ON THE RELATIVE IMPORTANCE OF THERMAL AND CHEMICAL BUOYANCY IN IMPACT-INDUCED MELTING ON MARS Thomas Ruedas[1,2], Doris Breuer[2], [1]Institute for Planetology, University of Münster, Germany; [2]Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany (t.ruedas@uni-muenster.de)

Introduction: Convection in planetary mantles is driven by buoyancy that results from density variations, which may have thermal or compositional causes. We study the relative importance of the thermal and compositional contributions to the buoyancy of melt-induced density heterogeneities in Mars by coupling two-dimensional, fully dynamical convection models with a detailed model of the mineralogy and material properties of martian peridotite (e.g., [1, 2]). The main focus lies on the anomalies created by giant impacts, which lead to particularly intense, high-degree melting that may reach deeper than the regular global asthenospheric melting zone. We investigate the differences in the evolutions of models with only thermal and with both thermal and compositional buoyancy for impacts of different sizes; the compositional aspect has been neglected in most previous studies (e.g., [3, 4, 5]).

Method: The convection code is a modified version of STAGYY [6] and solves the conservation equations of mass, momentum, and energy in the compressible, anelastic approximation on a two-dimensional spherical annulus grid [7]. Material properties are derived from mineral physics improved and updated after [1]. For the models with purely thermal buoyancy, the compositional contribution was suppressed by forcing the density (and other physical properties) to remain at the value they would have for undepleted mantle, although the melting degree and changes in trace element composition are changed as usual.

The impact itself is represented as an instantaneous thermal anomaly, with shock-heating derived from the peak shock pressure based on the impedance-match model (cf. [4]); the material properties of the target are derived from the convection model, and the pressure decay with distance from the impact center is given by the "inverse-r" parameterization from [8, 9]. As we model the impacts after existing martian craters, we use their observed final diameters D_f as input and deduce impact parameters such as the impactor size from them using empirical scaling laws [10].

Model: The general model parameters used in all models are listed in Table 1. Impacts of three different sizes corresponding to the Huygens ($D_\mathrm{f} = 467.25\,\mathrm{km}$), Isidis ($D_\mathrm{f} = 1352\,\mathrm{km}$), and Utopia ($D_\mathrm{f} = 3380\,\mathrm{km}$) impact basins, respectively, are considered. All impacts are assumed to occur at 4 Ga, i.e., 400 My after the model run begins; this choice approximates reasonably well the estimated age of the three craters and ensures that the model has developed a lithosphere of a certain thickness, comparable to that of Mars at that age. Most models assumed a bulk water content of 36 ppm by mass, as proposed by [11], but with respect to the ongoing discussion concerning the water content of the martian mantle [12, 13], we also ran some models with the fourfold initial concentration; the principal effect of this parameter concerns the rheological effect of water.

Table 1: Important model parameters

Mantle thickness	1659.92 km
Surface temperature	215 K
Initial potential temperature	1723 K
Initial core superheating	150 K
Simple/complex transition	5.6 km
Bulk silicate Mars Mg#	0.75
Present-day K, Th, U contents	305 ppm/56 ppb/16 ppb
Initial bulk water content	*36*, 144 ppm

Results: Figure 1 shows the temperature and melting degree fields for the model pair with an Isidis-sized impact and a planet with an initial bulk water content of 36 ppm. The impact can be seen in the upper left quarters; it is located in different places in each model, because we tried to avoid sites directly above up- or downwellings. In the model with both thermal and compositional buoyancy (TC), the strongly depleted compositional anomaly from the impact, visible as a dark red patch, spreads beneath the lithosphere and remains there as a stable layer, which is progressively incorporated into the growing thermal lithosphere. By contrast, the compositional anomaly in the purely thermal model (T) is mixed back into the mantle and leaves no coherent trace that survives to the present. The thermal anomaly decays by diffusion within a few tens of millions of years in both cases. The additional melt production results in additional crust production at the impact site, but the net effect is not necessarily a thickened crust, because the impact itself also removes a large amount of crustal material, and a part of it is deposited outside the final crater as ejecta. The results further suggest that the crustal thickness can be locally overestimated by up to 4–8 km if impact-induced density anomalies in the mantle are neglected.

The different behavior displayed by the two model variants is due to the additional density deficit caused by compositional changes of the melting rock, especially the loss of iron. The density deficit suggests that the signature of an impact-generated compositional anomaly may be detectable by gravimetric methods, but a detection with seismic means would not be expected with

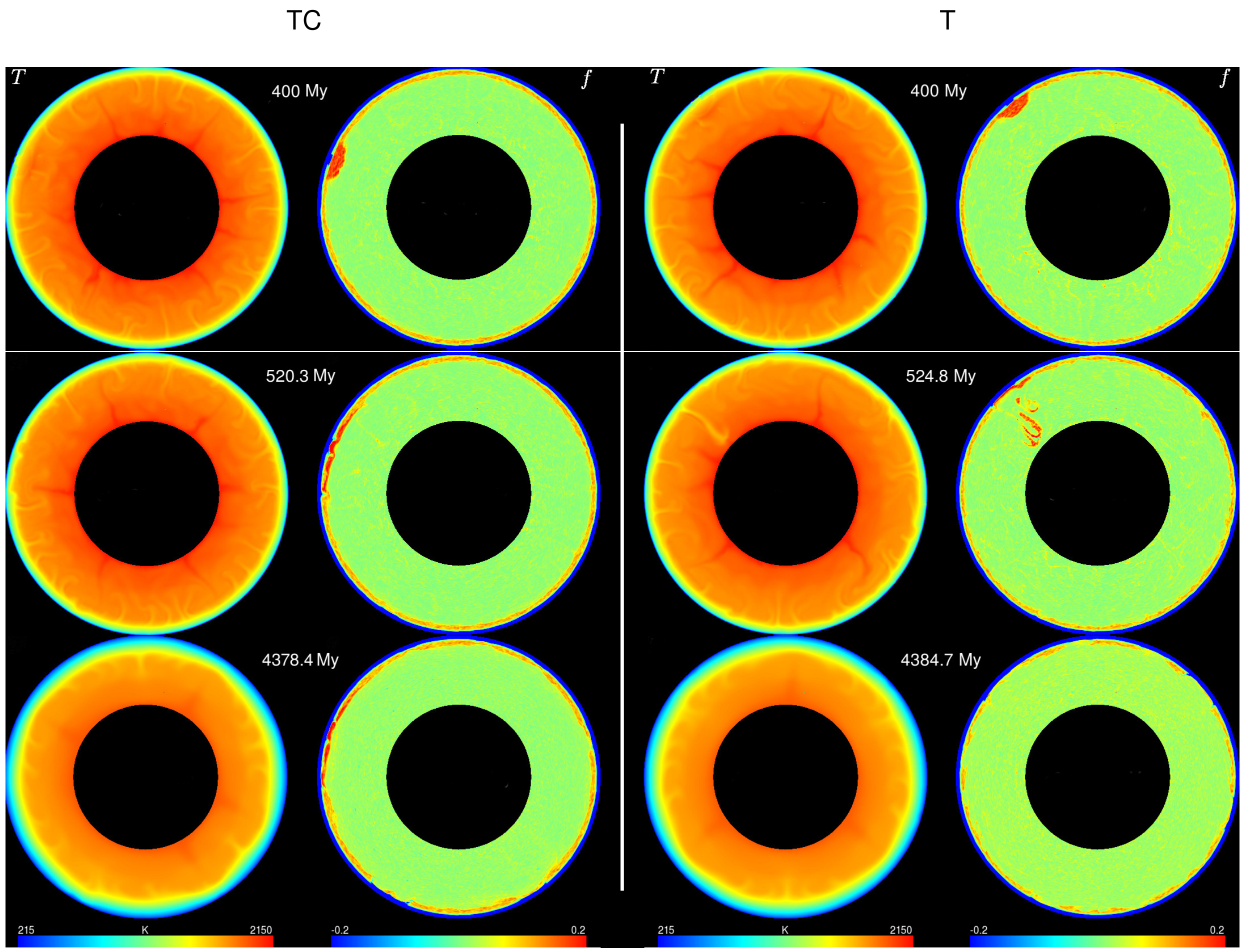

Figure 1: Temperature (T) and composition (f, positive values indicate depletion/melting degree) fields for the models with an Isidis-like impact. Left half: thermal and compositional buoyancy (TC); right half: only thermal and compositional buoyancy (T).

instrumentation whose deployment on Mars can be expected within the next decades (Figure 2).

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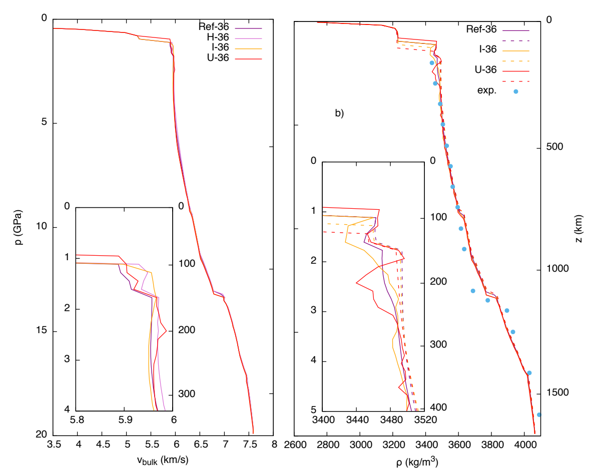

Figure 2: Bulk sound velocity (left) and density (right) from TC models from the 36 ppm water series at 4.4 Gy. The Ref-36 profile is laterally averaged, the profiles of the models with impacts were taken at the impact site. Also shown are experimentally determined densities from [14] for a similar composition.