

In the development of any field there is a time of reconnaissance followed by a period in which more precise data are sought. In experimental petrology, this time has arrived. If we are to progress to the assignment of more exact conditions of stability in more complex systems, then we must look critically and intelligently at experimental results and methods. The term "equilibrium diagram" should not be used unless it is reasonably justified by both experimental and geological criteria. Where, as has commonly happened, experimental

results conflict with inferences based on geological observations, the experimentalist has a special responsibility to scrutinize and state clearly the limitations of his laboratory procedure.

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## REFERENCES CITED

- BARRER, R. M., 1950, Hydrothermal synthesis of potash feldspar in the range 195–200° C.: *Nature*, v. 166, p. 562.
- and WHITE, E. A. D., 1952, Synthetic crystalline sodium aluminosilicates: *Chem. Soc. London Jour.*, p. 1561–1571.
- BOWEN, N. L., and TUTTLE, O. F., 1949, The system MgO-SiO<sub>2</sub>-H<sub>2</sub>O: *Geol. Soc. America Bull.*, v. 60, p. 439–460.
- CARR, R. M., and FYFE, W. S., 1958, Some observations on the crystallization of amorphous silica: *Am. Mineralogist*, v. 43, p. 908–916.
- COOMBS, D. S., ELLIS, A. J., FYFE, W. S., and TAYLOR, A. M., 1959, The zeolite facies; with comments on the interpretation of hydrothermal synthesis: *Geochim. et Cosmochim. Acta*, v. 17, p. 53–107.
- DICKSON, F. W., and TUNELL, G., 1958, Equilibria of red HgS (cinnabar) and black HgS (metacinnabar) and their saturated solutions in the system HgS-Na<sub>2</sub>S-H<sub>2</sub>O and HgS-Na<sub>2</sub>S-Na<sub>2</sub>O-H<sub>2</sub>O from 25° C. to 75° C. at 1 atmosphere pressure: *Am. Jour. Sci.*, v. 256, p. 654–679.
- EHLERS, E. G., 1953, An investigation of the stability relations of the Al-Fe members of the epidote group: *Jour. Geology*, v. 61, p. 231–251.
- ERVIN, G., and OSBORNE, E. F., 1951, The system Al<sub>2</sub>O<sub>3</sub>-H<sub>2</sub>O: *Jour. Geology*, v. 59, p. 381–394.
- FYFE, W. S., 1955, Results obtained by 1955 and contained in *Fyfe et al.* (1958).
- 1958, A further attempt to determine the vapor pressure of brucite: *Am. Jour. Sci.*, v. 256, p. 729–732.
- TURNER, F. J., and VERHOOGEN, J., 1958, Metamorphic reactions and metamorphic facies: *Geol. Soc. America Mem.* 73.
- GIAUQUE, W. F., 1949, An example of the difficulty in obtaining equilibrium corresponding to a macrocrystalline non-volatile phase. The reaction Mg(OH)<sub>2</sub> → MgO + H<sub>2</sub>O: *Am. Chem. Soc. Jour.*, v. 71, p. 3192–3194.
- and ARCHIBALD, R. C., 1937, The entropy of water from the third law. The dissociation pressure and heat of the reaction Mg(OH)<sub>2</sub> → MgO + H<sub>2</sub>O: *Am. Chem. Soc. Jour.*, v. 59, p. 561–569.
- GOLDSMITH, J. R., 1953, A "simplexity principle" and its relation to "ease" of crystallization. *Jour. Geology*, v. 61, p. 439–451.
- GRIGGS, D. T., and KENNEDY, G. C., 1956, A simple apparatus for high pressures and temperatures: *Am. Jour. Sci.*, v. 254, p. 722–735.
- HARKER, R. I., and TUTTLE, O. F., 1955, Studies in the system CaO-MgO-CO<sub>2</sub>. Part I. Thermal dissociation of calcite, dolomite and magnesite. *Am. Jour. Sci.*, v. 253, p. 209–224.
- JAMIESON, J. C., 1953, Phase equilibria in the system calcite-aragonite: *Jour. Chem. Phys.*, v. 21, p. 1385–1390.
- 1957, Introductory studies of high-pressure polymorphism to 24,000 bars by x-ray diffraction with some comments on calcite II: *Jour. Geology*, v. 65, p. 334–343.
- KENNEDY, G. C., 1955, Pyrophyllite-sillimanite-mullite equilibrium relations to 20,000 bars and 800° C.: *Geol. Soc. America Bull.* (abs.), v. 66, p. 1584.
- 1956, The brucite-periclase equilibrium: *Am. Jour. Sci.*, v. 254, p. 567–573.
- 1959, Phase relations in the system Al<sub>2</sub>O<sub>3</sub>-H<sub>2</sub>O at high pressures and temperatures: *ibid.*, v. 257, p. 563–573.
- KRACEK, F. C., NEUVONEN, J. J., and BURLEY, G., 1951, A thermodynamic study of the stability of jadeite: *Washington Acad. Sci. Jour.*, v. 41, p. 373–383.
- MACDONALD, G. J. F., 1955, Gibbs free energy of water at elevated temperatures and pressures, with applications to the brucite-periclase equilibrium: *Jour. Geology*, v. 63, p. 244–252.
- ROBERTSON, E. C., BIRCH, F., and MACDONALD, G. J. F., 1957, Experimental determination of jadeite stability relations to 25,000 bars: *Am. Jour. Sci.*, v. 255, p. 115–137.

ROEDDER, E., 1959, Silicate melt systems. Physics and chemistry of the earth, v. 3, p. 224-297: London, Pergamon Press.

ROSSINI, F. D., WAGMAN, D. D., EVANS, W. H., LEVINE, S., and JAFFE, I., 1952, Selected values of chemical thermodynamic properties: Nat. Bur. Standards Circ. 500.

ROY, DELLA M., 1954, Hydrothermal synthesis of andalusite: Am. Mineralogist, v. 39, p. 140-143.

— and ROY, R., 1957, A re-determination of equilibrium in the system MgO-H<sub>2</sub>O and comments on earlier work: Am. Jour. Sci., v. 255, p. 573-582.

—, —, and OSBORNE, E. F., 1953, The system MgO-Al<sub>2</sub>O<sub>3</sub>-H<sub>2</sub>O: Am. Jour. Sci., v. 251, p. 337-361.

ROY, R., and OSBORNE, E. F., 1954, The system Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>-H<sub>2</sub>O: Am. Mineralogist, v. 39, p. 853-885.

SAND, L. B., ROY, R., and OSBORNE, E. F., 1957, Stability relations of some minerals in the Na<sub>2</sub>O-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>-H<sub>2</sub>O system: Econ. Geology, v. 52, p. 169-179.

SMYTH, F. H., and ADAMS, L. H., 1923, The system, calcium oxide-carbon dioxide: Am. Chem. Soc. Jour., v. 45, p. 1167-1184.

TURNER, F. J., and VERHOOGEN, J., 1960, Igneous and metamorphic petrology: New York, McGraw-Hill Book Co.

TUTTLE, O. F., and BOWEN, N. L., 1958, Origin of granite in the light of experimental studies in the system NaAlSi<sub>3</sub>O<sub>8</sub>-KAlSi<sub>3</sub>O<sub>8</sub>-H<sub>2</sub>O: Geol. Soc. America Mem. 74.

YODER, H. S., and EUGSTER, H. P., 1954, Phlogopite synthesis and stability range: Geochim. et Cosmochim. Acta, v. 6, p. 157-185.

— — — — — 1955, Synthetic and natural muscovites: *ibid.*, v. 8, p. 225-280.

BAKER, R. M., 1956, Hydrothermal synthesis of talc and chlorite in the range 150-300°C. Nature, v. 180, p. 502.

— and WRIGHT, I. A. D., 1952, Synthetic crystalline sodiumaluminosilicates: Chem. Soc. London Jour., p. 1561-1571.

BOWER, N. L., and TUTTLE, O. F., 1949, The system MgO-SiO<sub>2</sub>-H<sub>2</sub>O: Geol. Soc. America Bull., v. 60, p. 489-499.

CARR, K. M., and FYFE, W. S., 1958, Some observations on the crystallization of amorphous silica: Am. Mineralogist, v. 43, p. 904-910.

COOPER, J. S., KALLA, A. J., FYFE, W. S., and TAYLOR, A. M., 1952, The zeolite habitus: with comments on the interpretation of hydrothermal synthetic: Geochim. et Cosmochim. Acta, v. 17, p. 21-107.

DUNSON, F. W., and TURNER, G., 1958, Equilibrium-ordered H<sub>2</sub>S (clausenite) and black H<sub>2</sub>S (mactanite) and their saturated solutions in the system H<sub>2</sub>S-Na<sub>2</sub>Si<sub>2</sub>O<sub>7</sub> and H<sub>2</sub>S-Na<sub>2</sub>Si<sub>2</sub>O<sub>7</sub>-H<sub>2</sub>O from 25°C. to 75°C. at 1 atmosphere pressure: Jour. Chem. Phys., v. 28, p. 654-679.

EMERSON, E. G., 1958, An investigation of the stability relations of the Al<sub>2</sub>SiO<sub>5</sub> minerals of the chlorite group: Jour. Geology, v. 66, p. 251-281.

FYFE, W. S., and OSBORNE, E. F., 1951, The system Al<sub>2</sub>O<sub>3</sub>-H<sub>2</sub>O: Jour. Geology, v. 59, p. 281-294.

FYFE, W. S., 1952, Results obtained by 1952 and contained in File 44 (1952).

— 1958, A further attempt to determine the vapor pressure of bauxite: Jour. Chem. Phys., v. 28, p. 729-732.

— TURNER, F. J., and VERHOOGEN, J., 1958, Metamorphic reactions and metamorphic facies: Geol. Soc. America Mem. 73.

GUERRE, W. E., 1958, An example of the difficulty in obtaining equilibrium corresponding to a macrocrystalline non-equilibrium phase: The reaction Mg(OH)<sub>2</sub> + H<sub>2</sub>O = MgO + H<sub>2</sub>: Jour. Chem. Phys., v. 28, p. 3192-3197.

— and YACHTZMAN, R. C., 1957, The entropy of water from the third law. The dissociation pressure and heat of the reaction 2H<sub>2</sub>O = 2H<sub>2</sub> + O<sub>2</sub>: Jour. Chem. Phys., v. 25, p. 501-509.

GONZALEZ, J. R., 1953, A simplified principle and its relation to "cases" of crystallization: Jour. Geology, v. 61, p. 439-451.

GROSS, D. T., and KRIVOVY, G. C., 1955, A simple apparatus for high pressure and temperature: Jour. Chem. Phys., v. 23, p. 171-175.

HARRIS, R. E., and TUTTLE, O. F., 1955, Studies in the system CaO-MgO-CO<sub>2</sub>: Part I. Thermal dissociation of calcite, dolomite and magnesite: Jour. Geol. Soc. London, v. 112, p. 209-224.

JAMESON, J. C., 1952, Phase equilibria in the system calcite-magnesite: Jour. Chem. Phys., v. 21, p. 1382-1390.

— 1957, Introductory studies of high-pressure polymorphism in 34,000 bars p-x-ray diffraction with some comments on calcite II: Jour. Geology, v. 65, p. 244-248.

KRIVOVY, G. C., 1952, P-T-polyhedrism: stability equilibrium relations to 30,000 bars and 500°C.: Geol. Soc. America Bull., v. 63, p. 1781.

— 1950, The pressure-temperature equilibrium: Jour. Geology, v. 58, p. 267-278.

— 1952, Phase relations in the system Al<sub>2</sub>O<sub>3</sub>-H<sub>2</sub>O at high pressure and temperature: Jour. Chem. Phys., v. 20, p. 263-273.

KRIVOVY, G. C., MONTGOMERY, J., and BOWEN, N. L., 1951, A thermodynamic study of the stability of bauxite: Washington State Jour., v. 41, p. 273-281.

MALDONADO, C. J. T., 1952, Gibbs free energy of water at elevated temperatures and pressures with applications to the hydrothermal equilibrium: Jour. Geology, v. 60, p. 214-225.

ROBERTSON, E. C., JINCO, F., and MALDONADO, C. J. T., 1952, Experimental determination of bauxite stability relations to 23,000 bars: Jour. Chem. Phys., v. 22, p. 112-137.