Geol. Bull. Univ. Peshawar, 1988, Vol. 21, pp. 141–145

PETROGRAPHY AND GEOCHEMISTRY OF THE INCLUSIONS FROM THE AMBELA GRANITIC COMPLEX, N. PAKISTAN

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ABSTRACT

Petrography of twelve and geochemistry of three selected samples are presented for the inclusions of the Ambela granitic complex. The inclusions are silicic to intermediate in composition with a metaluminous chemical character. Major element geochemistry is inconclusive with regards to their origin, but incompatible trace elements are in correspondence with the concentration of these elements in the host granites and syenites. A closer match, however, is with the acidic volcanics which now make a part of the country rocks but were probably the early phase of the Ambela granitic complex.

INTRODUCTION

The Ambela Granitic Complex (AGC), which is one of the principal constituents of the Peshawar Plain Alkaline Igneous Province (Kempe and Jan, 1970, 1980; Kempe, 1973, 1983; Butt et al., 1980; Le Bas et al., 1987) has been a subject of several studies over the last three decades. Detailed petrographic accounts together with analytical data on major and trace element geochemistry for the principal lithologies of the complex (granites and syenites) have been included in several papers (Siddiqui, 1965; Siddiqui et al., 1968; Chaudhry et al., 1981; Rafiq et al., 1984; Rafiq and Jan, 1988). An important component of the complex so far undescribed, however, is the inclusions of intermediate to felsic composition which are contained in both the granites and syenites. In this paper, we present petrographic data and whole-rock geochemistry for a representative set of samples from these inclusions. An attempt is made to decipher their origin by comparing their trace element composition with their host rocks from the AGC, and country rocks in the surroundings.

FIELD RELATIONS AND PETROGRAPHY

The inclusions are more or less restricted to the granitic rocks exposed in the west-central part of the AGC. However, streaky and vein-like aggregates with schlieren structure are also present in the syenitic rocks exposed in the northwestern part of the complex. The inclusions are distinctly finer-grained than their host rocks. Generally, they are rounded to sub-rounded with diameter ranging from a few centimeters to three meters. Some have irregular shapes, with pointed to wispy projections or zigzag outlines. The contacts between the inclusions and the host rocks vary from sharp to gradational (a few centimeters wide).

The inclusions are characteristically porphyritic with phenocrysts dominantly of plagioclase. In rare cases K-feldspar, primary and/or secondary biotite, sphene, ore and in some tourmaline and apatite may form large crystals. They have a fine-grained groundmass consisting of both mafic and felsic minerals. The inclusions can broadly be divided into A) biotite-bearing and B) biotite-amphibole-bearing types.

The type A inclusions constitute nearly 2/3 of the collected samples and range from leuco to, rarely, melanocratic. The albite and oligoclase phenocrysts are mostly resorbed and almost free of inclusions. The phenocrysts of K-feldspar are commonly rimmed by albite. Phenocrysts of biotite are brownish green to yellowish green and are riddled with inclusions of epidote, sphene and ilmenite. Phenocrysts of sphene are euhedral rhombs and contain inclusions of ore and probably feldspar.

The groundmass displays very fine to fine-grained texture. Graphic and sometimes vermicular intergrowth of feldspars and quartz are seen; however, the feldspar is more or less cryptoperthitic, exhibiting various stages of unmixing. Irregular masses with euhedral grains of biotite, epidote, sphene and ilmenite are the common mafic phases in the groundmass. Thin needles of apatite and euhedral tiny crystals of zircon are the accessory constituents of these rocks.

A characteristic feature of the inclusions is their rather high mafic mineral content, especially in the type A, some of which have abnormally high amounts of biotite and epidote (this is not reflected in the chemical analyses because the samples selected were not high in mafic minerals). Whether some of the inclusions represent restites or metasomites is not clear.

The type B inclusions contain phenocrysts of albite, K-feldspar, biotite, sphene, quartz and ilmenite (in this order of decreasing abundances), and are very close in topocrystalline properties to the phenocrysts found in type A inclusions. However, in addition, these inclusions characteristically contain bluish green hornblende with cores of brownish green hornblende.

The groundmass is composed of fine to very fine-grained indistinct felsic minerals and fine flakes of biotite and bluish green amphibole. Neobiotite of dirty yellowish green colour and bluish green amphibole (most probably the product of metasomatism) occur as fine blebs to uncleaved structureless masses. Breakdown of primary biotite to ilmenite and sphene is seen in some thin-sections. Sphene, epidote and ilmenite are mostly found as aggregates or clusters in the groundmass. Apatite and zircon as euhedral crystals are found as accessories.

MAJOR ELEMENT GEOCHEMISTRY

Major elements in three representative samples were determined by XRF and were duplicated by wet chemistry (for details see Rafiq, 1987; Rafiq and Jan, 1989). The analyses are given in Table 1. The inclusions plot between rhyodacite and rhyolite fields of RI vs R2 classification diagram of De La Roche et al. (1980). They are classified as trachyandesite and trachydacite in the total alkalies vs silica classification diagram of Le Bas et al. (1986). On the characteristic mineral diagram of Debon and Le Fort (1983), the inclusions are distinguished as belonging to cafemic (metaluminous) association. This is further substantiated by their low $Al_2O_3/(K_2O+Na_2O+CaO)$ ratio (<1).

DISCUSSION AND CONCLUSIONS

The megascale characteristics of the outcrops show that the inclusions were incorporated into the host granitic and syenitic magma as blocks, fragments and partially fused material. This character is clearly reflected in their rounded shape, lobate to serrated boundaries and, at places, wispy protrusions into granites. Inclusions in the syeneitic rocks in the northern part of the complex may show extreme elongation (plastic flow) and at least some partial melting. Similar features have been widely recognized in the plutonic environments (e.g., Wiebe, 1974; Vernon, 1983, 1984; Reid et at., 1983; Moyes, 1986).

Major element geochemistry of these inclusions is inconclusive with regards to their origin. There are distinct differences between the composition of inclusions and their host granites and syenites in terms of elements such as $Si0_2$, Al_20_3, Mg0 and Ca0 (Table 1). Differences, however, are not reflected in trace-element composition. In particular, the incompatible trace elements such as Rb, Ba, K, Nb, LREE, Zr, P, Ti and Y in the inclusions generally correspond with the host granites and syenites, in terms of concentration. Similar concentration levels of these incompatible trace elements are also found in acid volcanic rocks exposed at the marginal contacts in the northwest, west, and south of AGC. These are thought to be related to AGC and are an extension of other volcanic and subvolcanic rocks of the Peshawar plain including those of the Shewa-Shabazgarhi (Rafiq, 1987, and in prep.).

TABLE 1. MAJOR AND TRACE-ELEMENT ANALYSES OF INCLUSIONS, REPRESENTATIVE GRANITE, SYENITE AND VOLCANIC ROCK FROM THE AMBELA GRANITIC COMPLEX

	Inclusions			Granite	Syenite	Volcanic
	Chemical analyses (weight percent)					
	1	2	3	4	5	6
SiO_2	59.43	68.56	53.91	74.55	60.43	66.94
TiO_2	1.76	1.45	2.10	0.58	1.05	0.90
Al_2O_3	16.50	6.45	14.93	12.59	16.52	8.26
Fe_2O_3	3.46	3.68	6.88	2.75	6.37	2.80
FeO	3.12	3.70	3.81	0.23	—	0.21
MnO	0.11	0.18	0.18	0.07	0.10	0.05
MgO	2.07	1.65	3.07	1.14	1.46	8.26
CaO	3.62	4.60	4.90	1.13	3.10	7.66
Na_2O	7.12	3.60	5.33	2.34	6.70	2.05
K_2O	2.34	4.50	2.88	4.22	3.20	2.68
H_2O^+	—	—	—	0.02	0.20	—
H_2O^-	—	—	—	0.80	0.25	—
P_2O_5	0.43	0.43	0.87	0.16	0.42	0.23
Total	99.96	98.80	98.86	100.58	99.80	100.04

	Trace element (parts per million)				
	1	3	4	5	6
Rb	197	—	250	115	86
Sr	458	301	94	500	174
Ba	629	337	391	522	372
Y	119	—	60	92	36
Zr	624	305	173	814	200
Th	17	—	—	16	—
U	3	—	—	3	—
Ta	4	—	—	4	—
Ce	250	122	133	280	93
Nb	—	94	12	123	30
V	—	1	25	—	1

Analyst: M. Rafiq

Explanation for sample Nos: 1—19X(A), 2 — NIAX, 3 — IIX(B), 4 — 680, 5 — 235, 6 — SpI.

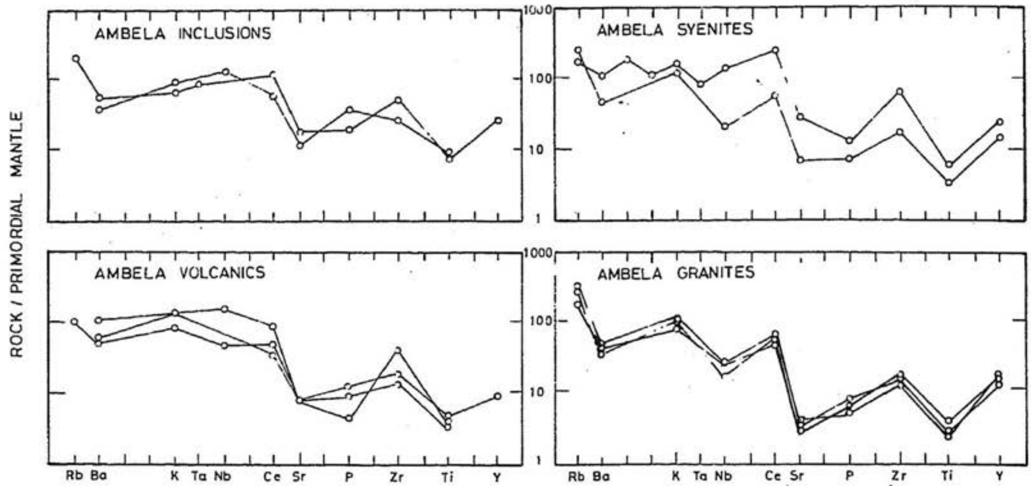

Fig. 1. Mantle-normalised trace element patterns of the inclusions from the Ambela granitic complex, compared with those of host granites, syenites and acid volcanics.

In Figure 1, mantle-normalized trace elements pattern of the inclusions are compared with those of the Ambela granites, syenites and volcanic rocks. As far as the general concentration is concerned the inclusions are not substantially different from all the three lithologies represented for comparison. Both the Ambela granites and syenites are characterized by a general negative Nb anomaly which is particularly pronounced in one of the later. Also the Rb-Ce segment of the pattern in granites and syenites is generally significantly spiked. In comparison the trace element pattern of the inclusions are characterized by a flat Rb-Ce segment and a positive Nb anomaly. These features of the incompatible trace elements of the inclusions are closely comparable with the patterns of the volcanic rocks, suggesting that these inclusions were derived from the acidic volcanic phases of the region which partly made country rocks to the AGC.

Acknowledgements: We thank Irshad Ahmed and M. Tahir Shah for their help with analyses.

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