Western Gabbro -petrology - St. Kilda: an illustrated account of the geology

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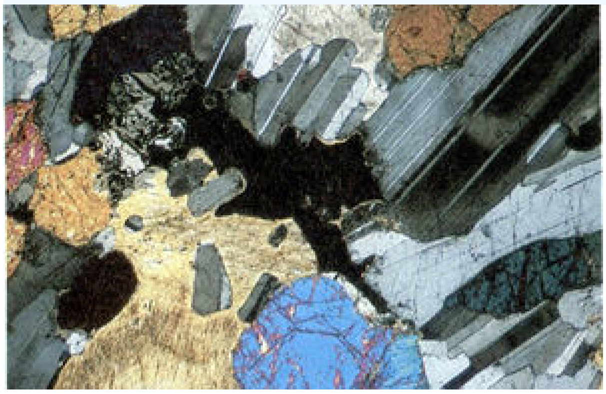

Figure 4A Rounded grains of olivine (blue and orange) are partly enclosed by augite (pale brown) next to magnetite and ilmenite (black) and to zoned plagioclase (grey). A fine vermicular intergrowth of orthopyroxene with magnetite and ilmenite occurs at one end of the central opaque mass. S65855, a Type I gabbro similar to that in (Figure 3B); cross polarised light; field 4 mm wide.

Figure 4B Mineral lamination in Type 3 gabbro from Claigeann an Tigh Faire. S65853, cross polarised light; field of view represents 4 mm (width) of rock.

Figure 4C Poikilitic augite (yellow) 2 mm across contains rounded inclusions of plagioclase (grey) and olivine (red and orange) which are smaller than the same mineral species outside the pyroxene. S64305 from the top of Mullach Bi; cross-polarised light.

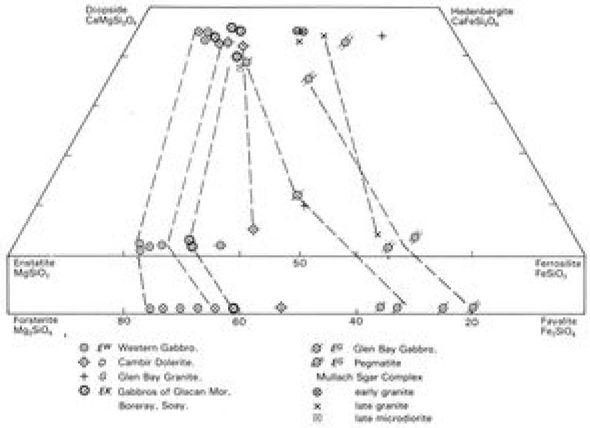

Figure 5 Pyroxene and olivine compositions of St Kilda igneous rocks. Compositions of minerals found in the same thin section are joined with tie lines.

Chapter 3 Western Gabbro: petrology

Keywords: mineralogy, texture, microprobe analyses

Feldspar, clinopyroxene and olivine form a number of interlocking granular and poikilitic textures in the Western Gabbro and some are illustrated in the photomicrographs (30 μm thick sections of rock photographed through a polarising microscope). The optical properties and composition of many minerals may be determined from such sections, and textural details of their relationships within the rock give some idea of how the rock was formed.

Plagioclase, a mixture of anorthite (An, $CaAl_2Si_2O_8$) and albite (Ab, $NaA1Si_3O_8$), is the most abundant mineral, generally forming 50–75% of the rock although in places it may be scarce (< 30%) or, as in (Figure 3B), concentrated in thin anorthosite bands (100%). In the Western Gabbro most grains have calcium-rich cores of composition between $An_{88}Ab_{12}$ and $An_{75}Ab_{25}$, and one or more outer zones that vary between $An_{80}Ab_{20}$ and $An_{55}Ab_{45}$. Sharply defined zone boundaries in some crystals indicate rapid changes in conditions of crystallisation and suggest that these grains have been moved into different parts of magma chamber, perhaps by flow in a silicate melt or crystal mush, whereas gradational zoning shown by a large proportion of the plagioclase indicates much slower changes in the chemical and physical environment during crystallisation. Rocks containing unzoned crystals are probably a result of static conditions where the process of ionic diffusion supplied material from the main body of magma to the growing crystals. Each plagioclase grain within the area of a thin section (2 cm^2) does not necessarily show the same zonal or compositional pattern, some grains may be unzoned, some with 2 or 3 zones and a few with 5 or 6, and this suggests that these crystals have accumulated from different environments. In many gabbros the first-formed plagioclase crystals are calcic and, as the intrusion cools, more sodic compositions are added. This process may be recorded in the feldspars as a 'normal' zoning pattern where progressively more sodic zones crystallise towards the grain margin. Normal and reverse zoning patterns are common in the Western Gabbro feldspars but an unusual feature of many grains is that, regardless of their inner zonal variation, they have relatively calcic rims.

In Type 2 gabbros (from Mullach Bi to Ruaival and Dun) olivine and plagioclase form a granular mosaic in which crystal shape has been determined by the mutual interference of grains during cooling and solidification of the rock. One can envisage a slowly cooling basic magma from which primary or cumulus crystals of olivine and plagioclase accumulated to the extent of about 60% of the mass. At this stage mechanical movement probably ceased and on further cooling of the liquid between the crystals (intercumulus liquid) more plagioclase and olivine formed on the primary grains, and large poikilitic clinopyroxenes grew into the remaining spaces. Nearly all the pyroxene in Type 2 gabbro was formed in this way, and its average size of 20 mm and its skeletal form is in marked contrast to the granular habit of pyroxene in some Type 3 gabbros (Figure 4B), and the modified granular habit characteristic of Type 1 gabbro. In Type 3 gabbros near Mullach Bi and Claigeann Mor, a third kind of pyroxene is part cumulus and part intercumulus in origin (Figure 4C), the cores having commenced crystallisation early and containing feldspars which are much smaller than those outside the pyroxene and the rims enclosing grains at a much later stage in their growth. These pyroxenes resist weathering to a greater extent than olivine and plagioclase and stand out on the gabbro surfaces creating a characteristic knobbly appearance (Figure 3D).

Despite these different habits, the compositional range of the clinopyroxene is small and, in terms of its three major components, the molecular percentages are: $MgSiO_3$, 42–45; $CaSiO_3$, 43–45; and $FeSiO_3$, 11–15. These values were obtained by analysing grains in polished thin sections with an electron microprobe. On the pyroxene diagram (Figure 5) they lie in the augite field, close to augites from gabbros in Glacan Mor, Boreray and Soay, but quite separate from clinopyroxenes in the Cambir Dolerite and the Glen Bay Gabbro. Orthopyroxene (hypersthene) and olivine compositions are shown on the same diagram and where these occur in the same slide as the augite this is indicated by a tie-line. Olivine composition in the Western Gabbro expressed as molecular proportions of forsterite (Mg_2SiO_4) and fayalite (Fe_2SiO_4) generally varies between $Fo_{78}Fa_{22}$ and $Fo_{70}Fa_{30}$ but individual crystals are unzoned. Orthopyroxene also shows a small range in composition and is typically found intergrown with opaque minerals (Figure 4A).

Magnetite (Fe_3O_4) and ilmenite ($FeTiO_3$) occur in small amounts as discrete irregular grains or intergrown with orthopyroxene (Figure 4A). In thin section they are opaque but examination in reflected light reveals a considerable amount of intergrowth. Microprobe analysis of the grains further indicates wide variation in magnetite composition with up to 25% TiO_2, 19% Cr_2O_3, 1% NiO or 1% V_2O_3 present in different grains, and up to 10% spinel ($MgAl_2O_4$) in the magnetite intergrown with orthopyroxene. Minor amounts of relatively pure magnetite occur as needles in clinopyroxene and as granules on the edges of altered olivine grains. Green spinel is a minor and sporadic constituent of Type 3 gabbros and occurs next to olivine or surrounded by amphibole and chlorite in zones of alteration. Its composition is $(Mg_{0.6}Fe_{0.4})Al_2O_4$ with possibly a trace of chromium. Minute quantities of sulphide minerals (mainly chalcopyrite with a little pyrite) occur either on the boundaries of larger grains or included in plagioclase.

The wide range in abundance of the minerals in different parts of the Western Gabbro is associated with a comparable range in whole-rock chemical composition, and it is difficult to determine the average composition of the gabbro. For this reason selected analyses which illustrate the range are given in the table and in (Figure 5) the range of the olivine and pyroxene composition is set in the context of values obtained from analyses of these minerals in other St Kilda rocks.

References

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