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Physical parameters of volcanites from Antarctica

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We identified thermal and magnetic properties, together with density and porosity, of some lavas from the Mt Melbourne Volcanic Field, North Victoria Land, Antarctica. This information is of basic importance for the interpretation of gravity and magnetic anomalies, and is essential for studies of the thermal structure of the area. The alkali-silica diagram of the sampled rocks shows three main differentiation trends: the alkali-basalt benmoreite, the alkali basalt-trachyandesite-trachyte and the basanite tephrite. Thermal and magnetic properties were investigated according to standard procedures implemented at our laboratory. A Gamma-ray spectrometer was used to determine the heat-production rate from the concentrations of the thermally important radioactive isotopes.

Thermal conductivity results are comparable to that of the glass; it varies from 0.48 (trachyte) to 1.38 W/(m K) (basalt). The volumetric heat capacity and the thermal diffusivity are less variable; on the average, they are 1.85 10^6 J/(m^3K) and 0.51 10^{-6} m^2/s, respectively. Since the chemical composition is relatively homogeneous, thermal conductivity is mainly controlled by porosity. The magnetic susceptibility, which ranges between 0.001 to 0.046 SI units, is more variable than the other physical properties. Among the several iron-titanium oxides, it appears primarily controlled by the ulvöspinel-magnetite solid solution series. Many titanomagnetites are slightly oxidized towards the titanohematite line, or reduced.

The determination of the heat-producing isotopes has been carried out by analysing the gamma-ray spectra of the samples, within the 0 - 3 MeV energy range. We used the three window method, which is based on the determination of characteristic photo-peaks of daughter products of ^{238}U and ^{232}Th, and the primary decay of ^{40}K, under the assumption of the secular radioactive equilibrium. Some volcanic sub-fields of Mt Melbourne are as young as 0.25 My. This involves that secular equilibrium in the uranium decay series might not be fulfilled for all the rock sampled. To bypass this problem, the low-energy region of the gamma-ray spectrum, where there are a number of gamma rays produced by the decay of ^{234}Th, was investigated. This radioelement can be safely assumed to be in secular equilibrium with ^{238}U as its half-life is only 24.1 days. As the NaI(Tl) scintillation detector does not have sufficient resolution to reliably distinguish individual peaks in this region of low energy, it was necessary to operate with a relatively wide window, ranging from 0.010 to 0.123 MeV.

Generally, all lava samples denoted rather low radioelement concentrations. The largest concentration of heat producing elements (K, U and Th) was found in a trachytic sample (4.53%, 5.3 and 19.0 mg/kg, respectively), whereas the poorest K and Th contents (0.67% and 2.1 mg/kg, respectively) were measured in a basalt. The lowest concentrations of U (0.6 mg/kg) were obtained for basanite and trachybasalt. Despite the homogenous composition of the investigated lavas, there is an apparent positive correlation between U and SiO_2 concentration. Thorium presents the same distribution pattern; the Th/U ratio is 3.93, which indicates that the sampled lavas have undergone neither hydrothermal alteration nor U depletion processes.

The radiogenic heat productivity of the analyzed lavas is relatively low, as a consequence of the low concentration of heat-producing radioelements. It ranges from a minimum of 0.38 for a basanite to a maximum of 2.00 μW/m^3 for a trachyte. Thorium contributes to the radioactive heat-production rate by almost one half (44.4%), whereas U accounts on average for 40.5%. The largest contribution due to Th (65.7%) was found for a trachybasalt sample. The heat yielded by K accounts for only 15.1% of the total heat-production rate.