MAGNETIC PETROLOGY OF CENOZOIC BASALTS IN CENTRAL ASIA

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The hotspot hypothesis proposed by Morgan [1972] provides a deeper insight into many processes in the Earth as well as into their interrelations. The hotspots are surface evidence of ascending convective mantle flows. Usually they coincide with areas of recent or ancient triple junctions of diverging plate boundaries. Most of the typical hotspots (Hawaii, Reunion, Samoa, Iceland, Bouvet) are located on the surface of the oceanic lithosphere. The hotspots recognized within the continental lithosphere are few, and one of the most studied is the Afar triangle at the triple junction of the Sheba Range, Ethiopian rift, and Assal rift [Shilling et al., 1992].

Grachev [1998] believes that the number of hotspots is actually much greater and theoretically must coincide with the number of triple junctions existing in the lithosphere; they need a detailed isotope-geochemistry analysis. In this respect, of great interest is Central Asia with its widespread intraplate basaltic volcanism. The hotspot (or hotspots) located on the territory of the trans-Baikal region and Mongolia is unique because an intense magnetic anomaly is present there.

Two spatially separate areas of Cenozoic volcanism exist on this territory: (1) a zone trending nearly N-E and extending from the Baikal rift zone in the north to the trans-Altai Gobi in the south and (2) the vast Dariganga plateau in southeastern Mongolia with a small area in the Halhin-Gol River basin [Grachev, 1998; Saltykovsky and Genshaft, 1985]. Geomorphological and stratigraphic evidence and absolute datings of basalts suggest that an E-W magmatic zone existed in Mongolia (present-day coordinates) in the Cenozoic and migrated north-northeast, with the Pliocene-Quaternary volcanism being localized within the Khamar Daban and Hangai Ranges and the Dariganga plateau [Continental volcanism ..., 1983].

The Cenozoic volcanic rocks of Mongolia are represented solely by basaltic varieties dominated by rocks that are strongly depleted in silica. Tholeiitic varieties with more than 5%-7% of normative hypersthene are rather widespread and compose most of the Pliocene sheets and extended flows that likely associated with fissure eruptions. However, according to classification schemes based on the SiO_2-(Na_2O+K_2O), nearly all of the basaltoids under consideration belong to alkaline and subalkaline varieties. The volcanics are primarily alkali-olivine basalts (mostly of the Na-K type), which defines their petrochemical properties. They are characterized by low concentrations of silica and alumina and by high Ti and P concentrations.

Over 70 samples from the collections of Yu.S. Genshaft and A.F. Grachev were taken for the petromagnetic examination which included measurement and analysis of such standard characteristics as the magnetic susceptibility, natural remanent magnetization (NRM), Koenigsberger ratio, remanent destructive field, saturation magnetization and its remanent value. Petromagnetic analysis was conducted to study the magnetic mineralogy of the basalts: the J_s-T and J_{rs}-T relations were examined and used for the determination of Curie points.

The preheating magnetic parameters of the study samples virtually coincide with similar characteristics of the majority of both oceanic and continental basalts, thereby implying a general mechanism that controlled the formation of their ferromagnetic fraction, although there are some divergences in ferromagnet concentrations. In the collection studied, the latter are 1.5 to 2 times as high as in oceanic basalts.

The thermomagnetic analysis showed that the Curie points, determining the ferromagnetic fraction composition, vary within wide limits (from 140° to 600°C), ranging from titanomagnetites to weakly oxidized magnetite. Some of the titanomagnetites are likely to have been altered as a result of secondary oxidation, which increased their Curie points. However, no continuous alteration of the ferromagnetic fraction is observed. The resulting histograms showed the presence of four modal T_C values of about 150, 230, 350 and 560°C (table). Grouping the petromagnetic characteristics in accordance with the modal T_C values (the magnetite phase is ignored because it is a product of the primary titanomagnetite decomposition), the following regular pattern is observed: an increase in the extent of titanomagnetite oxidation decreases the magnetic susceptibility (from 0.028 to 0.01 SI units) and saturation magnetization (from 1.4 to 0.8 A m^2/kg) and results in a more than twofold increase in the remanent coercivity (from 13.1 to 28.7 mT).

Table

Petrochemical characteristics of basalts

T_C,° C	J_n, A/m	$\kappa \times 10^2$, SI units	Q_n	J_s, A m^2/kg	J_{rs}/J_s	H_{cr}, mT	J_{st}/J_{s0}
150	13.2	2.8	19.4	1.4	0.13	13.1	1.17
230	17.6	1.8	44.6	1.1	0.13	15.5	1.54
350	4.7	1.0	8.1	0.8	0.15	28.7	0.97
560	16.4	2.6	14.9	2.2	0.17	37.7	0.90

Note: The notation is as follows: T_C, Curie point; J_n, NRM; κ, initial magnetic susceptibility; Q_n, Koenigsberger factor; J_s, saturation magnetization; H_{cr}, remanent coercivity; J_{s0} and J_{st}, saturation magnetizations before and after laboratory heating to 650°C, respectively.

Such correlations (negative, between T_C and J_s, and positive, between T_C and H_{cr}) are characteristic of basalts subjected to oxidation, when fragmentation of the effective magnetic volume into several domains increases the magnetic hardness and decreases the volume concentration of magnetization carriers in rock. It remains unclear whether the 230 and 350°C Curie points are oxidized or initial values. The primary nature of the titanomagnetites with Curie points of about 150, 230 and 350°C is supported by the discreteness of their distribution, and a model of melt formation at different depths may be suggested as an alternative to the oxidation variant. The basalts with 150°C Curie points were derived from melts that formed at the deepest depth level, and the 230°C basalts, from shallower melts.

Such a mechanism was already proposed by Didenko et al. [1999] for the formation of hotspot basalts at the Bouvet triple junction: as well as in central Mongolia, a bimodal distribution of Curie points of basalts (120-140°C and 210-240°C) and their positive correlation with magnetic hardness parameters are observed there. In this case, a higher magnetic hardness appears to be related to the defects acquired by magnetic grains at the stage of their crystallization.

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