Kinetic isotope eEffects in snow crystal growth: Lattice-Boltzman approach

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The fractionation of the major water isotope species (HHO, HDO, $H_2^{18}O$) during ice crystal (snow) formation is critical to understanding the global distribution of isotopes in precipitation, and for interpreting ice core data. The morphology of snow crystals is also a subject of continuing interest in physical chemistry and atmospheric science (Libbrecht, KG, *Rep. Prog. Phys.*, **68**, 2005). Although it is known that crystal growth rate, which depends largely on the degree of vapor over-saturation, determines crystal morphology, there is no general model to relate morphology to vapor saturation. Since kinetic (vapor phase diffusion-controlled) isotopic fractionation also depends on growth rate, there should be a direct relationship between vapor saturation, crystal morphology, and crystal $\delta^{18}O$ and δD.

We use a 2D Lattice-Boltzmann model to simulate diffusion-controlled ice crystal growth from vapor-oversaturated air. The two-dimensional, nine-speed model of Kang *et al*. (*Geophys. Res. Lett.* **31**, L21604, 2004) was modified to accommodate the specific boundary conditions needed. In the model, "crystals" grow solely according to the diffusive fluxes just above the crystal surfaces, and hence morphology arises only from the initial and boundary conditions. The input parameters are the isotope-dependent vapor deposition rate constants (k) and vapor diffusivities in air (D). The values of both k and D can be computed from kinetic theory, and there are also experimentally determined values of D. The values of k depend on the sticking coefficient (or accommodation coefficient) for ice, which we assume is independent of position on the crystal surface. The ratio D/k is a length (≈ 0.2 to 0.5 μm) that allows us to scale the numerical calculations to atmospheric conditions using a dimensionless Damkohler number: $Da = kh/D$, where $h \times h$ is the size of the 2D calculation domain.

Our calculations confirm that the crystal/vapor isotopic fractionation approaches the equilibrium value, and the crystals are compact (circular in 2D) as the saturation factor approaches unity ($S = 1.0$). At higher oversaturation (e.g. $S = 1.2$), dendritic crystals of millimeter size develop on timescales appropriate to cloud processes and the isotopic fractionations are dominated by kinetic effects. The results help clarify the controls on dendritic crystal growth, and the relationships between saturation state, growth rate, crystal morphology and isotopic fractionation. They also show the extent to which crystals are likely to be isotopically heterogeneous.

Late Mesozoic volcanism of the eastern flank of Mongol-Okhotsky orogenic belt (Russia)

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In the end of Mesozoic in frames of Eastern flank of Mongol-Okhotsky orogenic belt the volcanic zones were formed. Morinskaya zone of late Jurassic – early Cretaceous (800 km^2) is made by volcanites of basic-acid composition. The age of the rocks is stated by floral remains (Agaphonenko, 2001) and geochronological data by U-Pb method - 120±5 Ma. Seltkanskaya zone of early Cretaceous (6000 km^2) is made by volcanites of basic-acid composition. We defined an age of the rocks of the zone (U-Pb) - 101 ± 2 Ma, and by the data (Agaphonenko, 2001) (U-Pb) - 105 ± 2 Ma. Ezop-Yamalinskaya zone of late Cretaceous (2000 km^2) is made by tuffs, ignimbrites, lavas of asid composition. Age of the rocks is 95.2±0.7 Ma (Rb-Sr) [1]. The period of the formation of the zones is pretty wide, but their geochemical charakteristiks are comparable (Fig. 1). They are impouverished by Nb, Ta, Zr, Hf, Sr and enriched with Rb, Ba, K, Th. According to diagrams that are used to state geodynamical situations it turns out that this rocks are the most close to the formations of edge-continental associations, The rocks are characterized by La/Yb=10-32, La/Ta=20-37.

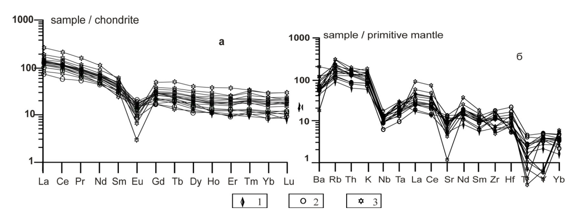

Figure 1. Rocks of volcanic zones: Morinskaya (1), Selitkanskaya (2), Ezop-Yamalinskaya (3).

Conclusions

The geochemical characteristics of volcanites of Eastern flank of Mongol-Okhotsky belt show the presence of the subductional situation under conditions of an activ continental edge during late Jurassic – beginning of late Cretaceous. And the presence of Sr minimum (many authors connect with this a process of the subduction extinguishing) is characterized for the volcanites of the zones and it's enlargement in the rocks to the beginning of late Cretaceous, may show the slowly coming subductional processes, that extinguish in the beginning of late Cretaceous.

References

Agaphonenko S.G. Geological map of Russian Federation. 1: 200 000. Page N -53-XXVI. Blagoveshchensk. 2001.