p. 793) appears to be based on the usual criteria of moulding, inclusion, and partial inclusion of one mineral by another, although these criteria are inadequate for establishing an order of crystallization (Shand, 1950, pp. 105–16). They can tell us only about the relative order of *conclusion* of crystallization, not its initiation. This principle applies to both igneous and metamorphic rocks. For example, a porphyroblast and all its inclusions may have nucleated at the same time; whereas the included minerals formed many stable nuclei, the porphyroblast mineral formed only one, and grew much faster than the other grains, thus enclosing them. Similarly, the occurrence of mineral A moulded on mineral B tells us only either that A finished crystallizing after B (they could have nucleated synchronously), or that both minerals finished crystallizing together on impingement, B retaining a relatively stable crystal form against A (cf. Kretz, 1966). Mutual inclusion and partial inclusion of several minerals of a compatible metamorphic assemblage (e.g. Harte and Johnson, 1969; Vernon, 1968) show that variable nucleation sites, coupled with variable growth-rates, can lead to contrasting inclusion and moulding relationships, where all grains are growing at the same time. Simultaneous growth of metamorphic minerals, rather than an order of crystallization, avoids the necessity for repeated metasomatic events to account for the unique appearance of a mineral of chemical composition radically different from the bulk of the rock (Carmichael, 1969).

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REFERENCES

CARMICHAEL (D. M.), 1969. *Contr. Min. Petr.* **20**, 244–67.
HARTE (B.) and JOHNSON (M. R. W.), 1969. *Scottish Journ. Geol.* **5**, 54–80.
KRETZ (R.), 1966. *Journ. Petrology*, **7**, 68–94.
SAGGERSON (E. P.), 1974. *Min. Mag.* **39**, 793–7.
SHAND (S. J.), 1950. *Eruptive Rocks*. London (Murby).
VERNON (R. H.), 1968. *Journ. Petrology*, **9**, 1–22.

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# Ortho- and clino-pyroxenes from the granulites of Namakkal, Tamil Nadu (Madras), India

CHEMICAL analyses of fourteen pyroxenes from pyroxene granulites and pyroxenites suggest equilibrium conditions were attained at about 650 °C in this part of India.

Namakkal (78° 10′ E., 12° 50′ N.) lies in the Taluk of Salem District, Tamil Nadu (formerly Madras) and contains granulites intruded by pyroxenites containing two

TABLE I. *Chemical analyses of pyroxenes*

| | 144 | 215A | 329 | 557 | 593 | 404 | 396 | 144 | 15 | 593 | 557 | 404 | 396 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 51.50 | 52.45 | 49.81 | 49.50 | 49.95 | 49.90 | 49.91 | 50.21 | 49.50 | 49.25 | 49.55 | 50.20 | 49.50 | 49.50 |
| $TiO_2$ | 0.10 | 0.20 | 0.74 | 0.12 | 0.10 | 0.10 | 0.18 | 0.32 | 0.51 | 0.16 | 0.12 | 0.33 | 0.21 | 0.26 |
| $Al_2O_3$ | 4.26 | 5.40 | 6.11 | 4.18 | 4.06 | 3.57 | 4.07 | 4.44 | 5.09 | 6.11 | 6.83 | 5.09 | 5.60 | 6.40 |
| $Fe_2O_3$ | 1.12 | 1.05 | 2.86 | 1.16 | 0.86 | 0.81 | 0.91 | 1.89 | 1.25 | 1.05 | 1.22 | 1.11 | 1.15 | 1.54 |
| FeO | 14.93 | 14.80 | 16.42 | 23.70 | 23.75 | 24.80 | 25.71 | 4.51 | 8.03 | 8.45 | 8.12 | 9.63 | 9.62 | 14.16 |
| MnO | 0.28 | 0.25 | 0.20 | 0.26 | 0.28 | 0.36 | 0.40 | 0.13 | 0.07 | 0.14 | 0.13 | 0.16 | 0.19 | 0.60 |
| MgO | 26.15 | 23.45 | 24.52 | 19.77 | 19.96 | 19.56 | 17.66 | 14.82 | 12.65 | 12.87 | 11.96 | 13.08 | 11.91 | 9.30 |
| CaO | 0.82 | 1.95 | 0.68 | 0.89 | 0.52 | 0.28 | 0.86 | 23.50 | 23.34 | 21.74 | 21.56 | 20.34 | 21.74 | 18.50 |
| $H_2O^+$ | 0.08 | 0.28 | 0.16 | 0.15 | 0.13 | 0.17 | 0.11 | 0.11 | 0.10 | 0.15 | 0.12 | 0.15 | 0.12 | 0.11 |
| $H_2O^-$ | 0.03 | 0.08 | 0.02 | 0.09 | 0.09 | 0.09 | 0.09 | 0.08 | 0.07 | 0.08 | 0.06 | 0.06 | 0.06 | 0.07 |
| | 99.63 | 99.91 | 99.52 | 99.82 | 99.20 | 99.74 | 99.66 | 99.69 | 100.61 | 99.95 | 100.28 | 100.15 | 100.10 | 100.34 |
| *Number of metal atoms on the basis of 6 oxygens* | | | | | | | | | | | | | | |
| Si | 1.874 | 1.921 | 1.851 | 1.889 | 1.887 | 1.898 | 1.902 | 1.861 | 1.852 | 1.840 | 1.839 | 1.881 | 1.861 | 1.837 |
| Al | 0.126 | 0.089 | 0.149 | 0.111 | 0.113 | 0.103 | 0.098 | 0.139 | 0.148 | 0.160 | 0.151 | 0.119 | 0.139 | 0.163 |
| Al | 0.058 | 0.141 | 0.112 | 0.076 | 0.068 | 0.056 | 0.083 | 0.052 | 0.077 | 0.109 | 0.147 | 0.101 | 0.109 | 0.126 |
| Ti | 0.002 | 0.007 | 0.019 | 0.002 | 0.002 | 0.002 | 0.005 | 0.009 | 0.013 | 0.004 | 0.002 | 0.009 | 0.067 | 0.009 |
| $Fe^{3+}$ | 0.031 | 0.026 | 0.011 | 0.031 | 0.023 | 0.023 | 0.027 | 0.027 | 0.035 | 0.043 | 0.033 | 0.031 | 0.031 | 0.041 |
| $Fe^{2+}$ | 0.453 | 0.448 | 0.502 | 0.752 | 0.754 | 0.794 | 0.819 | 0.140 | 0.249 | 0.260 | 0.305 | 0.301 | 0.302 | 0.452 |
| Mn | 0.008 | 0.007 | 0.006 | 0.005 | 0.006 | 0.005 | 0.009 | 0.004 | 0.002 | 0.002 | 0.002 | 0.003 | 0.003 | 0.018 |
| Mg | 1.436 | 1.274 | 1.341 | 1.117 | 1.131 | 1.111 | 1.007 | 0.817 | 0.703 | 0.711 | 0.661 | 0.730 | 0.669 | 0.581 |
| Ca | 0.031 | 0.076 | 0.026 | 0.036 | 0.010 | 0.012 | 0.034 | 0.933 | 0.935 | 0.870 | 0.856 | 0.815 | 0.872 | 0.749 |
| $X+Y$ | 2.019 | 1.989 | 2.015 | 2.019 | 1.994 | 2.003 | 1.984 | 1.982 | 2.023 | 1.999 | 1.996 | 1.989 | 2.052 | 1.976 |
| $\frac{100\ Mg}{Mg+Fe^2+Fe^3+Mn}$ | 75.06 | 73.15 | 72.29 | 59.16 | 59.42 | 58.10 | 54.40 | 82.76 | 72.30 | 71.41 | 71.08 | 71.03 | 60.19 | 52.04 |
| $Fe^2/Mg$ | 0.3148 | 0.350 | 0.375 | 0.6735 | 0.666 | 0.715 | 0.810 | 0.172 | 0.355 | 0.3691 | 0.380 | 0.412 | 0.450 | 0.778 |
| Ca | 1.57 | 3.98 | 1.39 | 1.89 | 1.06 | 0.58 | 1.82 | 28.00 | 49.60 | 46.63 | 47.87 | 43.73 | 46.97 | 40.63 |
| Mg | 73.91 | 70.97 | 70.81 | 58.60 | 59.42 | 57.21 | 53.52 | 42.05 | 36.40 | 38.11 | 37.04 | 39.15 | 36.16 | 31.56 |
| $2V\alpha$ | 72° | 70° | 70° | 57° | 57° | 56° | 55° | — | — | — | — | — | — | — |
| $2V\gamma$ | — | — | — | — | — | — | — | 61° | 63° | 63° | 64° | 64° | 66° | 66° |
| $\gamma\wedge[001]$ | 0° | 0° | 0° | 0° | 0° | 0° | 0° | 42° | 42° | 42° | 43° | 44° | 44° | 44° |

144. Pyroxenite from NE of Jambadai, Pavittiram area.
215A. Garnetiferous pyroxene granulites from Tolutu Karadu, Namakkal.
15. Garnetiferous pyroxene granulite two miles East of Namakkal.
329. Garnetiferous pyroxene granulite from Jambadai, Pavittiram area.
593. Pyroxene granulite from NW of Sendamangalam, Namakkal.
557. Pyroxene granulite from SE of Vadagupatti, Namakkal.
404. Pyroxene granulite from SE of Nainar Malai, Namakkal.
396. Amphibole-bearing pyroxene granulite from Marurpatti, Namakkal.
14. Silicified pyroxene granulite from West of Valaiyapatti, Namakkal.

pyroxenes. The granulites consist of pyroxenes and plagioclase ($An_{35}$ to $An_{60}$) sometimes with garnet, and having amphibole, apatite, opaques, and quartz as accessories. The six analysed orthopyroxenes (Table I) range from $En_{58}$ to $En_{75}$. The Al content is variable but generally high and is not apparently related to host rock $Al_2O_3$ or the composition of the coexisting plagioclase and so it is suggested that high pressure is important, following previous opinions (e.g. Leelanandam, 1967). The six analysed clinopyroxenes (Table I) are sahlites with one ferroaugite. The metamorphic and igneous clinopyroxenes coexisting with orthopyroxene do not exhibit significant differences of trend. The ratio $(Fe^{2+}/Mg)_{opx}/(Fe^{2}/Mg)_{cpx} = K_p$ obtained for the five coexisting pyroxene pairs varies from 1·7 to 1·8. Bartholome (1962), Kretz (1963), and Engel, Engel, and Havens (1964) have constructed a diagram showing $K_p$ as function of temperature of crystallization. This gives an average temperature of around 650° for the present rocks.

The distribution coefficient

$$K_D = [Mn/(Mg+Fe^2+Mn)]_{opx}/[Mn/(Mg+Fe^2+Mn)]_{cpx}$$

is 1·1 for the granulites with one sample having 1·2. Kretz (1963) suggested 1·2 is the $K_D$ value for the granulite facies. From $K_p$ and $K_D$ then it may be suggested that the pyroxenes attained chemical equilibrium in the granulite facies.

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REFERENCES

BARTHOLOME (P.), 1962. *Geol. Soc. Amer., Buddington vol.*, 1.
ENGEL (A. E. J.), ENGEL (C. G.), and HAVENS (R. G.), 1964. *Geol. Soc. Amer. Bull.* **72**, 131.
KRETZ (R.), 1963. Ibid. **71**, 773.
LEELANANDAM (C.), 1967. *Min. Mag.* **36**, 153.

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# Occurrence of peculiar tabular zircon crystals

DURING a systematic study of zircon typology in endogenous rocks, we were led to examine the distribution of tabular zircon mentioned by Phillips (1974) as existing in these types of rocks; 245 samples were studied.

We found, like Phillips, that this tabular zircon is made up of idiomorphic grains flattened on two faces {110} and shows an elongation ratio less than 1. These zircons correspond to the subtypes $S_{3-4-5}$, $S_{8-9-10}$, and more rarely $P_{1-2}$ according to the typological classification of Pupin and Turco (1972a). Most of the grains are clearly