Petrology and geochemistry of dykes from Hurd Peninsula, Livingston Island, South Shetland Islands

Петрология и геохимия на дайки от полуостров Хърд, остров Ливингстън, Южношетландски острови

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Hurd Peninsula is located in southern Livingston Island, the second largest in the archipelago of the South Shetland Islands. Subduction of proto-Pacific ocean floor beneath the South Shetland Islands originated a Mesozoic-Cenozoic magmatic arc and most of the magmatic complexes in the islands are subduction-related. Numerous dykes cut all rock sequences and their concentration in Hurd Peninsula especially is impressive. Neither their stratigraphic position is always known, nor are they fresh enough to apply their geochemical properties properly. In spite of the several attempts for radiometric dating of some of the dykes (Willan, Kelley, 1999; Zheng et al., 2003; Kraus et al., 2007) the magmatic evolution of the dykes is still not clarified in a reliable way. The sequence of the different in relative age and composition dyke stages and magmatic events was identified up to now with ambiguity. The lack of trustworthy petrological and geochemical data is one of the reasons for this problem. The present contribution aims to fill the gaps of our knowledge in this field with the hope that the magmatic dyke swarms in Hurd Peninsula could provide new arguments for tectonic and magmatic interpretations in the area.

The crosscutting relationships are used as important clues in assigning the dykes to several magmatic pulses. Six different intrusive dyke pulses are deduced out of their relative age. The spatial orientation of the dykes is often similar and dykes from different intrusive pulses are emplaced in nearly identical joint systems and vice versa, dykes of one and the same intrusive pulse may occupy more than one joint system. Obviously the older tectonic trends have been reactivated during almost all later tectonic events. The correlation of the chemical composition of the dykes with their strike is also difficult. The advanced alteration of the vast majority of the dykes questions not only the correlations, but even some of the isotopic datings. On the basis of complex repeatedly mutual crosscuttings in some areas around Bulgarian Antarctic base, combining with the present petrographical and geochemical study and paying attention to the new Ar/Ar geochronological data on representative dyke samples (Zheng et al., 2003; Kraus et al., 2007) the following six intrusive dyke pulses are determined: **I dyke pulse** is presented by only one moderately altered dyke (latite in TAS system) with a strike of 145° and thickness of 55 cm. Dykes from the II, III and IV pulse cut the dyke. **II dyke pulse** includes dykes emplaced predominantly in the joint system striking 25° and having average thickness of 265 cm. The nomenclatures are theralite, andesite and dacite. The degree of alteration is significant. The porphyry textures are often observed. Fractures with a strike of 150° cut and displaced some of the dykes. **III dyke pulse** comprises several dykes intruded in the tectonic system around 150°. Single dykes of this pulse follow the system of 70–110°. The average thickness is 320 cm. The petrographical variety is larger in this pulse — basaltic andesite, andesite, dacite and rhyolite are the main varieties, but mugearite and latite are also described. **IV dyke pulse** is presented by numerous mainly basic and mafic dykes striking around 150°, which is the same direction as in the first dyke pulse. Usually their thickness is smaller — average 90 cm. The rock varieties are basalt, potassium trachybasalt, shoshonite and hawaiite. The greatest part of the dykes is intensively altered and their detailed classification is problematic. **V dyke pulse** is weakly developed in the area. The petrographical composition varies between basaltic andesite and andesite. The thickness exceeds 400 cm. The main strike of the dykes is close to 70°, like the dykes from the III pulse. The alter-

ation degree is low. **VI dyke pulse** is presented by a single andesitic dyke with a strike of about 135°. The repetition of the tectonic systems 120–150° (I, IV and VI dyke pulses) and 70–90° (III and V dyke pulses) is a proof that the general geometry of the subduction zone, including its direction and its rate had been enough steady during the long period of the different dyke intrusions.

The published already geochronological data (K-Ar and Ar-Ar) in combination with our new geochemical results assign the dyke pulses to the following magmatic stages: 1) 80–55 Ma (I, II and partly III pulses), 2) 48–42 Ma (partly III and IV pulses) and 3) 40–31 Ma (V and VI intrusive pulses). The directions used by the dykes are expressed as joints within the dykes, indicating that the stress field that caused the deformation of the country rocks remained stable during the time of dyke intrusion.

It is demonstrated that all TAS-classification nomenclatures of the dykes are deformed by the alterations. Low temperature metamorphism at increased fluid pressure is established in most of the dykes and that is why the immobile trace element classifications are applied after several geochemical tests. The revised nomenclature of the dykes using the immobile elements discards the transitional in alkalinity rock varieties and confirms the following suite of rocks: basalt — basaltic andesite — andesite — dacite — rhyodacite — rhyolite as typical for the Hurd Peninsula. The magmatic serial affinity of the dykes is predominantly tholeiitic with a weaker presented calc-alkaline high-alumina series. The strong Ti-enrichment observed for the dykes from Hurd Peninsula accompanies the Fe-enrichment is also typical for tholeiitic suites. The study of rock forming minerals reveals unusually wide compositional range of the plagioclases — from secondary albite to anorthite. The most striking feature of the clinopyroxene phenocrysts is the restricted range in their composition, corresponding to the different magmatic phases. Several division clinopyroxenes are divided according to their composition. Magnetites are dominantly high-Ti, high-V, low-Cr, moderately-Al and Ca-bearing varieties.

Substantial crystal fractionation is required to explain the geochemical characteristics of the dykes. The negative correlations of Ti and V with Zr and with the ratio of FeO_t/MgO and the invariably low TiO_2 whereas Al_2O_3 is rather high are typical characteristics of arc rocks. The arc characteristics are confirmed by chondrite-normalized REE spidergrams and by MORB-normalized trace-element diagrams. The most distinctive features are that they are depleted in compatible elements and moderately enriched in incompatible elements. The mantle source is characterized by the absence of residual garnet, as indicated by the REE patterns and the missing negative Y anomaly. The mantle source of the magmas could have been enriched in incompatible elements prior to the initiation of the subduction. Tectonic setting deduced from some discrimination diagrams clearly suggest that during magma-generation process oceanic materials were involved (MORB-component of the subducted ridge-crests) as well as a mantle source affected by subduction-related melts and fluids (subduction component).

The systematic covariation of Sr, Ba and Ca elements is evaluated and it seems to be related with their magma generation and fractionation history. The rather high Zr/Nb and Ba/Nb ratios of the dated dykes reflect the lower absolute Nb abundances in their source and are also signatures of the arc-derived magmas. The observed relative fractionation of Zr and Nb is a function of degree of melting rather than source-region heterogeneity. The Hurd Peninsula dykes have constantly higher K/Nb and Ba/Nb ratios than the mafic alkaline basalts of Antarctic Peninsula. Probably they are result of the integration of small melt fractions with higher degree melts. Some time-dependant geochemical ratios are revealed, like K/Ba, Ba/Zr, K_2O/MgO, K_2O/TiO_2 etc. They support a gradual increasing of the basicity and alkalinity of the parental magmas along with their age decreasing. A rough correlation between the degree of crustal contamination and the sequence of the following intrusive phases is evident also. The crustal component of the dykes decreases to the younger ages, according to the new geochemical data and the published isotope results. Notable contribution of subducted sediment to arc genesis is established. The degree of melting is estimated as 15 to 40 % from fertile mantle source.

The new finds should assist in the better understanding of arc-building process in the South Shetland Islands, which presents intriguing geodynamic setting with showing of subduction, cessation of island arc volcanism as well as apparent onset of back-arc rifting. Relative age relationships deduced from detailed dyke study turned out to be an essential precondition for every successful reconstruction of the geodynamic history.

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