IMPACT-GENERATED HYDROTHERMAL ACTIVITY: THE RECORD IN TERRESTRIAL CRATERS.

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Any impact into water-bearing planetary surfaces produces the long-term (hundreds of thousands years) hydrothermal activity in formed craters. Its record in terrestrial craters is the following: occurrence of appropriate associations of minerals (including ore-forming parageneses), migration of a series of chemical elements, and existence of specific fluid inclusions. The general model of impact-induced hydrothermal process is suggested, based on both simulation of the thermal evolution of central uplift and petrological analysis of hydrothermal mineral associations in large craters. The volume of the circulation cell occurring mainly the central uplift, is estimated to reach 1000 km^3 in large (D=50 km) craters; besides super-heated bodies of impact melt rocks create local circulation systems in crater fill. Similar process may contribute to the formation of the Martian soil.

The creation of hydrothermal circulation systems in astroblemes caused by the kinetic energy of impact [1, 2]. Several factors controlling parameters of impact-induced hydrothermal activity may be distinguished: a) long-term (in large craters, many tens of thousands years at least) thermal anomaly, that causes the convection of ground and meteoric water; this thermal anomaly is provided by both shock heating and uplift of primary deep-seated target rocks in crater centre; b) the creation of the extensive zone of fractured rocks, favourable to the circulation of solutions; c) shock-enchanced deformation of structures of minerals which stimulates reactions between minerals and active fluids; d) potential amount of fluid transfering agents due to water reserves of system. The factors *a*, *b*, *c* assigne potential parameters of hydrothermal circulation system, whereas the intensity of alteration is depended by the latter one, i.e. paleogeographic conditions during an impact.

Any records of impact-induced hydrothermal activity are established in 60 terrestrial craters. They include: occurence of appropriate associations of minerals (including ore-forming parageneses); migration of a series of chemical elements; and existence of specific fluid inclusions. Different impact craters are characterized by similar associations of post-impact hydrothermal minerals: smectites, chlorites, zeolites, calcite, anhydrite, epidote, pyrite, quartz etc. The volume of circulation cell is estimated to reach 1000 km^3 in large (D=50 km) craters. Inferred from distribution features of hydrothermal minerals, two special areas of hydrothermal circulation may be distinguished in an impact crater: the one of them, embraces the central uplift of crater and overlying impact deposits, and the other, associates with large bodies of super-heated melt rocks which fill the ring depression.

In central uplifts of craters, the intensity of hydrothermal alteration decreases both outward from the centre and downward the section. Moreover, vertical zonation of distribution of hydrothermal minerals is established, best examined in the Puchezh-Katunki impact crater, Russia. In this giant astrobleme two zones of hydrothermal alteration are distinguished in vertical section, from top downward: 1) *smectite-zeolite zone*, including coptomictic crater lake deposits, suevites and allogenic breccia, and the upper part of authigenic breccia down to 2550 m; moreover, zeolites as well as smectites vary regularly in compositions in vertical section [3]; 2) *chlorite-anhydrite zone* in the depth interval 2550-5374 m, Ca-Fe silicates (andradite, salite, epidote, prehnite) occuring there as accesory hydrothermal phases. On the margins of the convection cell, phyllosilicates occur in reverse order locally: chlorites are replaced by smectites downward the vertical section. The generalized order of crystallization of minerals is the following: Ca-Fe silicates, chlorites/smectites - anhydrite/calcite - Ca-zeolites - Ca-Na zeolites - calcite, nontronite; it indicates the regressive tendency of hydrothermal alteration process. In geochemical aspects, the addition of Ca, Mg, Fe and releasing of Si, Al, Na and K in the centre of the convection cell is revealed.

In other astroblemes where the distributions of hydrothermal minerals in vertical columnes where examined, some features of the above-mentioned zonation are recorded, for instance in Ries, Germany [4]; Siljan Ring, Sweden [5]; Boltysh and Zapadnaya, Ukraine. Mineral facies analysis using, the decisive force of temperature field on hydrothermal zonation is established, the variability of chemical parameters of solutions being unessential. Thus the upper zone subdivided above is correspond to low-temperature (100-200°C) facies, and the lower, to moderate-temperature (180-300°C) facies, respectively.

Hydrothermal alteration of impact melt rocks in ring depression includes: a) autometasomathic successive replacement of primary phases by more and more low-temperature water-bearing minerals (for instance, in impact melt of the Brent crater: pyroxene - ferroactinolite - clynozoisite, chlorite - saponite); b) late alteration by infiltrating solutions. Secondary mineral associations in impact melt rocks are similar to ones in authigenic breccia, but no zonation in their space distribution is observed. As a sample, suevite blanket in Kara crater may be considered: the mineral association including smectites (replaced after impact glasses), analcime, pyrite, and calcite (in vugs and fractures) dominates in all over the suevite sheet (>2000 km^3) there.

Special features of hydrothermal minerals distribution are interpreted by the model based on the simulation of thermal field evolution in a complex impact crater [6]. This model assumes the meteoric origin of circulated water solutions, the fact is performed by fluid inclusion studies in the Siljan Ring [7] and a series of other craters. Isotopic and geochemical data indicate the shock-enhanced target rocks are the source of mineral substance of solutions. No evidence any abyssal heat and mass addition in post-impact hydrothermal activity is found.

Principal model of post-impact hydrothermal alteration is the following. Alkali surface-derived solutions enriched by Ca, Fe, Mg, SO_3 and CO_2 infiltrate heat rocks of central uplift. During they reacting with shock- and thermal-transformed target rocks, Fe-Mg clay minerals and minor Ca-Fe silicates are being formed, and Si, Al, K, and Na removing to the upper zone of convection cell. The dominating of shock-amorphized aluminosilicates in wall rocks causes the over-saturation of solutions by silica, that stimulates crystallization of zeolites and Fe-smectites as main alteration minerals in this zone. Spatial differentiation of minerals is caused by change of parameters (pH, fco_2, temperature, etc.) of solutions ascending in thermogradiental field.

The study of the impact-induced hydrothermal activity might be used in order to evaluate physical and chemical conditions in impact structures during the late modification stage as well as to study special features of post-impact ore-forming processes and probable contributions of analogous alteration process to the formation of the Martian soil. The occurrence of hydrotermal Cu, Pb, and Zn ore deposits in some craters (Sudbury, Siljan Ring, Crooked Creek, Decaturville etc) demonstrates the reality of post-impact ore-forming hot-water systems; this problem requires special consideration. Recent deep coreholes investigations in craters (Puchezh-Katunki [8], Siljan Ring [5], Manson [9]) create facilities of success to the construction of a detail evolutionary model of post-impact alteration.

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