The effect of Rayleigh-Taylor instabilities on the thickness of undifferentiated crust on Kuiper Belt objects like Charon

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The recent models of KBO thermal evolution presented by Desch et al. (2009) argue that for Charon-sized bodies, temperatures in the outermost 85 km always remain low enough that viscosity prevents differentiation of ice and rock. This outer crust, representing 37% of the moon's mass, remains undifferentiated, despite the fact that its interior is warm enough to have formed a rocky core and ice mantle, even support liquid water today. More recent work (Cook et al. 2011) suggests that one consequence of this undifferentiated crust: the impact that formed Haumea would have ejected substantial ice/rock crustal fragments that would be unrecognized members of Haumea's collisional family.

These models assumed differentiation occurs only when viscosities are low enough (and temperatures high enough) to allow Stokes flow of large (meter-sized) rocks through ice on geological timescales. In practice this requires temperatures above the eutectic of ammonia-water ice, 176 K, above which the viscosity drops 5 orders of magnitude. It is questionable whether rocks are large enough to undergo Stokes flow; the rocky component may instead be sand-sized and well mixed with ice. This treatment also has neglected Rayleigh-Taylor (RT) instabilities at the ice mantle-crust interface.

We have calculated the viscosities and temperatures needed for RT instabilities to overturn the crust on geological timescales. We conclude that temperatures over 140 K are required. Differentiation is therefore more effective than previously considered; however, a substantial crust remains. For our canonical case the crust thickness is still 75 km, representing 33% of Charon's mass.

We conclude that the Desch et al. (2009) models remain substantively correct. We predict that Charon's crust should be largely undifferentiated, down to depths of many tens of km. The possibility of cryvolcanism, raised by Desch et al. (2009), remains valid.

References: Cook, J. C., Desch, S. J., & Rubin, M. E., LPSC 42, 2503. Desch, S. J., Cook, J. C., Doggett, T. & Porter, S. B., 2009, *Icarus* 202, 694.