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The formation of super large stratified apatite and rare-metal (Nb,Ta, REE, Zr,Hf) deposits in the peralkaline Khibina and Lovozero complexes (Kola Peninsula).

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The Khibina and Lovozero massifs represent two of the world's largest peralkaline layered intrusions of Devonian age. The Lovozero mainly consists of two intrusive phases- differentiated complex of urtites, foyaites and lujavrites, and eudialyte lujavrites.The Lovozero massif comprises two super-large rare-metal (Nb, Ta, REE, Zr, Hf) deposits. The first main ore mineral is loparite (Na, Ce, Ca)2 (Ti, Nb)2O6 which was mined during many years. In the deepest zone of the intrusion loparite forms anhedral grains confined to interstitial spaces. Above 800m in stratigrafic section loparite makes up euhedral crystals which were formed at the early stage of crystallization. Therefore the initial magma was undersaturated with loparite. .After the formation of approximately one-third of the volume of the Lovozerointrusion, the melt became saturated with loparite and this mineral accumulated in ore layers. The composition of cumulus loparite changed systematically upward through the intrusion with an increase in Na, Sr, Nb, Th, U and decrease in REE, Zr, Y, Ba and Ti. Our investigation indicates that the formation of loparite ore was the result of several factors including the chemical evolution of high alkaline magmatic system and mechanical accumulation of loparite as a heaviest phase at the base of convecting unit. The second ore mineral is eudialyte Na4(Ca, REE)2Zr3(Mn, Fe) $Si8O_22$(CL,OH)2 which is the complex ore for Zr, Hf, REE, Nb.Eudialyte forms euhedral good-shaped crystals only in eudialyte lujavrites, in the differentiated complex eudialyte crystallized as interstitial anhedral forms. Therefore the initial alkaline magma was not saturated in respect of eudialyte and after the crystallization about 80% -eudialyte became the liquidus phase and segregated in ore horizons which occur in the upper part of eudialyte intrusion. In the crossection of eudialyte intrusion the composition of pyroxenes changed systematically upward with an increase in Na, Ti and decrease in Mg and Ca. There is hidden layering in eudialyte with an increase of Fe and Cl and decrease in Mn and S.
The Khibina alkaline massif hosts the world's largest and economically most important apatite deposit.The Khibina massif is a complex multiphase body. The apatite intrusion is represented by a layered body of ijolitic composition with a thickness of about 1 -2 km. The upper zone is so-called sugar apatite ore consists of 60-90% euhedral very small (tenths of mm)apatite crystals.The lower zone is mostly ijolitic composition and grades into underlying massive urtite consisting of 75-90% large (several mm) euhedral nepheline.Our experimental studies of Ne-Ap-Di system demonstrate the near-eutectic nature of the apatite-bearing intrusion.
Our calculations show that under steady-state convection large crystals of nepheline continuously had been settling forming massive underlying urtite when smaller crystals of pyroxenes, nepheline and apatite had been stirred up in the convecting melt. Hidden layering of apatite in the vertical section is in agreement with proposed model.