LARSEN, E. S. JR., AND W. M. DRAISIN (1948) Composition of the minerals in the rocks of the Southern California batholith. *Internat. Geol. Cong. Rep. 18th Session, Great Britain* 2, 66–79.

MUELLER, R. F. (1961), Analysis of relations among Mg, Fe and Mn in certain metamorphic minerals. *Geochim. Cosmochim. Acta* 25, 267–296.

——— (1962), Energetics of certain silicate solid solutions. *Geochim. Cosmochim. Acta* 26, 581–598.

——— (1969) Hydration, oxidation and the origin of the calc-alkali series. *NASA TN* D-5400.

——— (1963) Interaction of chemistry and mechanics in magmatism. *J. Geol.* 71, 759–772.

——— (1964) Theory of immiscibility in mineral systems. *Mineral. Mag.* 33, 1015–1023.

PRIGOGINE, I., AND R. DEFAY (1951) *Chemical Thermodynamics* (English Translation by D. H. Everett, 1954). Longmans Green, London.

SAXENA, S. K. (1968a) Distribution of elements between coexisting minerals and the nature of solid solution in garnet. *Amer. Mineral.* 53, 994–1014.

——— (1968b) Chemical study of phase equilibria in charnockites, Varberg, Sweden. *Amer. Mineral.* 53, 1674–1695.

———, AND SUBRATA GHOSE (1971) Mg^{2+}-Fe^{2+} order-disorder and the thermodynamics of the orthopyroxene crystalline solution. *Amer. Mineral.* 56, 532–559.

SEN, S. K., AND K. R. CHAKRABORTY (1968) Magnesium-iron exchange equilibria in garnet-biotite and metamorphic grade. *Neues Jahrb. Mineral.* 108, 181–207.

STEINFINK, H. (1962) The crystal structure a trioctohedral mica phlogopite. *Amer. Mineral.* 47, 886–

WONES, D. R., AND H. P. EUGSTER (1965) Stability of biotite: experiment, theory and application. *Amer. Mineral.* 50, 1228–1272.

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STABILITY OF BIOTITE: A REPLY

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Mueller's (1972) proposed for an ideal solution model for biotite stabilities is sound, and his model is correct for biotites with low Fe^{3+} contents. Wones, Burns, and Carroll (1971) redetermined the stability of the end member, annite, $KFe_3AlSi_3O_{10}(OH)_2$. New data on Ni-NiO (Huebner and Sato, 1970) and Fe_2SiO_8-SiO_2-Fe_3O_4 (Wones and Gilbert, 1969) are also available. This led to a correction of the so-called

"standard state" on which the biotite solution theory of Wones and Eugster (1965) was based. As a consequence an "ideal" model seems most likely for biotites on the join phlogopite-annite. For the reaction

$$KFe_3AlSi_3O_{10}(OH)_2 + 1/2\ O_2 \rightleftarrows KAlSi_2O_8 + Fe_3O_4 + H_2O$$

an expression relating mole fraction Fe^{2+}, x: temperature, T; and the fugacities of oxygen (f_{O_2}) and H_2O (f_{H_2O}) is as follows:

$$\log f_{H_2O} = 7409/T + 4.25 + 1/2 \log f_{O_2} + 3 \log x - \log a_{KAlSi_3O_8} - \log a_{Fe_3O_4}.$$

This permits new estimates of H_2O fugacity in the rhyolite of the San Juans and gneisses of the Adirondacks:

	old estimate	new estimate
Piedra rhyolite	200–600 bars	200–2000 bars
Adirondack gneiss		
500°	0.1–1 bars	1–10 bars
600°	1–10 bars	10–50 bars

F. J. Turner (1970) has protested the earlier values estimated for the Adirondack gneisses. Although the new estimates are somewhat higher, they do not come up to Turner's expectations, which are based on the stability of muscovite. The data on the stability of amphibole is in agreement with the new estimates of f_{H_2O} for regional metamorphism of the intercalated gneisses and marbles of the Northwest Adirondacks, and makes sense for a series of decarbonation reactions.

References

Huebner, J. S., and M. Sato (1970) The oxygen fugacity-temperature relationships of manganous oxide and nickel oxide buffers. *Amer. Mineral.* **55**, 934–952.

Mueller, Robert (1972) On the stability of biotite. *Amer. Mineral.* **57**, 300–316.

Turner, F. J. (1968) *Metamorphic Petrology*. McGraw-Hill, New York, 123–125.

Wones, D. R., and M. C. Gilbert (1969) The fayalite-magnetite-quartz assemblage between 600° and 800°C: *Amer. J. Sci., Schairer Vol.* **267-A**, 480–488.

———, R. G. Burns, and B. M. Carroll (1971) Stability and properties of synthetic annite: *EOS, Trans., Amer. Geophys. Union*, **52**, 369–370.

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