EPSC Abstracts
Vol. 10, EPSC2015-547, 2015
European Planetary Science Congress 2015

Review on material recycling in planetary bodies

K.Kurita (1), D. Shoji (2), H.Ichikawa (3) and S,Omori(4)

(1) ERI, The Univ. of Tokyo,Tokyo, Japan, (2) DLR, Berlin,Germany, (3) GRC,Ehime University,Matsuyama,Japan, (4) Open Univ. Japan,Chiba,Japan

(corresponding address kurikuri@eri.u-tokyo.ac.jp / Fax: +81-25841-0796)

Abstract

As a basic process to drive material recycling without the plate tectonics in planetary bodies we propose a delamination process in the surface layer. Particularly we focus on the compositional delamination. In the silicate system the basaltic surface crust is produced by melting, which can transform higher density layer at depth. In icy bodies infall of ice/rock mixture can form higher density surface layer. In either situation the density reversal of the surface is expected to develop, which can drive delamination of bottom of the surface layer. We will review various styles of delamination in wide ranges of planetary/satellite systems.

1. Introduction

In planetary/satellite systems where the plate tectonics is not working thermal plumes contribute material transport from the inside and differentiations through induced volcanism. To ensure material recycling to the interior only possible style would be overturn/delamination of the surface crust. Since this process is principally Rayleigh-Taylor Instability, it requires development of density reversal of the surface layer. In this presentation we focus on the delamination as a basic style of mantle dynamics without the plane tectonics and review various styles of the delamination in wide ranges of planetary/satellite systems.

2. Two models

There are two origins for the development of density reversal of the surface: thermal and compositional origins, which will be driving factors for the delamination. In the thermal origin model, the surface boundary layer due to the planetary secular cooling becomes denser because of lower temperature. Since the uppermost layer is expected to be strong the intermediate layer between the surface and the interior could deform to be delaminated from the upper[1]. But this model is essentially same as the convective instability of the boundary layer and no compositional differentiation is involved so that the recycling can not affect the compositional evolution. In the compositional origin model the basalt formed by melting of the silicate mantle can transform to eclogite at depth, which could be denser than the mantle. Growing this layer can induce delamination. After first explicit description by Kay and Kay [2] this process has been widely considered in the orogenic tectonics in the Earth. In Venus importance of basalt-eclogite transition has been well recognized in 1990s such as [3] and [4] the role as a recycling process has only been incorporated since Dupeyrat et al 1999. Since the basalt-eclogite transition is induced at high pressures, a large planetary body is required. The exception is Mars, where iron-rich basaltic crust can transform to eclogite at relatively low pressure and thus induced delamination is highly plausible[6]. The model is extended to the case of super-Earth [7]
Similar process is incorporated in the evolution models of icy bodies [8] and Ceres [9] though the origin of density anomaly is exogenetic.

3. Some problems

There exist several problems to evaluate compositional delamination process properly. The most significant one, which is stated in [10] is the higher strength of eclogite comparing to the surrounding materials. This could resist deformation and detachment from the upper layer. This situation makes quite difficult to evaluate time scale of the process. In the current numerical treatments incorporation of high-strength behavior such as the fracturing process is difficult. Role of water in reduction of the strength and phase transition-induced weakening along the boundary may be important.

4. Planetary volcanism as observational constraints

Since the delamination itself is going on well below the surface it is quite difficult to trace and characterize by observable data ;the planetary remote sensing explorations. Here we suggest a volcanism as a surface manifestation of the delamination. In the Earth there exist many examples of delamination-induced volcanism[11]. The delamination could induce adiabatic rise of the mantle as a compensating flow. If the mantles temperature is close to the solidus it can easily melt during the ascent, which can appear as volcanoes at the surface. The volcanism such as at Colorado Plateau[12] and [13]Carpathia is proposed as a site of delamination-induced volcanism. We propose to explore characterization of volcanism in relation to other features such as gravity field in the planetary exploration data as well as extensive comparison with terrestrial examples for the future works.

References

[1] Bird, P.:JGRB 84,7561,1979.

[2] Kay, R. and Kay, S.: Tectonophysics 219,177,1993.

[3] Namiki, N. and S.Solomon.: JGRE 91,15025,1993.

[4] Dupeyrat, L. and C.Sotin:PSS 43,909,1995.

[5] Dupeyrat, L. et al: JGRE 104,27163, 1999.

[6] Kurita, K. et al EPSC 2013

[7] Shoji, D. and K.Kurita: PSS 109-110,38,2015.

[8] Rubin, M. et al: Icarus 236,122,2014.

[9] Shoji,D. and K.Kurita: JGRE 119,2014.

[10] Nimmo, F. and D.Mckenzie: Ann.Rev.Eart Planet. Sci.,26,23,1998

[11] Ducea, M.:Geology 39,119,2011

[12] Manley, C. et al: Geology 28,811,2000.

[13] Ismail-Zadeh et al. :GJInt. 168,1276,2007.