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References

- ADAMS, H. G. (1971) *Solid Inclusion Piezothermometry: Experimental Calibration of Quartz-Almandine and Sillimanite-Almandine*. Ph.D. Dissertation, University of California, Los Angeles, 156 p.
- , L. H. COHEN, AND J. L. ROSENFELD (1970) Solid inclusion piezothermometry: Experimental calibration of quartz-almandine and sillimanite-almandine. *Geol. Soc. Am. Abstr. Programs*, **2**, 479.
- , ———, AND ——— (1975) Solid inclusion piezothermometry. I: Comparison dilatometry. *Am. Mineral*, **60**, 574–583.
- BEVINGTON, P. R. (1969) *Data Reduction and Error Analysis for the Physical Sciences*. McGraw-Hill, Inc., New York, 336 p.
- CARSTENS, HARALD (1971) Plastic stress relaxation around solid inclusions in pyrope. *Contrib. Mineral. Petrol.* **32**, 289–294.
- CLARK, S. P., JR., AND E. JÄGER (1969) Denudation rate in the Alps from geochronologic and heat flow data. *Am. J. Sci.* **267**, 1143–1160.
- CLAYTON, R. N., J. R. O'NEILL, AND T. K. MAYEDA (1972) Oxygen isotope exchange between quartz and water. *J. Geophys. Res.* **77**, 3057–3067.
- COHEN, L. H., WILLIAM KLEMENT, JR., AND H. G. ADAMS (1974) Yet more observations on the high-low quartz inversion: Thermal analysis studies to 7 kbar with single crystals. *Am. Mineral.* **59**, 1099–1104.
- FREY, MARTIN (1969) Die Metamorphose des Keupers vom Tafeljura bis zum Lukmanier-Gebiet. *Beitr. Geol. Karte Schweiz, Neue Folge*, **137** Lieferung, Schweiz. Geologischen Kommission, Bern, 160 p.
- GARLICK, G. D., AND S. EPSTEIN (1967) Oxygen isotope ratios in coexisting minerals of regionally metamorphosed rocks. *Geochim. Cosmochim. Acta*, **31**, 181–214.
- GOLDSMITH, J. R., AND R. C. NEWTON (1969) *P-T-X* relations in the system $\text{CaCO}_3\text{-MgCO}_3$ at high temperatures and pressures. *Am. J. Sci.* **267-A**, 160–190.
- HOLDAWAY, M. J. (1971) Stability of andalusite and the aluminum silicate phase diagram. *Am. J. Sci.* **271**, 97–131.
- KELLER, FRANZ (1968) Mineralparagenesen und Geologie der Campo Tencia—Pizzo Forno-Gebirgsgruppe. *Beitr. Geol. Karte Schweiz, Neue Folge*, **135** Lieferung, Schweiz. Geologischen Kommission, Bern, 71 p.
- KLEMENT, W., JR., AND L. H. COHEN (1968) High-low quartz inversion: Thermodynamics of the transition. *J. Geophys. Res.* **73**, 2249–2259.
- LAHEE, F. H. (1941) *Field Geology*. 4th ed. McGraw-Hill, Inc., New York and London, 853 p.
- NADAI, A. (1950) *Theory of Flow and Fracture of Solids*, Vol. One, 2nd ed. McGraw-Hill Book Co., Inc., New York, 572 p.
- NEWTON, R. C. (1966) Kyanite-andalusite equilibrium from 700° to 800°C. *Science*, **153**, 170–172.
- NIGGLI, E. (1970) Alpine metamorphose und alpine gebirgsbildung. *Fortschr. Mineral.* **47**, 16–26.
- NYE, J. F. (1957) *Physical Properties of Crystals*. Oxford Univ. Press, London, 322 p.
- RICHARDSON, S. W., M. C. GILBERT, AND P. M. BELL (1969) Experimental determination of kyanite-andalusite and andalusite-sillimanite equilibria: the aluminum silicate triple point. *Am. J. Sci.* **267**, 259–272.
- ROSENFELD, J. L. (1969) Stress effects around quartz inclusions in almandine and the piezothermometry of coexisting aluminum silicates. *Am. J. Sci.* **267**, 317–351.
- , AND A. B. CHASE (1961) Pressure and temperature of crystallization from elastic effects around solid inclusions in minerals. *Am. J. Sci.* **259**, 519–541.
- , J. B. THOMPSON, AND E-AN ZEN (1958) Data on coexistent muscovite and paragonite. *Geol. Soc. Am. Bull.* **69**, 1637.
- SKINNER, B. J. (1956) Physical properties of end-members of the garnet group. *Am. Mineral.* **41**, 428–436.
- SOGA, NAOHIRO (1967) Elastic constants of garnet under pressure and temperature. *J. Geophys. Res.* **72**, 4227–4234.
- STEIGER, R. H. (1964) Dating of orogenic phases in the central Alps by K-Ar ages of hornblende. *J. Geophys. Res.* **69**, 5407–5421.
- THOMPSON, J. B., JR., AND S. A. NORTON (1968) Paleozoic regional metamorphism in New England and adjacent areas. In E-an Zen, W. S. White, J. B. Hadley, and J. B. Thompson, Jr., Eds., *Studies of Appalachian Geology: Northern and Maritime*. New York, Wiley, Interscience Publishers, p. 319–327.
- VERMA, R. K. (1960) Elasticity of some high-density crystals. *J. Geophys. Res.* **65**, 757–766.

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