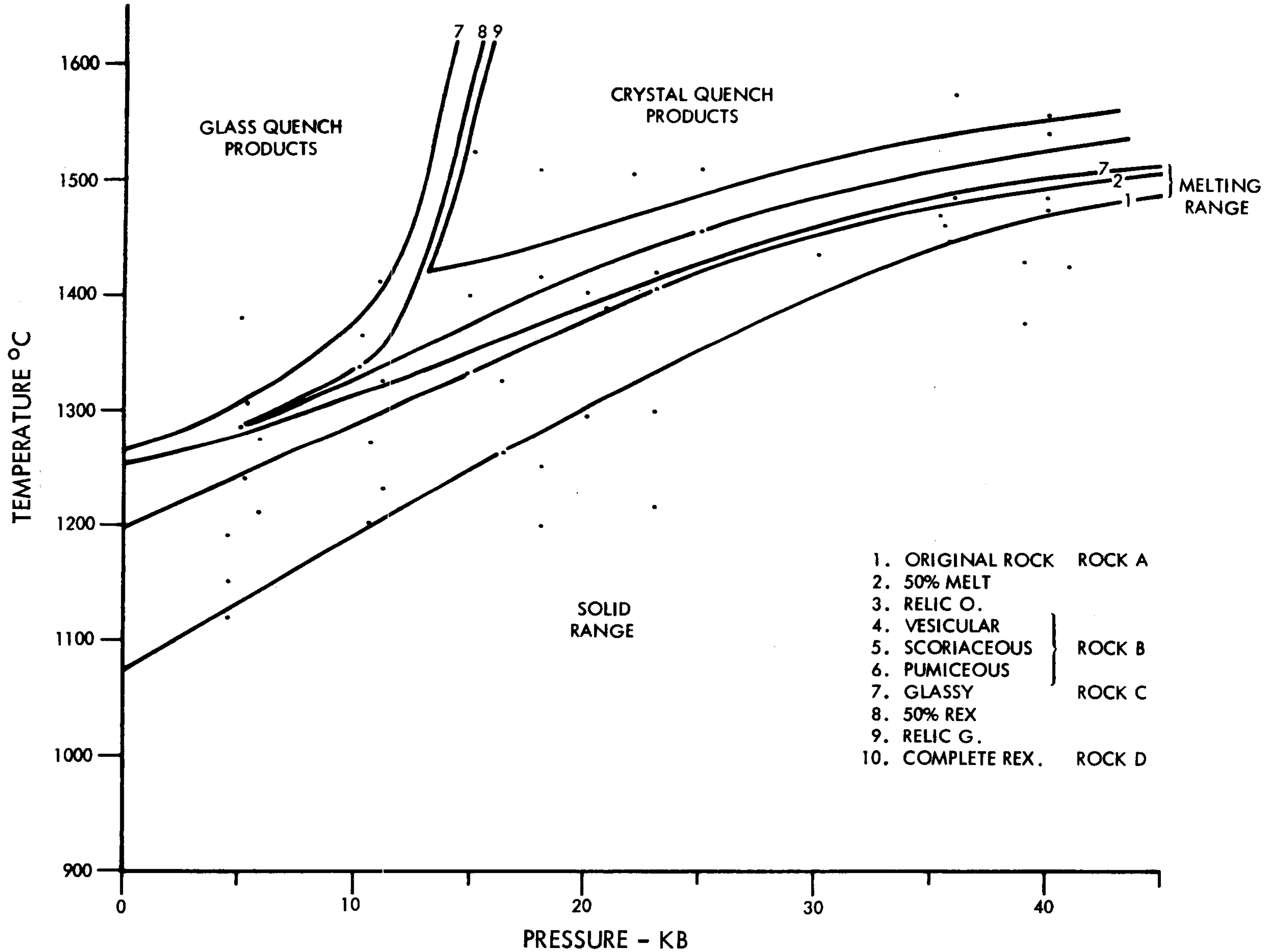

Figure 2. Genesis Diagram - Bruderheim, T° vs. P at ~ 5 Minutes Stay at T°, Then Quench