ANORTHOSITE IN THE SEPT ILES LAYERED INTRUSION (CANADA): IDEAS FOR THE FORMATION OF THE LUNAR CRUST. B. Charlier[1], O. Namur[1] and T. L. Grove[2], [1]University of Liege, Belgium, [2]Massachusetts Institute of Technology, USA.

Introduction: The ca. 6 km-thick Sept Iles layered intrusion covers 5000 km^2 in Quebec and has an estimated magma volume of ca. 20,000 km^3 [1] emplaced 564 ± 4 Ma ago during the Iapetus ocean opening [2]. It is thus one of the largest layered intrusion in the world, after Bushveld and Dufek. The intrusion is subdivided into (1) a 4700 m-thick layered series, made up of troctolite, Fe-Ti oxide troctolite and layered gabbro, (2) an anorthositic upper border series capped and cross-cut by (3) K-, REE-rich granites. Associated dykes and fine-grained rocks from marginal zones define a tholeiitic liquid line of descent starting with a basalt at 48 wt% SiO_2 and 15 wt% FeO_t that evolves to A-type granite with 78 wt% SiO_2.

Plagioclase flotation and anorthosite formation: During the fractionation of troctolites, plagioclase composition evolves from An_{70} to An_{60} and its density is lower than that of the liquid with which it is in equilibrium. Part of this plagioclase is interpreted to have accumulated at the top of the intrusion to form the 500-800 m-thick anorthosite, that has the same restricted range of plagioclase composition between An_{70} to An_{60}. The relative weight proportion of plagioclase/olivine in the layered series at the base of the intrusion is 70/30 on average, so that only a small proportion of buoyant plagioclase accumulated at the top the intrusion to form rocks with >90% plagioclase. Ferromagnesian minerals in these rocks are interpreted to result from the crystallization of trapped liquid. No plagioclase composition more evolved than An_{60} is found in the anorthositic upper border series. This results from the decreasing melt density after the saturation of Fe-Ti oxides and clinopyroxene that occurs when plagioclase reaches An_{60}. More evolved liquids are thus more dense than the plagioclase with which they are in equilibrium. The accumulation of buoyant plagioclase at the base of the magma chamber may be interpreted as resulting from in situ crystallization in an advancing front of solidification against the floor where crystals nucleated and grew in a static boundary layer [3] or through sinking of plagioclase-chain network that has entrapped dense ferromagnesian minerals [4].

Plagioclase sinking and autolith accumulation: Blocks of anorthosite that range from a few dm to hundreds of meters are found in cumulates with plagioclase, olivine, Fe-Ti oxides and clinopyroxene at the base of the intrusion in which negatively buoyant plagioclase starts at An_{60} and evolves to An_{30}. These blocks are interpreted as foundered rocks detached from the anorthositic upper border series that sink as a result of the decreasing melt density with differentiation.

Ideas for the LMO: The lunar crust is commonly interpreted to be formed by the crystallization and flotation of plagioclase from a global magma ocean [5]. Even if there are many occurrences of pure anorthosites (nearly 100 vol% plagioclase) in the upper ca. 30 km lunar highland crust [6], there are reasons to suggest that the lunar crust is vertically zoned with more mafic lithologies (norite, troctolite) in its lower part [7]. While the presence of less than 10 vol% dense ferromagnesian minerals in floated cumulates might be easily explained as resulting from trapped liquid crystallization, it becomes a serious issue if bulk cumulates are more mafic, such as noritic and troctolitic lithologies that contains up to 50 vol% olivine and/or pyroxenes [7].

Magma chamber processes that occur in the Sept Iles layered intrusion might give rise to new ideas about the lunar crust formation. Considering that buoyant plagioclase may partially accumulate at the top of the magma chamber and partially accumulate at the bottom, we suggest that only the lunar upper crust is a floated cumulate while the lower crust might be its counterpart cumulate. Detailed knowledge of modal proportions in the lower and upper lunar crusts, their relative thickness and data on cotectic plagioclase proportion during the late-stage evolution of the lunar magma ocean will further constrain the formation of the primordial lunar crust.

References: [1] Loncarevic B. D. et al. (1990) *Can J Earth Sci, 27*, 501–512. [2] Higgins M. D. and van Breemen O. (1998) *Journal of Geology, 106,* 421-431. [3] McBirney A. R. and Noyes R. M. (1979) *J Pet, 20*, 487–554. [4] Philpotts A. R. and Dickson L. D. (2000) *Nature, 406*, 59–61. [5] Warren P. H. (1990) *Amer Min, 75*, 46–58. [6] Ohtake M. et al. (2009) *Nature, 461*, 236-240. [7] Wieczorek M. A. et al. (2006) *Reviews in Mineralogy and Geochemistry, 60*, 221–364.