for the formation of baryte in the more porous rock, while a much lower f_{O_2} in the recrystallized type resulted in the formation of helvine.

The baryte–fluorite assemblage in the epigenetic veins of this area helps to group them in the upper part of the epithermal zone of hypogene mineralization (Hewett, 1965). The presence in the wall-rock of the veins of a zinc mineral that is totally absent from the unaltered gondite and the associated bedded deposits is interesting and is an indicator of the presence of base metal sulphides at depth.

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High-calcic pigeonite from pegmatitic segregations in a dolerite dyke from Huli, Mysore State, India

ELONGATED columnar crystals of high-calcic pigeonite (see below), 5 to 30 mm long form an important constituent of the pegmatitic segregations in a dolerite dyke at Huli. The outcrop is marked in a generalized geological map accompanying a detailed geological account of the area by the author (Sathe, *et al.* 1966). The dyke is exposed on a hill-side, $\frac{1}{2}$ km W. of Huli.

The pegmatitic segregations contain two pyroxenes, high-calcic pigeonite and augite, in the ratio of 30:70. Textural evidence points to early precipitation of augite and later growth of pigeonite. Thin-section study shows that the pigeonite is not exsolved from orthopyroxene but forms discrete small euhedral to subhedral grains and also elongate columnar crystals.

The pigeonite is pinkish-brown in colour and feebly pleochroic. Universal stage plots for 10 grains gave $2V_\gamma$: 0°, 26°, 30°, 24°, 28°, 30°, 31°, 19°, 24°, 26°. For γ:[001] the grains respectively gave: 30°, 38°, 39°, 38°, 36°, 38°, 39°, 33°, 38°, 38°. Birefringence varies from 0·002–0·004, and β from 1·678–1·689. The mineral does not exhibit any exsolved orthopyroxene laminae. It tends to occur side by side with augite which gives 2V from 49° to 59° and γ:[001] from 45° to 48°. In view of the unexsolved origin of the pigeonite and its coexistence with augite, the mineral was crushed, carefully

tested under the microscope and separated for chemical analysis, which gave: SiO_2 50·75, TiO_2 0·60, Al_2O_3 1·23, Fe_2O_3 1·61, FeO 16·20, MgO 14·48, MnO 0·31, CaO 14·91, Na_2O and K_2O nil, total 100·09 %; the atomic ratios on a basis of 6 oxygen are: Si 1·935, Ti 0·015, Al^{iv} 0·050, Al^{vi} 0·004, Fe^{3+} 0·045, Fe^{2+} 0·513, Mg 0·825, Mn 0·009, Ca 0·606, or $MgSiO_3$ 42·3, $FeSiO_3$ 26·7, $CaSiO_3$ 31·0 mol. % (Anal. R. V. Sathe).

Though this composition falls in the augite field of Poldervaart and Hess (1951), the low optic axial angle brings it within the older definition of pigeonite. It is, however, an unusual pyroxene, and has evidently formed under some special conditions of cooling from a magma of appropriate composition.

It was long believed that pigeonite is restricted to flows. However, since the studies of Walker and Poldervaart (1941) on the Hangnest sill, South Africa, Edwards (1942) on the Mt. Wellington sill, Tasmania, and Naidu (1943) on quartz dolerites of Halguru, it has been accepted that it is not restricted to flows only but is also found in dykes and other intrusions of all ages, and it is the cooling history and the composition of the magma that control the development of pigeonite and other clinopyroxenes.

Origin of the high-calcic pigeonite. As mentioned above this mineral follows the early precipitation of augite, by crystallization on the augite liquidus within the field of pyroxene immiscibility. With slight undercooling an augite solid solution stable at lower temperature separates. With strong undercooling, the liquid could reach the metastable liquidus of the Ca-poor phase and precipitate a metastable member of the Ca-poor pyroxene series, viz high-calcic pigeonite. Spontaneous crystallization of augite would not interfere with this course until undercooling of 30° to 50° occurs (Doelter, 1905). Release of latent heat would prevent the high-calcic pigeonite from further lateral growth but would not hinder its extension as thin columnar crystals into fresh volumes of supersaturated melt.

Yoder *et al.* (1963) regard high-calcic pigeonite as a quenching product of extrusive rocks. Muir and Tilley (1964) have compared the quench crystallization trend and the intra-telluric trend for basaltic magmas. The nature of pyroxene crystallization of the two types of rocks is evidently related to pyroxene miscibility under varying conditions, but the composition of the quenching pyroxene may be related to metastable extension of liquidus boundaries rather than suppression of the solvus.

The cause of undercooling is rather difficult to explain. It is probable that some initial loss of fugitive constituents of the magma may have increased its viscosity, reduced stirring movements, and produced the necessary degree of undercooling to nucleate the quenching product. Thus for each solid solution series, augites and pigeonites, crystallization once started could continue below the eutectic temperature if the second phase failed to appear, and the extent of crystallization below this point would be largely determined by the rate of cooling or the rate of crystallization and the temperature of labile crystallization of the second phase. Further, when rapid cooling inhibits the initial precipitation of pyroxene, and subsequent crystallization occurs at the metastable extension of a liquidus surface, then the course of crystallization will depend on the initial composition. Liquids normally crystallizing augite would precipitate, metastably, a high-calcic pigeonite, and the liquids normally separating pigeonite would develop sub-calcic augite.

Conclusion. It appears that the initial tholeiitic magma, after the early precipitation and settling of olivine, was intruded in a dyke fissure. Strong undercooling, due probably to some loss of fugitives or also to the comparatively cool walls of the fissure, led to the nucleation of high-calcic pigeonite, the release of heat of crystallization keeping pace with the undercooling, so that its crystallization continued, promoting the growth of large elongate crystals in a melt that became supersaturated.

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On the blue colour of natural banded fluorites

K. J. D. MACKENZIE and J. M. Green propose, in a recent article (this vol., p. 459), an explanation of the blue colour of natural fluorites based upon the presence of colloidal calcium particles. It seems, however, that this explanation—from studies on specimens gathered in two places (Ashover, Derbyshire, and Weardale, Co. Durham) —cannot be generalized and should be received with the greatest prudence. It is surprising, in fact, not to see recent studies on natural (Bill *et al.,* 1967) or synthetic (Staebler and Schnatterly, 1971) fluorites, to explain this blue colour.

Firstly, it is necessary to remind the reader that the classic 'four-band spectrum', first found by Smakula in X-irradiated fluorites, is constituted by bands at 224, 335, 400, and 580 nm. O'Connor and Chen (1963) have shown the action of yttrium concentration on this spectrum; from studies of Staebler and Schnatterly (1971) on synthetic fluorites doped with yttrium and some rare earths (La, Ce, Gd, Tb, and Lu)