COMPLEX PYROXENES IN WYOMING DIABASE DIKES: LUNAR ANALOGUES


A microprobe study of the mineralogy of various types of diabase dikes in the Wyoming Precambrian craton, northwestern USA, has revealed that these rocks have complex primary pyroxene assemblages, manifest principally by variations in their Ca, Mg and Fe contents. These complex pyroxenes contrast with the relatively simple ones found in most gabbroic intrusions, whose uniform compositions frequently reflect differentiation over the scale of the intrusion. Pyroxenes in Lunar mafic rocks are characterised by extreme chemical zoning, and provide an insight into crystallisation histories and differentiation on a microscopic scale. The Wyoming dike pyroxenes appear also to preserve evidence of considerable differentiation on a grain scale, and in this respect they are more closely analogous to Lunar pyroxenes than to their terrestrial plutonic counterparts.

Dykes from the Bighorn, Beartooth, Laramie and Granite Mountain ranges all contain a wide variety of pyroxenes. Most of the examined Laramie range dikes have sub-solidus assemblages, partially or completely re-equilibrated during deuteric or secondary alteration. Three principal types of primary pyroxene assemblages have been recognised, corresponding to Types I, II and II from elsewhere. The first type constitutes 1-, 2-, and rarely 3-pyroxene assemblages in which each phase shows little Ca variation but a very wide range of $X_{Mg} (Mg/(Mg+Fe))$ values. For example, the ophitic pyroxenes in one sample from the Bighorn Mountains comprise intergrown augites ($Wo_{30-35}$) and pigeonites ($Wo_{12}$) with $X_{Mg}$ ranging from 0.73 to 0.38 (Fig.1a). In some grains pigeonite precipitation appears to have preceded that of augite, while in other grains the reverse is true. The calcic pyroxenes in another dike have $X_{Mg}$ ranging from 0.8 to 0.3 (Fig.1b) accompanied by a sequential decrease in Ca content ($Wo_{40-25}$). The pyroxenes in Wyoming dike samples such as this indicate differentiation on a millimetre scale equivalent to half of that shown by entire Skaergaard-type intrusions (3,4). Many Lunar samples show extreme Fe-enrichment in variably calcic pyroxenes (e.g. Fig.1c).

The pyroxenes in magnesian dikes in the Bighorn and Beartooth Mountains show a considerable Ca variation, but a more limited $X_{Mg}$ range (Fig.2a). The Beartooth dikes have been investigated previously in terms of their contrasting compositions, possible relation to parental magmas of the Stillwater Complex and their Lunar noritic analogues (1,5,6). The mineralogy of these dikes is dominated by phenocrysts of Ca-poor pyroxene (orthopyroxene and pigeonite) mantled by variably calcic pyroxene, in a groundmass of more Fe-rich pyroxenes.
with equally variable Ca contents, and labradoritic plagioclase. Apollo 15 noritic rocks show a similar (though more extreme) pyroxene evolution (Fig.2b).

Type III pyroxenes mainly comprise Ca-poor augites which vary from more calcic magnesian types to subcalcic ferroaugites. In individual samples this range corresponds to a variation in X_{Mg} values of around 0.4. However, the zoning trends are neither clearly defined nor consistent. Some show no correlation between Ca and Mg/Fe variation, while others develop from calcic and Ca-poor pairs to more subcalcic ferroaugite (Fig.3). This variation is demonstrated by individual grains rather than the differences between neighbouring grains. The differences in zoning from one part of a grain to another indicate multiple nucleation and partitioning effects on a sub-grain scale.

The differences between the compositional ranges and zoning trends in the three main types of pyroxenes clearly reflect differences in the physico-chemical conditions under which they crystallised, among which the most important are presumably magma composition and cooling rate. Ca diffusion gradients are clearly affected by the timing of plagioclase precipitation, while Fe and Mg differentiation are closely related to the timing of Fe-bearing oxide phase crystallisation, which in turn depends largely on fO2. The late precipitation of ulvospinel in the tholeiite dykes is clearly significant in this respect. Despite some obvious differences, analogous crystallisation conditions are demonstrated more extremely by Lunar basaltic rocks.