Thermal state of the lithosphere during Late Heavy Bombardment

OLEG ABRAMOV* AND STEPHEN J. MOJZSIS

Dept. of Geological Sciences, University of Colorado, Boulder, CO 80309-0399, USA
(*correspondence: Oleg.Abramov@colorado.edu, Stephen.Mojzsis@colorado.edu)

We model thermal effects of impacts on the terrestrial lithosphere during the period of Late Heavy Bombardment (LHB), a ~100 Ma epoch of sharply elevated impactor flux at ca. 3.9 Ga. We created a stochastic cratering model which populates all or part of the Earth's surface with craters within a probability field of constraints derived from the lunar cratering record, the size/frequency distribution of the asteroid belt, and dynamical models. For each crater in the model, a temperature field was calculated using analytical expressions for shock-deposited heat and central uplift. The resulting thermal anomaly was then introduced into a 3-dimensional model of the lithosphere, and allowed to cool by conduction in the subsurface and radiation/convection at the atmosphere interface. Parameters tested in the model include the duration, mass flux, and average impact velocity during the LHB, mean lithospheric thickness, lithospheric composition, and the presence or absence of oceans. We also assessed habitability by monitoring habitable volumes for mesophile, thermophile, and hyperthermophile microbial life in what we term the "geophysical habitable zone"; the inhabited crust within a few km of the surface.

Preliminary results of this study indicate that most of the crust was not thermally metamorphosed to a significant degree (e.g., melting) by the LHB, and favor the survival of subsurface microbial biosphere throughout the bombardment.

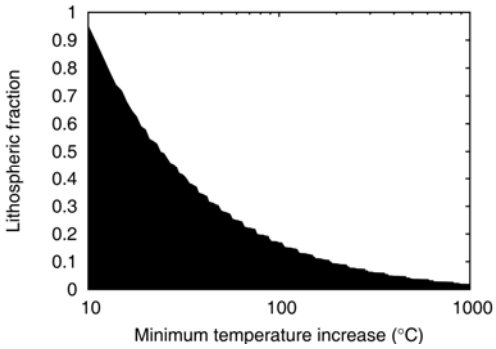

Figure 1: Fraction of lithosphere to experience a temperature increase of at least *x* °C as a result of the LHB. Lithospheric thickness has no significant impact on these results.

Melilitic rocks of the CECIP - Examples from Vogtland/W-Bohemia (Germany/Czech Republic)

M. ABRATIS[1], L. VIERECK-GOETTE[1], J. ULRYCH[2], AND D. MUNSEL[3]

[1]IGW, Universitaet Jena, D-07749 Jena, Germany (*correspondence: michael.abratis@uni-jena.de)
[2]Institute of Geology, Academy of Sciences CR, 16500 Praha 6, Czech Republic (ulrych@gli.cas.cz)
[3]Inst. Mineralogie u. Geochemie, Univ. Karlsruhe, D-76131 Karlsruhe, Germany (dirk.munsel@img.uni-karlsruhe.de)

W Bohemia (Czech Republic) and the Vogtland (Germany) are part of the Central European Cenozoic Igneous Province (CECIP) and one of the seismically most active areas in Central Europe: frequent swarm earthquakes and massive degassing with increasing isotopic mantle signatures indicate subsurface magma migration or magmatic fluid circulation. Quaternary volcanism is restricted to the Ohře/Eger Rift, however, Miocene volcanism extends further to the N along the trace of the Mariánské Lázně fault zone into the Vogtland.

Strongly silica-undersaturated alkaline rocks including olivine melilitites, melilite-bearing and melilite-free olivine nephelinites are prevailing in the W Bohemian/Vogtland area and built up volcanic necks, dikes, diatremes and scoria cones, respectively. The typical mineralogy of the present rocks comprises abundant olivine, diopside, nepheline and melilite as well as volatile-rich minerals such as nosean, haüyne, phlogopite, amphibole and incompatible element-rich minerals such as perovskite. Rarely, carbonate droplets are found enclosed by fresh glass.

Whole rock geochemistry shows that the rocks are highly enriched in incompatible elements such as HFSE (Zr: 280-450 ppm, Nb: 90-170 ppm, TiO_2: 2.6-3.3 %, P_2O_5: 0.9-1.3 %), LREE (La: 65-110 ppm, Ce 150-220 ppm) and other LILE (Ba: 700-1400 ppm, Sr: 900-1600 ppm). All rock types are uniform in their Sr- and Nd- isotopic signature close to the typical European asthenospheric mantle composition (EAR/LVC) with only minor effects by assimilation: $^{87}Sr/^{86}Sr = 0.7032 – 0.7036$, $^{143}Nd/^{144}Nd = 0.51282 – 0.51287$. Trace element ratios (Gd/Yb: 4.6-5.9) and the major element composition (Fe_8: 13%) suggest that melting occurred at rather deep levels >80km and at very low degrees of melting in a considerably fluid and LILE enriched mantle source. The degree of hydrothermal alteration of the rocks increases towards geodynamically active zones.

The abundance of melilitic rocks in the Vogtland/W Bohemia seems to give evidence of intense metasomatism of the subcontinental mantle by carbonate phases in the area of the Mariánské Lázne fault zone.