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PETROGRAPHIC AND GEOCHEMICAL EVIDENCE FOR CRUSTAL CONTAMINATION IN SOME KEWEENAWAN FLOWS AND DYKES FROM MAMAINSE POINT, ONTARIO

N. W. D. MASSEY
*Department of Geology, McMaster University, Hamilton, Ontario L8S 4M1**

ABSTRACT

Partially resorbed plagioclase xenocrysts, subrounded to irregular glassy matrix domains and spherical glass globules are reported in some flows and dykes from the Mamainse Point Formation (Mamainse Point, Ontario). The same samples show anomalous trace-element behavior, compared to normal flows. These features are explained by the incorporation and incomplete mixing into the basalt host of crustally derived felsic melts.

Keywords: Keweenawan rift, basalts, contamination, textural heterogeneities, geochemistry.

SOMMAIRE

Certaines coulées basaltiques et dykes associés de la formation Mamainse Point (à Mamainse Point en Ontario) contiennent des xénocristaux de plagioclase partiellement résorbés, dans une pâte à domaines vitreux irréguliers ou quelque peu arrondis montrant aussi des globules sphériques de verre. Comparés aux coulées normales, les échantillons montrent un comportement anomal des éléments en traces. On explique ces observations par l'incorporation au basalte de roches felsiques fondues incomplètement miscibles provenant de la croûte terrestre.

(Traduit par la Rédaction)

Mots-clés: rift de Keweenaw, basaltes, contamination, hétérogénéités texturales, géochimie.

INTRODUCTION

The Mamainse Point Formation, which accumulated on the margin of the Late Proterozoic Keweenawan rift, consists of olivine- and feldspar-phyric tholeiitic flood basalts with minor felsic intrusive bodies and conglomeratic sediments (Annells 1973, Thomson 1953). The sequence rests unconformably on the Archaean basement. Despite the effects of low-grade burial metamorphism in the zeolite and prehnite–pumpellyite facies (Smith 1974, Massey 1980), primary textures are preserved in the basalts, and many trace elements appear to have been immobile.

PETROGRAPHY OF THE FLOWS

The basaltic flows consisted originally of varying proportions of olivine, labradorite, augite, magnetite and glass. Common textures are poikilophitic, subophitic or intersertal, but coarser glomeroporphyritic and gabbroic types also occur. Usually, only sparse ($<5\%$) phenocrysts of olivine and plagioclase are found, although some of the flows nearest the base are variably enriched in cumulate(?) olivine phenocrysts.

A few flows about 2800 m above the base show distinctive features not seen in the rest of the sequence. Apart from phenocryst and groundmass plagioclases similar to those in other flows (Fig. 1A), they also contain rounded to euhedral crystals of plagioclase with abundant dark inclusions that are often aligned parallel to the long axis or the margins of the grains (Fig. 1B). Such crystals exhibit a clear, inclusion-free marginal zone. They may show sector zoning of optical properties. Albite twinning is occasionally seen, though obscured by the abundant inclusions that render compositional determinations impossible.

These grains appear to be xenocrysts that were out of equilibrium with adjacent melt and that have reacted with it. Digestion has occurred along cracks in the grains; the inclusions may represent melt droplets formed during incipient melting in the grain.

Also found within these rocks are small, irregular to roundish patches of matrix of cryptocrystalline aspect (owing to quench?), which differs markedly from the surrounding coarse matrix (Fig. 1C). These textural heterogeneities are not seen in other flows.

PETROGRAPHY OF THE DYKES

Dykes are scarce in the Mamainse Point

*Present address: c/o School of Physical Sciences, University of Port Harcourt, P.M.B. 5323, Port Harcourt, River State, Nigeria.

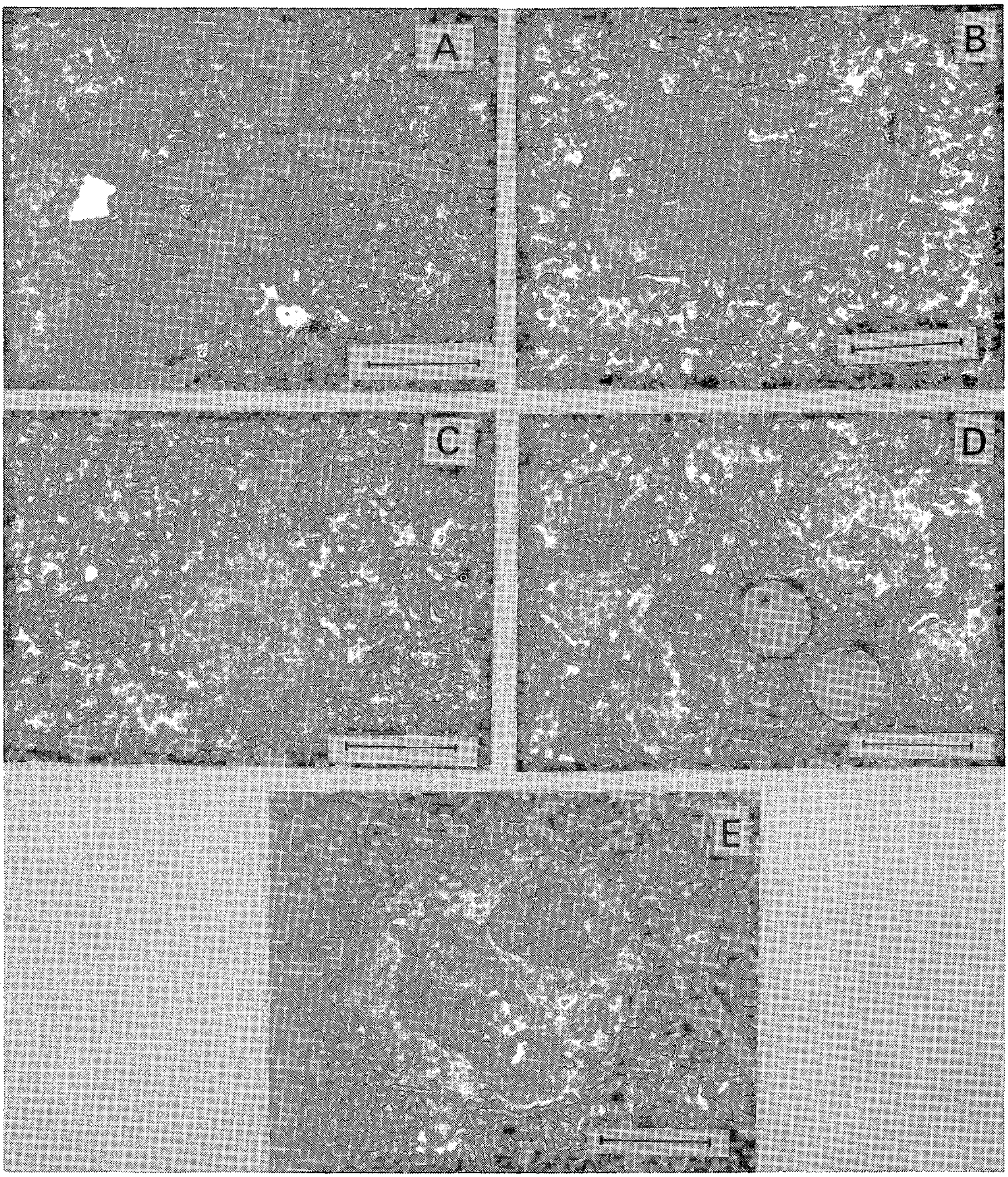

FIG. 1. A. Normal plagioclase phenocrysts in a series III flow, partly replaced by chlorite and epidote. Transmitted light, scale bar = 1 mm. B. Plagioclase xenocryst, same sample as A. Note trails of melt inclusions, resorption along cracks and clear reaction rim. Transmitted light, scale bar = 1 mm. C. Roundish glassy domain in normal intersertal matrix. Same sample as A and B. Transmitted light, scale bar = 0.25 mm. D. Glass globules and vesicles in a dyke. Two vesicles infilled by chlorite. Glass globules replaced by plagioclase microlites, oxide dendrites and chlorophaeite. Two globules (upper left and lower right corners) contain chlorite-filled "bubbles". Transmitted light, scale bar = 1 mm. E. Glass globule with two irregular "bubbles" (infilled with calcite and hematite). Matrix plagioclase arranged tangentially to the globule. Transmitted light, scale bar = 1 mm.

area; only a dozen or so were observed in the 4000 m of section. Only one holocrystalline, diabasic sample was found; the others are sparsely porphyritic to intersertal in texture, with labradorite phenocrysts set in an intersertal matrix of plagioclase ± augite + magnetite + glass. Vesicles are common, suggesting a shallow level of intrusion.

Devitrified glass shows several modes of occurrence in the dykes. Apart from normal mesostasis between plagioclase grains or quench around some large vesicles, some glass occurs as irregular to roundish domains similar to the patches in the flows described above. These grade into normal groundmass at their edges and may include plagioclase microlites. More distinctive are the spherical globules or bleblets found in three of the dykes (Figs. 1D, 1E). These vary in size from 0.3 to 1.8 mm in diameter (av. 0.7 mm) and are spherical with distinct and sharp contacts with the surrounding rock. Some globules contain a vesicular "bubble" within them, which may be in contact with the globule wall. The bubbles also have spherical contacts with the glass. Vesicles in the same thin sections are similar in size and shape, but are defined by an opaque integument rather than any glassy selvedge.

Discussion

Features similar to those noted above, although rarely together in one area, have been described by several authors. The glass globules are similar to the segregation vesicles of Smith (1967), and are also observed in ocean-floor basalts (Baragar *et al.* 1977, Sato 1978). They are interpreted as vesicles that have been infilled with residual melt from the crystallizing magma surrounding them, as the original gas fillings contract. For this mechanism, pressure differences between vesicles and matrix should be similar in all cases, at least on the thin-section scale; all vesicles should thus be infilled to the same degree. This is clearly not the case, as is shown by the variability in bubble size in the globules and the presence of vesicles devoid of glass next to completely filled vesicles (Fig. 1D). The occurrence of globules with two bubbles (Fig. 1E) is also difficult to explain by this mechanism.

Other authors have ascribed similar globule structures to silicate-liquid immiscibility. The immiscibility may be real, resulting from the separation of two liquid phases during fractionation of an original single melt (Arndt 1975, Philpotts 1976), or may be pseudo-immiscibility, due to the incorporation of droplets of a second melt into the magma and failure to achieve homogenization (Holgate 1978). The less well defined glassy domains found in other dykes and in the flows may represent a first stage in the mixing process, frozen in before completion. The plagioclase xenocrysts undoubtedly suggest that extraneous material was available to these flows and dykes, further supporting the interpretation of the glass globules and domains as pseudo-immiscible droplets that have failed to mix with the host basalt. Two possible sources for the contaminant melt can be suggested: either felsic material derived from mobilized sialic country rock (Holgate 1978) or fractionated residual liquid in the magma chamber, *i.e.*, a case of magma mixing (Shibata *et al.* 1979).

Geochemical Evidence

Based on the stratigraphic variation of immobile elements such as Ti, P, Y, Zr, *etc.*, the Mamainse Point basalts can be divided into five series, each being derived from its own parental magma by fractionation of olivine–chromite–plagioclase assemblages (Massey 1980). Within each series good positive correlations are found between incompatible ele-

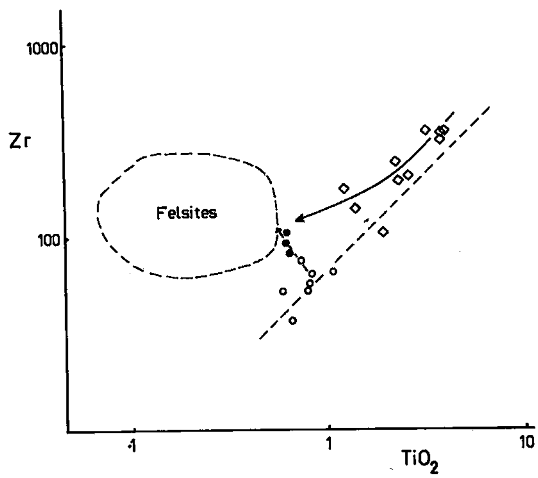

FIG. 2. TiO_2 (wt. %) *versus* Zr (ppm) for dykes (◇) and series III flows (○ normal flows, ● flows with textural heterogeneities). Dashed line indicates trend found in normal lavas. Arrows indicate the effects of contamination by felsic material; the field occupied by Mamainse Point felsic rocks is labeled *Felsites*.

ments, constant ratios being maintained. However, flows containing plagioclase xenocrysts and glassy domains deviate markedly from the other samples of their series (series III), showing negative correlation between Ti and Zr (Fig. 2). Similar anomalous behavior is found with Y, Nb, U and the rare earths. Felsites from the Mamainse Point Formation occupy a large field at the end of both this anomalous trend and the trend shown by the dykes. The felsites are fairly heterogeneous chemically (Annells 1973, Jackson 1977, Massey unpubl. data) and cannot be derived in any simple way by the differentiation of the mafic lava series. They are more likely the products of partial melting of the variable sialic crust that forms the basement to the Mamainse Point sequence (Annells 1973). They are thus a good example of crustally derived contaminating melt, which can be accidentally incorporated into ascending magmas and, by incomplete mixing, produce the petrographic features described and the anomalous geochemical behavior found in the same rocks.

The bimodal character of the Mamainse Point and other Keweenawan sequences suggests that contamination was generally minimal. Contamination has, however, been put forward by Annells (1974) as the mechanism for the generation of intermediate flows in the Michipicoten Island Formation. Some of these andesites show textural heterogeneities (spheroidal blebs, mesostasis domains, *etc.*) and chemical characteristics (high Zr and Ba contents) in line with those described here.

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