PETROLOGY AND GEOCHEMICAL COMPARISONS OF THE QUATERNARY VOLCANIC ROCKS FROM LIVINGSTON ISLAND, ANTARCTICA

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Late Cenozoic mafic alkaline volcanic rocks occur throughout the entire Pacific coast of West Antarctica, including some of the islands adjacent or within the Bransfield Strait. Amongst them, Livingston Island is the least well-known, particularly in respect to mineralogy, petrology and geochemistry of the scarce manifestations of this type rocks, known as Inott Point Formation. This contribution presents new major element and trace element data from old and new-discovered outcrops in Livingston Island and compares them geochemically with similar rocks from the island Greenwich situated in South Shetland Islands arc and with Quaternary basalts in the islands Penguin, Deception and Bridgeman, within the back-arc rift basin Bransfield Strait. Alkaline basalts from the provinces in Antarctic Peninsula (AP), Marie Byrd Land (MBL), and Patagonia and from the Atlantic Ocean Island Ascension are also used in the correlations.

The South Shetland Islands and Antarctic Peninsula was a site of Jurassic to late Tertiary continental arc magmatism, associated with subduction of oceanic crust. Crustal extension has occurred in the Bransfield Strait since the late Oligocene, but the graben-like structure in the deepest part of Bransfield Strait is a relatively recent feature – less than 4 Ma thought to represent a back-arc rift or a marginal basin.

The new study specify the nomenclature as low-Ti undersaturated olivine basalts mainly and hawaiites rarely. The highly porphyritic varieties are seldomly observed and subporphyric rocks are most common. Phenocrysts are clinopyroxene (salite, Mg# 78-83), olivine (Fo_{83-86} in the cores and Fo_{81-83} – in the rims) and plagioclase (An_{80-87} in the cores to An_{60} – in the rims with normal and reverse zoning). Accessories are magnetite, ilmenite and chromite. The alteration is unusually slight and most of the specimens are fresh. The volcanic glass in the tuffs is palagonitized.

The majority of the samples plot beneath the dividing line for alkalic and subalkalic rocks on a TAS diagramme. The analyzed samples are relatively primitive and the effects of fractional crystallization are insignificant. A close similarity is found between the Inott Point Formation samples and the alkaline basalts from Penguin and Greenwich islands, situated in the Bransfield Strait area. The samples from these islands occupy a common field, located on the most primitive end of the chemical range of the all-magmatic rocks in Hurd Peninsula, Livingston Island. The basalts from Bridgeman and Deception islands are more evolved than the lavas from the same age from Livingston Island. All studied rocks belong basically to a calc-alkaline medium-K series related to arc magmatism. The same series is typical for the other Quaternary volcanic rocks from the islands Deception, Bridgeman, Penguin and Greenwich.

N-MORB-normalized multi-element plots of the basalts from Livingston Island resemble the ones for the transitional basalts in the continental arcs. Similar peculiarities and subduction-related affinity of their magmas show the patterns for the samples from the islands Penguin, Greenwich and Bridgeman. In contrast, the samples from Patagonia demonstrate typical within-plate or ocean-island basalt patterns, like the ones in the Antarctic Peninsula province and Ascension Island.

Common geochemical features between the olivine basalts in Livingston Island and the volcanic rocks in the islands Greenwich, Bridgeman, Deception and Penguin are revealed, amongst them the high LILE/HFSE ratios (e.g. Ba/Zr=1.4-2.2; Ba/Nb=42-67; Rb/Nb = 2.7-4.0; Ce/Nb = 2.5-10.0; Th/Nb = 0.25=0.90; K/Zr = 39-67 etc.) These ratios are opposite to the low LILE/HFSE ratios in the alkalic provinces in AP and in MBL. The generally low absolute abundances of HFSE in all within and around Bransfield Strait alkaline basalts and their high Zr/Nb (19-43) and Sr/Nb (>100) ratios are in contrast to such ratios in AP and MBL samples. Higher degree of melting and variable interaction with the continental lithosphere is probably responsible for the geochemical differences with the alkaline basalts from the other provinces in West Antarctica. The HFSE fractionation is considered to be a function of the amount of residual clinopyroxene and garnet at the mantle source of the volcanic rocks. Negative correlation between the ratios Ti/Nb, Zr/Nb, Sr/Nb, Ti/Zr, P/Nb and the degree of partial melting expressed as ratios La_N/Yb_N, Ce_N/Y_N, Nb/Y suggests that inter-element ratios involving only the HFSE are not reliable indicators of the composition of the mantle source region. The essential geochemical differences between the group of samples from Bransfield Strait lavas and the one from AP, Patagonia and the island Ascension are explained by the higher melting degree for the former and the lower melting degree for the last group.

The LILE variations in the alkali basalts from Livingston Island (e.g. K/Ba=26-38 and K/Rb=380-630) cover nearly the same ranges as in the other volcanic islands within the Bransfield Strait area. The broad range of values of these ratios are independent of the Nb/Y ratio and therefore it is unlikely these variations to be simply an artifact of the partial melting. These LILE variations differ greatly from the absolute and relative LILE abundances in AP and MBL alkaline provinces. The regional trace element variations found in the Quaternary basalts from Livingston Island and in the basalts from the other islands within the Bransfield Strait are considered to be a result of generating the basalts from different portions of the asthenosphere and continental lithosphere. The lithospheric involvement in alkaline genesis is a characteristic feature of the Bransfield Strait basalts and a subarc source region contamination might have affected their mantle source. The AP samples, occupying the fields close to OIBs sources on the most geochemical plots could simply demonstrate that they represent a low degree melts of shallow convecting MORB-source or HIMU OIB asthenosphere beneath the Peninsula. The data from MBL are consistent with their derivation from a plume-related source.

The possible contamination of the mantle source of the lavas from Livingston Island by rich in Ba and Pb pelagic sediments is supported by a K/Rb vs. Ba/Rb plot. The samples from Inott Point Formation fall in this plot in an area where the mixture of altered MORB and sediments, continental crust and OIB field overlap. Trends for Penguin and Greenwich islands basalts are more explicable by loss of Rb relative to K and Ba from the subducted crust as a whole. The long history of subduction and arc volcanism in the South Shetland Islands provides ample opportunity for migration of slab-derived fluids through the mantle wedge, resulting in depletion of Rb in the residual mantle. A striking difference between the basalts in Bransfield Strait islands, Ascension Island and Patagonia flood-basalts is the location of AP basalts in the same plot. They form a field, entirely within the MORB source of their magmas.

In terms of incompatible element trace element ratios Livingston Island and Penguin basalts exhibit some similarities with ocean-island basalts sources OIB (Fig. 1).

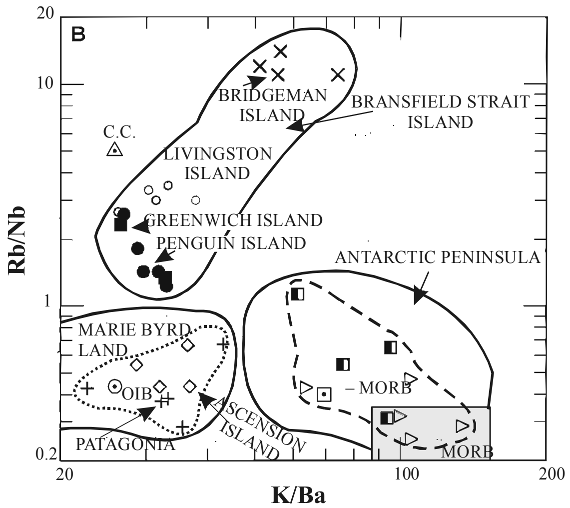

Fig. 1. A trace-element variation diagramme Rb/Nb vs. K/Ba for Livingston Island samples compared to samples from the islands Penguin, Greenwich, Bridgemen and to samples from Alexander Island, Seal Nunataks, Ascension Island and Pali-Aike volcanic field, Patagonia. The samples for comparison in this study are outlined with dashed line. Fields for Antarctic Peninsula and Marie Byrd Land are from Hole and LeMasuruer (1994).

All the so-called "Bransfield Strait" basalts form an elongated common field, characterized with high Rb/Nb ratios like in the volcanic arcs. The close location to the average continental crust gives a hint to the suggestion that Inott Point samples and their adjacent Bransfield Strait occurrences have sources of back-arc extensional setting strongly influenced by the subduction process. The two fields of samples with low Rb/Nb ratios comprise from one-side Marie Byrd Land, Patagonia and Ascension Island basalts (low K/Ba plume-related enriched within-plate basalts) and Antarctic Peninsula high K/Ba basalts from the other side (explained as small-degree melts of the asthenosphere in a slab-window setting (Hole and LeMasurier, 1994). The first group of samples is close to/or within the range of the OIB field, but the second group is close to/or within the MORB source.

The range of Ba/Zr ratios in Livingston Island samples is nearly the same as in the samples from the islands Penguin, Greenwich and Bridgeman. All these ratios fall within the range of the orogenic basalts in Antarctic Peninsula and they differ essentially from the ratios in the Antarctic Peninsula alkaline basalts.

Patagonia flood basalts and the Quaternary lavas from Ascension Island, which we used for comparison in some of the geochemical plots, are quite similar to those in MBL in their trace element characteristics and the conclusion for a plume-related OIB source should be valid for them

The results from the application of some discrimination plots are equivocal. The source of the alkali magmas in the islands in Bransfield Strait area was probably complex and transitional. Volcanic-arc basalts mainly, but also within-plate basalts and even a little N-MORB characteristics appear out of the geochemistry of the basalts. The only one satisfactory discrimination for the case is the Th-Zr/117-Nb/16 plot of Wood (1980). The high Th contents of the alkaline basalts exposed in and around Bransfield Strait causes them to plot in the arc field, despite some of their MORB-like HFSE characteristics. The samples from Antarctic Peninsula fall mainly in the field of E-MORB/OIB and partly in the field of the alkaline within-plate rocks, while the samples from Patagonia, Ascension Island and MBL are placed entirely in the last field. The revealed geochemical peculiarities are similar to those of many intra-oceanic back-arc basins settings, like the modern Lau Basin. A wide range of rock types have erupted in these basins, including N-MORBs, MORBs with arc signature (i.e. back-arc basin basalts or BABBs), OIBs and also arc tholeiites. Generation of high LILE/HFSE ratios in the subcontinental mantle is a consequence of subduction-related magmatism and it is recognized that such process is extremely important in determining the geochemical evolution of this mantle source.

Conclusion

The main inference out of the discriminating results is that the observed geochemical differences between the Quaternary basaltic rocks of the Antarctic Peninsula and of the Bransfield Strait region must be due to tapping of geochemically distinct domains within the asthenosphere and the stronger lithospheric contamination of the source of the last region basalts, comprising the Inott Point Formation in Livingston Island. The olivine basalts from Livingston Island and from the volcanoes in Bransfield Strait area display several unusual geochemical features, some of which are indicative of island arc magmatism and others, which are more typical of ocean floor basalts. The dual characteristics of MORB-like major element geochemistry and the arc-element signature are suggestive that these alkaline basalts bear most of their arc trace element features, because they are adjacent to the South Shetland magmatic arc, in spite of the extensional setting in the back-arc rift of Bransfield Strait. The unique tectono-magmatic regime, which developed within the Bransfield Strait rift, bears a strange combination of subduction-related volcanic-arc characteristics and an extensional within-plate setting. The melts of the altered MORB, contaminated with continental crust materials recycled into the upper mantle were obviously responsible for the geochemical peculiarities of all Quaternary basalts in the adjacent islands Penguin, Greenwich and Bridgeman, as well.

The West Antarctic alkaline basalts can be subdivided not into two provinces, as Hole et al. (1993) proposed, but into three, based on the absolute and relative abundances of the trace elements: (i) ***Bransfield Strait*** province with alkaline basalts, bearing traces of lithospheric contamination and subduction-related magmatism; (ii) ***Antarctic Peninsula*** province with alkaline basalts derived from MORB-source asthenosphere in slab-window setting and (iii) ***Marie Byrd Land*** alkaline basalts related to a deep-seated mantle plume (Hole and LeMasurier, 1994). The study of the isotope variations in the new-defined Bransfield alkaline basalt province would confirm better such new division.

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