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BARBERTON GREENSTONE BELT VOLCANISM: SUCCESSION, STYLE, AND PETROGENESIS; Gary R. Byerly and Donald R. Lowe, Department of Geology, Louisiana State University, Baton Rouge, Louisiana 70803 USA

The Barberton Mountain Land is a small but remarkably well-preserved and accessable early Archean greenstone belt along the eastern margin of the Kaapvaal Craton of southern Africa. Although there is some question about the role of structural repetition of various units, detailed mapping in the southern portion of the belt leads to the conclusion that a substantial thickness is due to original deposition of volcanics and sediments (1). In the area mapped, a minimum thickness of 12km of predominantly mafic and ultramafic volcanics comprise the Komati, Hooggenoeg, and Kromberg Formations of the Onverwacht Group, and at least one km of predominantly pyroclastic and epiclastic sediments derived from dacitic volcanics comprise the Fig Tree Group. Much greater apparent thicknesses of Fig Tree are due to numerous structural repetitions. The essentially non-volcanic Moodies Group lies conformably on top of the Fig Tree. The position or correlation for the Sandspruit and Theespruit Formations relative to the above units is not known. The Barberton greenstone belt formed primarily by ultramafic to mafic volcanism on a shallow marine platform which underwent little or no concurrent extension. Vents for this igneous activity were probably of the non-constructional fissure type. Dacitic volcanism occurred thoughout the sequence in minor amounts. Large, constructional vent complexes were formed, and explosive eruptions widely dispersed pyroclastic debris. Only in the final stages of evolution of the belt did significant thrust-faulting occur, generally after, though perhaps overlapping with, the final stage of dacitic igneous activity.

The volcanic succession in the Barberton greenstone belt is often used as a general model for greenstone belt stratigraphy (2). Previous workers have suggested that volcanism there was cyclic, ultramafic to mafic to felsic, on a scale that ranged from tens of meters to tens of kilometers in stratigraphic thickness, with small cycles superimposed on large cycles. In the grossest sense, the base of the sequence is predominantly komatiitic and the top dacitic, but beyond this the detail of volcanic succession is complex. Thin units of dacitic tuff are recognized within the Komati Formation and komatiitic lavas are interbedded with Fig Tree Group sediments. Simple, small-scale cycles are not present. Sequences previously interpreted as small-scale cycles are now known to represent thick, stratiform alteration zones of mafic and ultramafic lavas to silicic rocks with a remarkably calc-alkaline-like chemistry (3). Systematic increases in Si,K, and Rb accompany decreases in Fe,Mg, and Ni, while Al,Ti, and Zr remain constant from base to top in these cyclic units(4). Throughout these alteration zones the flows typically have mafic volcanic textures and structures, and are usually fine-grained and in places pillowed. Preserved spinels in silicified rocks initially crystallized in mafic or ultramafic lavas. After taking into account the nature of this common style of alteration it appears there are no obvious systematic trends in lava composition in the stratigraphic sequence. Notably, however, the two thick sequences of dacitic volcanics seem to represent prolonged volcanic episodes with no mafic or ultramafic activity.

Komatiitic or basaltic igneous activity seems also to occur with little or no other type of igneous activity in three or four thick sequences.

Styles of igneous activity vary primarily as a function of lava composition. Komatiites throughout the sequence occur as massive flows with typical spinifex textures or as thick flows that often display cumulus-layered bases or as pillowed flows and only rarely as hyaloclastite units. In most sections the flows are quite thin, typically 50cm to 5m, and only rarely up to 50m. They are rarely vesicular, suggesting deep water extrusion, but in several sections interbedded sediments are of shallow-water origin. We have observed no vent complexes for the komatiites, though they are relatively widespread units. The komatiitic unit within the Hooggenoeg can be traced for over 50 km of strike around the Onverwacht anticline. The komatiitic unit beneath the Msauli Chert crops out over a similar distance. Only in the uppermost komatiitic unit is there a local lateral facies; here the lavas interfinger with shallow marine sediments and were of more local extent, though again no vents are recognized. Basaltic igneous activity is characterized by thick to thin lava flows, in places pillowed or massive and only rarely by pillow breccias. Two separate basaltic sequences in the Hooggenoeg crop out for 50 km along the Onverwacht anticline. These lavas are non-scoriaceous, but commonly contain up to 5% vesicles primarily as radial vesicles about the margins of pillows. The lower basalts of the Kromberg occur as a thick sequence of lapilli tuffs, especially thick on the west limb of the Onverwacht anticline (5). These units are locally crosscut by irregular dikes and sills of basalt, and in places contain blocks and bombs of both juvenile and accidental lithologies. They appear to represent near-vent facies and were perhaps similar to modern basaltic cindercone fields. Some lithologies in this unit are moderately scoriaceous. Laterally, these units are represented by interbedded sediments and pillowed to massive lava flows. Dacitic igneous activity is represented on two different scales: by the relatively common tuffaceous units that occur throughout the section, and by very thick sequences of lavas, pyroclastics, and epiclastics at two locations in the sequence (1). Thin, typically a few tens of cm but rarely to a few tens of m, tuffaceous units occur throughout the sequence, and are usually completely altered to a micromosaic of quartz and sericite. Textures are remarkably well preserved, however, and indicate highly pumiceous particles often in the form of accretionary lapilli commonly in graded airfall beds. These units are regionally extensive, greater than 50 km strike length, but associated vent complexes are not found. The two major dacitic units, at the top of the Hooggenoeg and top of the Fig Tree, clearly represent vent complexes. They form complex associations of lava flows or domes, breccias, and tuffs hundreds of m thick. Along strike systematic changes in lithologies can be recognized where sedimentary rocks represent debris being shed off the constructional vent complex. These units do not appear to be laterally interbedded with more mafic lavas.

Petrogenesis of Barberton greenstone belt volcanics is not likely a single, one-stage process. Indeed, the succession of units and common isolation of one compositional group from the others may even require a separate petrogenesis for komatiites, basalts, and dacites. Komatiites from the top and the base of the sequence are remarkably similar in composition (4,6,7). They are typical of komatiites worldwide except for very low Al/Ti, very high Ti/V, and other ratios that require a very depleted upper mantle source (6). Otherwise, most compositional variation within the komatiitic suite seems consistent with low-pressure fractionation of olivine, later joined by clinopyroxene in komatiitic basalts. Basalts of the Hooggenoeg and Kromberg Formations have typical tholeiitic compositions, including a pronounced iron-enrichment and lack of alumina-enrichment, that can be produced by low-pressure fractionation of plagioclase, clinopyroxene, and olivine. Immobile trace elements and their ratios, such as very low LREE/HREE, also require a depleted upper mantle source. Compositional data are not inconsistent with a single liquid line of descent of komatiites and basalts. While both komatiite and basalt sequences suggest substantial low-pressure fractionation there is not generally an adequate mass of layered intrusives to account for this fractionation in situ. The Barberton sequence contains less than 5% layered intrusives, yet basaltic komatiites and Fe-rich basalts each require 50% or more fractional removal of crystalline phases from their parental melts which must have taken place beneath the present level of the greenstone belt. Dacites are the only intermediate to silicic magmatic rocks found. They range from 60-70% SiO_2, 15-16% Al_2O_3, and have Na_2O/K_2O ratios of about 3 in the freshest samples and are thus trondjhemitic in character. They display extreme fractionation of LREE to Y, and have very high concentrations of highly incompatible elements such as U and Th. Plagioclase and hornblende are the major phenocryst phases in all dacites. Some also contain either quartz or biotite as phenocrysts. Their compositions suggest a source that was mafic in composition and a relatively small degree of partial melting of an assemblage dominated by amphibole. They are not related to associated basalts by any simple, one-stage magmatic process, though could be related to a second stage of igneous activity at the base of a thick, hydrated pile of mafic volcanics.

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