Energy of kimberlite formation

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The few works which concern the energy of kimberlite magmatism conventionally consider the endogenic processes in the Earth's interiors as the reasons of kimberlite melts formation (gravitational differentiation, chemical and phase transitions of the substance in the core and mantle, radiogenic heating of mantle, decompression in the deep fault zones, etc.). Different researchers associate the formation of the subvertical channels of the diatrems and extrusions of deep substance on the surface with large extra-pressures of magma which intrudes the above-lying units from the depth of 1-2 km, explosion-like release of volatiles from kimberlitic melts due to reducing of lithostatic pressure of the top at near-surface layers as well as explosions of oil-gas mixtures near the contact between sedimentary cover and platform basement.

It should be noted that presented considerations are in rather poor agreement with geological data. At the first stages of the planet evolution the gravitational differentiation and phase transitions of the substance beneath the crust apparently made a noticeable contribution to the energy, however, had one-directional extincting character. Therefore, the presumption of genetic link existed between such processes and repeated kimberlite magmatism activization for the period of near 3.5 bil.y. is unsound. Essential heating of upper mantle substance at the expense of radioactive elements decomposition could not occur due to their absence in the mantle substrate. Hypotheses for kimberlite magma generation under decompression in the deep fault zones is not more substantiated. Mineralogical, petrological and experimental data testify to kimberlite melts initiation at the pressures of tens kbar which correspond to the depths of several hundreds km. However, the faults penetration up to the depths of hundreds km, including through the asthenosphere layer where substrate occurs in semi-ductile conditions seems completely improbable. The possible formation of subvertical diatrem channels (pipes) and "fontane-like" eruption of the mantle substance through them onto surface after magma being at high pressure reaches the depth of 1-2 km seems very questionnable.

The major objection against kimberlite diatrem formation under the influence of uprising magma pressure and explosion-like extrusion of the deep substance on the surface consists not so much in doubts on extremely high (more than 6.5 kbar) extra-pressures of kimberlite melts which are necessary to break the top of 1-2 km thick (Milashev, 1972) as in incompatibility between diatrem morphology and typical craters.

Complicated evolutionary processes differing in energy obviously occured in kimberlite magmas in the interval since the heating of upper manle substrate and appearance in it of first portions of kimberlite melt till their extrusion on the surface through the pipe channels of diatrems on their way from subcrustal depths to near-surface horizons of the Earth's crust. In the context of geological history and energy every epoch of kimberlite magmatism can be subdivided into 5 main periods:

1. Heating and deconsolidation of the mantle substrate with its subsequent floating up as giant plumes which are spread out in mushroom-like shape at the Earth's crust base. The final shape of

mobilized substrate block could be the lense with shape and dimensions corresponding in plan to territories of kimberlte provinces. The areas of the largest ones reach 2 mln.sq.km. The volumes of substance captured by convective currents reached tens mln.cub.km and transverse dimensions of upwelling currents are comparable in area with internal zones of kimberlite provinces which account for first hundreds km (Milashev, 1972, 1974, 1990). The probable reasons of regional heating of the upper mantle are discussed in the final part of the report.

2. The beginning of the second part of kimberlite formation epoch is associated with appearance in uprising mantle plume of kimberlite magma chambers. When the chambers reached the critical volume they acquired the ability of autonomous radial motions in accordance with the zonal melting mechanism. Kimberlite melts initiated in upwelling convective currents of the heated substrate at the depth where the temperature of composing it peridotites appeared to be equal to their melting temperature at correspondent lithostatic pressure. Specific melting heat of silicates exceeds their heating capacity by hundreds times therefore the complete melting of mobilized substrate was impossible even when it reached the Earth's crust base where the pressure does not exceed 15 kbar. This limited the number and total volume of magmatic chambers arising in convective current, which accumulated the heat from the host rocks and finally became concentrators of heat energy carried away from the depths. According to the estimations performed the minimum (critical) volume of magmatic chambers when autonomous movement of kimberlite magma according to zonal melting mechanism became possible accounts for some 0.25 cub.km. Distinctions in melting substate composition and cryslallized magma caused the exothermal character of the reaction (near 29 kJ/cub.dm) that resulted in steady increase in magma volume and accumulation in it of heat energy (Milashev, 1994).

3. When kimberlite magmas reached the increased permeability zones in the lithosphere the new (plutonic) stage in their evolution began. It differed sufficiently from previous (intratelluric) one in energy and other characteristics. The uprising along the weakened lithospheric zones among relatively cold rocks was accompanied by decrease in heat reserves at magma volume maintenance (together with porphyric crystalls) and temperature remaining at the optimum level owing to partial crystallization which provides necessary heat energy release.

4. Rising along the weakened zones the kimberlite melts reached the upper layers of the Earth's crust where hypabissal stage of their evolution proceeded. Mineralogical and petrological data definitely suggest that the boundary between plutonic and hypabissal stage was characterized by the relative overheating of the magma which caused the partial melting of all earlier crystallized porphyric inclusions. Melting was caused not by heating but by the fact that at pressure drop as magma rising the temperature of crystallization-melting of minerals decreased faster than melt temperature.

5. Explosive stage included the processes of formation and filling of diatrems. In complicated-structured bodies it was composed of several repeated stages, each consisting in break of the top and filling of the channel formed by kimberlite melt which cemented the fragments of the intruded rocks. The formation of diatrems occured due to heat resources of kimberlite melts but with gases predominantly served as operating bodies. The leading role belong to water vapors initiated on the contact of magma with underground waters. The leading mechanism of this process was release of strongly compressed and heated gases which execute thermo-mechanical abrasion of the units intruded and gradual transformation (development) of fractured channel to pipe-like one (Milashev, 1984, 1988). Taking into account large unproductive energy losses (90-99%) the energy n (10^{15} - 10^{16}) J is required to develop the medium-size kimberlite pipe. This work is done at adiabatic

widening of n (10^6-10^7) t of water vapor initiating on the contact with n (10^6-10^7) cub.m of ultrabasic melt which rises from the depth of 2 km to Earth's surface. The acquired volume of magmatic melt which can provide the energy of the process is one order less or approaches the volume of medium kimberlite pipe (5.05 x10^7 cub.m) . In these terms the evaluation conducted do not face principal objections.

In such a manner the convective currents of upper mantle heated substrate not only initiate the kimberlite magma but also provide these melts with heat energy which is sufficient for their further evolution. If so, than both mantle plumes and kimberlite magmatism were finally the derivatives of the unified energy impulse.

Analysis of genetic relations and radiologic datings of kimberlites, permanently presenting completely crystalline ultramafites nodules ("related inclusions") and diamonds allows to conclude that 17 stages of kimberlite magmatism occured within the interval from 3300 to 20 Ma (Milashev, 1994, 1996). The identical and rather close age values which conform to the major stages of kimberlite intrusions, crystallization of nodules and diamonds, are observed not only within single provinces and continents, but in global scale. At the same time, nodules and diamonds in the kimberlite of the same pipe have different radiological datings. Some of them coincide in age with enclosed rocks, others - with kimberlites, nodules and diamonds of more ancient stages that suggest repeated manifestations of the deep magmatism in the same areas, i.e. periodical activization of numerous "hot spots" in the upper mantle of the planet.

Searching of endogenic ("Earth") energy source which could provide episodical "functioning" of hot spots for the period of bill.years has failed. Alternative option consisted in "pumping" of space energy in subcrustal depths of the Earth. It was noticed that periodicity of kimberlite magmatism is correlated with Galaxy chronology and, at least, since the end of Proterozoic the epochs of activization repeated in time intervals which are multiple not only to the wholes but to halfs of siderial year (Table). It is associated with repeated intersections of magnetic and radiation belts of the Galaxy by the Solar system. Each intersection induced Foucault currents and was accompanied by significant release of heat energy in planet interior.

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