RESEARCH INTERESTS — LINDA T. ELKINS-TANTON

The internal evolution of planets is the focus of my research. My long-term goal is to better understand how the processes of conductive and convective heat loss combined with crystallization and melting lead to lateral and radial heterogeneities on a range of scales in the mantles of terrestrial planets, with focuses on early planetary evolution as well as volcanic processes. Research results to date include:

Results relying primarily on numerical modeling, linear analysis, and analytic solutions:

- Fractional solidification of a planet initially molten from the heat of accretion and subsequent overturn of the solid phases through density instabilities, with implications for mantle heterogeneity and magnetic field and crustal generation (Elkins-Tanton *et al*., *EPSL*, 2002; Elkins-Tanton *et al*., *MAPS*, 2003; Elkins-Tanton *et al*., *Science*, submitted)
- Rayleigh-Taylor instabilities of the conductive lid on planets, and resulting mantle heterogeneity, topographic changes, and volcanism (Elkins-Tanton and Hager, *GRL*, 2000; Elkins-Tanton and Grove, *JGR*, 2003; Elkins-Tanton, *GSA* book, in press)
- Melting and mantle convection induced by giant meteorite impacts (Elkins-Tanton *et al*., *EPSL*, 2004; Elkins-Tanton and Hager, *EPSL*, submitted)

Results relying primarily on experimental studies:

- Melting and melt evolution in the present-day Cascades volcanic arc (Elkins-Tanton *et al*., *Geology*, 2001; Grove *et al*., *CMP*, 2003; Grove *et al*., *CMP*, 2004)
- Phase equilibria of three lunar picritic glasses, leading to a model of temperature and pressure of the lunar interior ca. 3 billion years before present (Elkins *et al*., *GCA*, 2000; Elkins-Tanton *et al*., *MAPS*, 2003; Elkins-Tanton *et al*., *GRL*, 2003)

RESEARCH TOOLS AND TECHNIQUES

To solve problems involving solid-state fluid flow on planets combined with heat conduction and chemical diffusion I use finite element convection codes in FORTAN (ConMan and our new version, SSAXC) and C (CitCom) run on UNIX systems, though I begin each new problem in a simple way, usually with linear analysis, building to more complex models as my understanding grows.

In addition to mathematical techniques I have conducted several kinds of experiments to place constraints on models. At Brown we are building tanks for fluid dynamic experiments of crystal settling, and I have obtained a 50-hour machining certificate to facilitate manufacturing parts. I intend to continue with fluid experiments when I build my own laboratory. I have also used for high-pressure and –temperature petrologic experiments one-atmosphere, piston-cylinder, and multi-anvil furnaces, with electron microprobes and optical microscopes for analysis.

CURRENT RESEARCH

Physics of magma ocean crystallization: NASA MFR grant

The terrestrial planets are expected to have melted significantly or perhaps completely during formation through the conversion of kinetic energy to heat during rapid accretion of planetesimals, the potential energy release of core formation evolution, and heat from short-lived radionuclides. Supported by my Mars Fundamental Research grant, our research on magma oceans has been ongoing for two years. We model the fractional solidification of a magma ocean while tracking major and trace element compositions and phase assemblages. The resulting cumulate mantle is gravitationally unstable to overturn. During overturn dense cold cumulate from near the surface sink to the core-mantle boundary and warmer cumulates rise, surpass their solidii, and melt.

Solidification models can explain several major aspects of Mars believed to have developed before 4.0 Ga: differentiation of mantle source regions within ~50 Myr of solar system formation into isotopically distinct reservoirs preserved to the present day; development of an early, brief, strong magnetic field (Elkins-Tanton *et al*., submitted); the formation of an early crust with two distinct compositions to record that field; and heat flow low enough to allow the preservation of differences in crustal thickness over the lifetime of the planet. The compositional consequences also include a mantle source region consistent with formation of the Martian meteorites (Elkins-Tanton *et al*., 2003). My collaborators and I are now developing theories on porous flow in cooling, solidifying regions, crystal settling and entrainment in convecting magma oceans, as well as implementing cumulate overturn models in 2D and 3D numerical codes.

Lithospheric controls on flood basalt volcanism: NSF grant

Periodically through Earth history giant volcanic events have occurred on otherwise stable conductive continents. The ductile and brittle processes that lead to the formation of these large igneous provinces are not completely understood. To place constraints on numerical models of melting processes we are working on determining the pressure and temperature of melting and the source composition of a lava from the largest and most destructive of these events, the Siberian flood basalts. Two undergraduate thesis students, Jessica Jewell and Andrew Thorpe, and I, in collaboration with colleagues at the Institute for Meteoritics at the University of New Mexico, have completed experiments at pressures up to 5 GPa.

Through numerical modeling I am working to reconcile the traditional fluid dynamic “plume” model for formation of large igneous provinces with the formation conditions from our experimental study and with geological observations that the crust under Siberia subsided significantly during eruption. Previous and ongoing work indicates that gravitational instability of the lower lithosphere combined with a plume-like upwelling can satisfy the geological constraints for subsidence and the volume of magma produced (Elkins-Tanton and Hager, *GRL*, 2000). One paper on delamination is in press (Elkins-Tanton, accepted for upcoming GSA book *Melting anomalies: Their Nature and Origin*) and another paper is in preparation.

The numerical models of instabilities and resulting topographic changes and mantle melting are also being applied to Venus, where they can explain the planet’s unusual volcanic activity.

Fluid flow and melting in subduction zones

I am collaborating with colleagues at Brown to create numerical models of two-phase flow (solid mantle flow and buoyant rise of fluids) in subduction zones. We find that the rheology of the mantle wedge significantly affects the directions of flow of fluid-activated mantle melts; over a wide range of parameters some fraction of hydrous fluid and melt are carried down into the mantle and not allowed to erupt. Initial results of this study have been presented at conferences and a paper is in preparation.