Refining Thermodynamic and Geochemical Understanding of Magmatic Systems:

Two New PhD Projects at the Univ. of Helsinki

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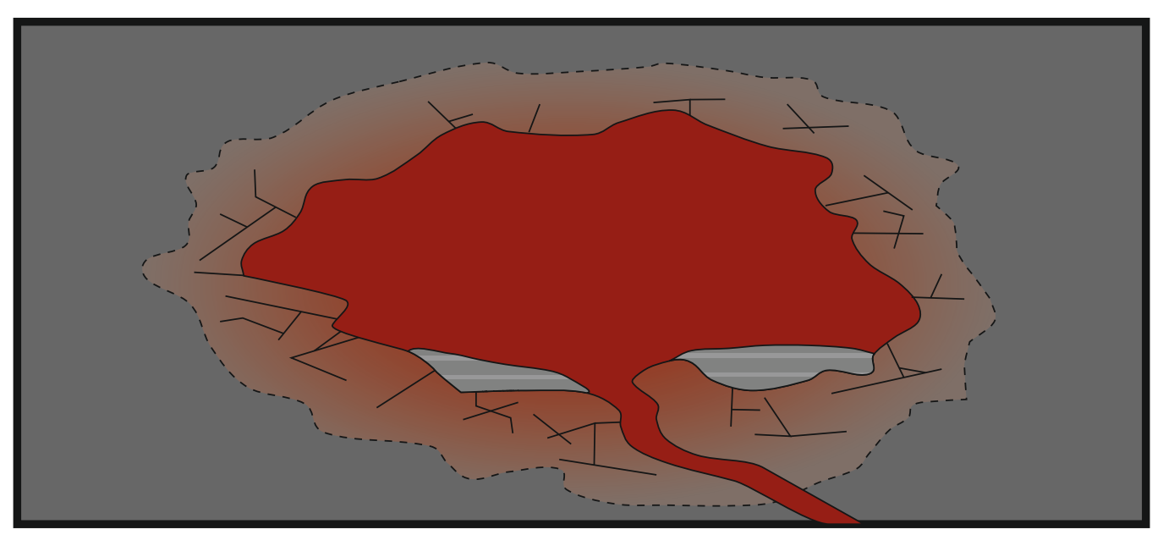

New Tools to Study Magma Chamber Processes

Magmatism is largely responsible for the transport of energy and matter within the Earth's crust. Magma-wallrock interaction in crustal magma chambers (a process known as crustal assimilation) is critical to the thermodynamic and chemical evolution of a magmatic system and formation of many of the most economically important base and precious metal (e.g., Cu, Ni, platinum-group elements (PGE)) deposits on Earth. Although such generalized model is largely accepted, details on how these interactions take place are relatively poorly characterized. One of the major issues has been the lack of models that integrate mass and energy exchange, thermodynamics and geochemistry.

The so-called AFC (assimilation-fractional crystallization) model (DePaolo 1981) is a classical and the most widely used chemical assimilation model in geoscientific research. However, it does not provide any hint on whether its results are thermodynamically feasible or not. The Magma Chamber Simulator (MCS; Bohrson et al. 2014) significantly improves on these shortcomings by adding thermodynamic constraints for a multicomponent + multiphase magma body that crystallizes in contact with a crustal wallrock and is recharged with batches of fresh magma. This tool, accompanied with partial melting experiments in relevant temperatures and pressures, will enable more accurate constraining of the thermodynamical and chemical evolution of any igneous system.

Project #1

Focus: Wallrock Partial Melting and Mafic Layered Intrusions

Wallrock assimilation is a major process controlling chemical and physical evolution of mafic layered intrusions (Fig. 1), and many of the largest Ni-Cu-sulfide deposits owe their existence to adjacent sulfur-bearing sedimentary rocks (Naldrett 1999). Partial melting behaviour of wallrocks is a compilation of overlapping processes, e.g. dehydration and congruent and incongruent melting that are controlled by the mineral and chemical composition of the wallrock as well as the prevalent P-T conditions. Laboratory experiments on wallrock powders under relevant conditions provide essential knowledge of the nature of partial melting of different wallrocks.

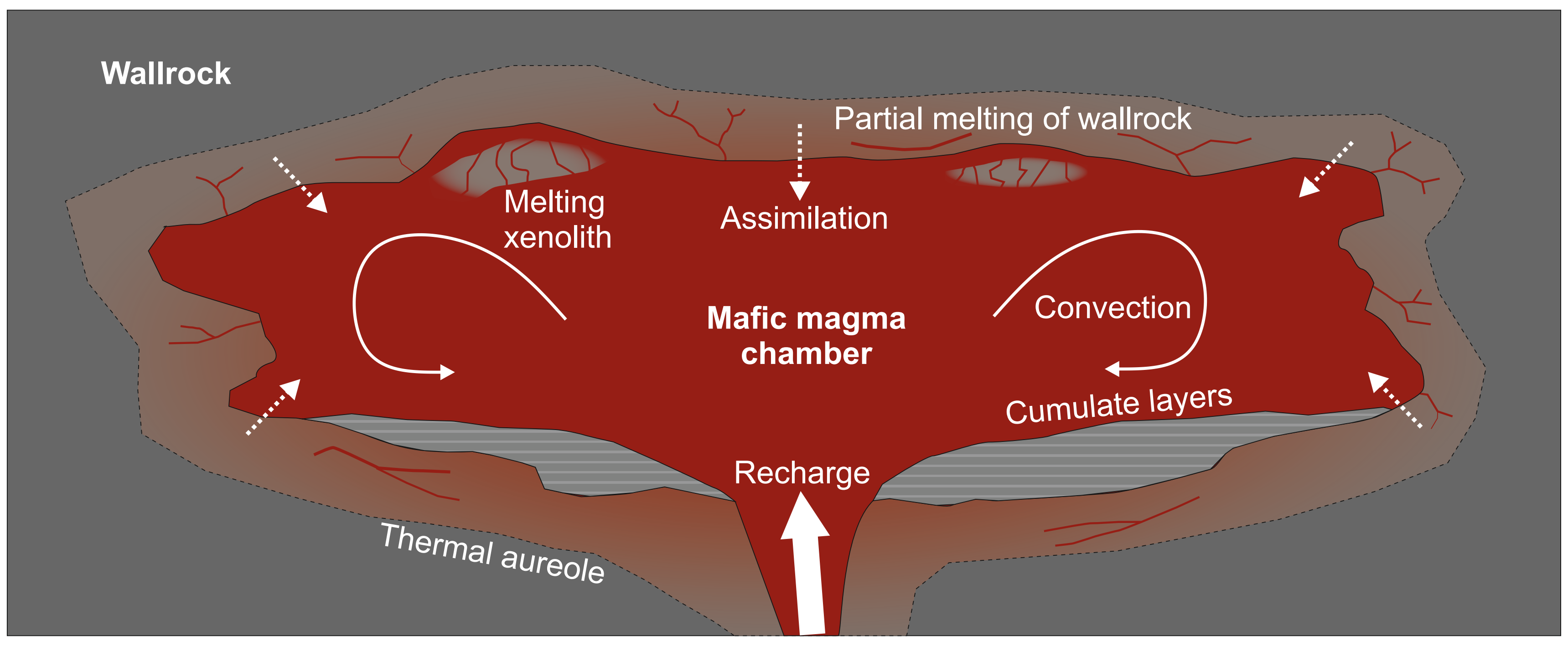

Figure 1. Sketch of a mafic magma chamber and the major processes affecting its compositional evolution after emplacement. Assimilation and recharge may result in significant phase changes in the magma chamber, e.g., formation of an immiscible sulfide melt.

Project Outlines

Partial melting data will be experimentally produced from various wallrock types: black schists, banded iron formations, and hydrothermally altered basalts, which are suggested to cause major effects (e.g. sulfide immiscibility, stability of atypical phases, isotopic overprinting) when assimilated by mafic layered intrusions. Partial melting experiments will be conducted with cold seal pressure vessels (Fig. 2) and the end products will be studied using EPMA and LA-ICP-MS. Emphasis will be placed on the following aspects:

1. Solidus temperature
2. Nature of melting
3. Peritectic reactions
4. Major and trace elements
5. The effects caused by adjacent basaltic melt

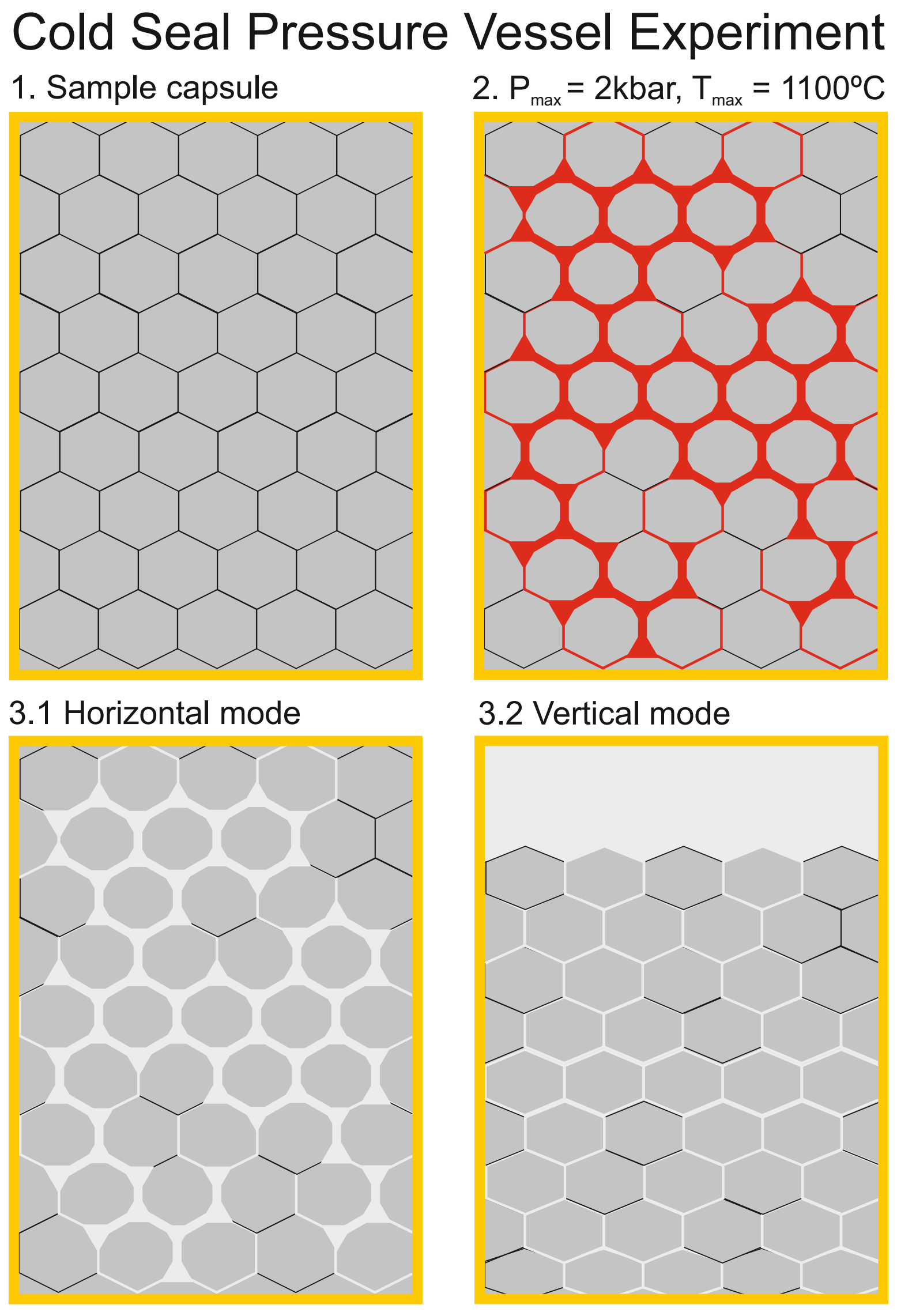

Figure 2. 1. Sample powder is placed in gold capsule. 2. Partial melting begins. 3.1 The melt is rapidly quenced as pockets. 3.2 The melt is gravitatively segregated before quenching to enable trace element analysis by LA-ICP-MS.

Project #2

Focus: Massif-type Anorthosites and Related Ni-Cu ore Potential

The 1.64 Ga Ahvenisto complex and 1.35-1.29 Ga Nain Plutonic Suite (NPS) are anorthositic complexes that share geological and geochemical characteristics (Figs. 3, 4). NPS hosts the Voisey´s Bay intrusion and massive Ni-Cu sulfide ores, which are related to the most mafic members (troctolites) of the suite. The evalution of parental magma composition for massif-type anorthosites has proven to be challenging, and no lasting solution has yet been presented. The aim of this project is to produce a comprehensive melt evolution model for the anorthosites and to study related ore forming processes with the help of geochemical and thermodynamical modeling (MCS). Similarities between the two suites has sparked interest in the possible ore potential of the Ahvenisto complex.

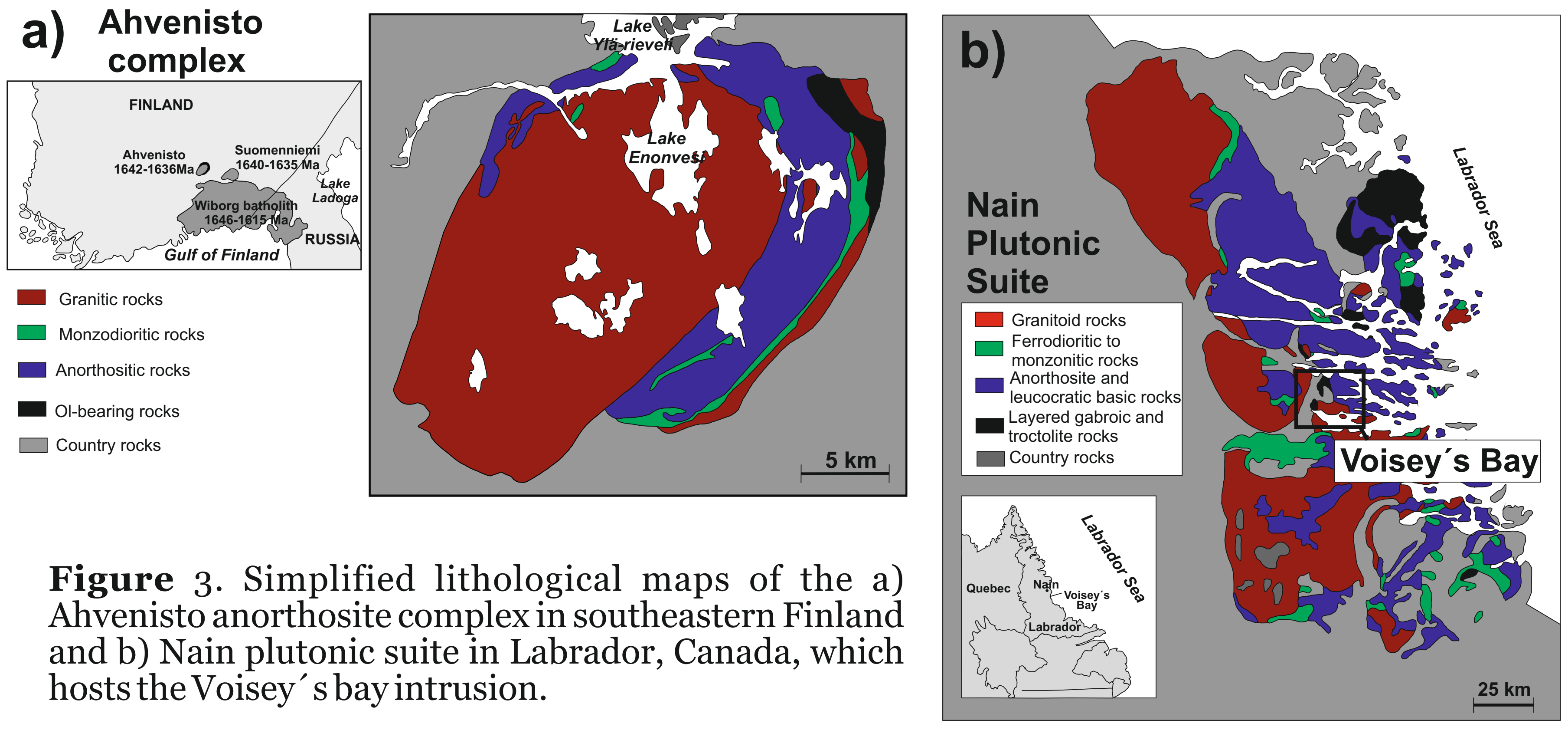

Figure 3. Simplified lithological maps of the a) Ahvenisto anorthosite complex in southeastern Finland and b) Nain plutonic suite in Labrador, Canada, which hosts the Voisey´s bay intrusion.

Recent studies (Fig. 4, Fred et al. 2016) in the Ahvenisto complex have revealed that monzodioritic members of the anorthositic Ahvenisto suite show evidence of magma differentiation and most likely represent a residual melt phase. A detailed melt evolution model of the monzodioritic rocks could be used to better constrain the parental magma composition of the Ahvenisto suite and also massif-type anorthosites elsewhere.

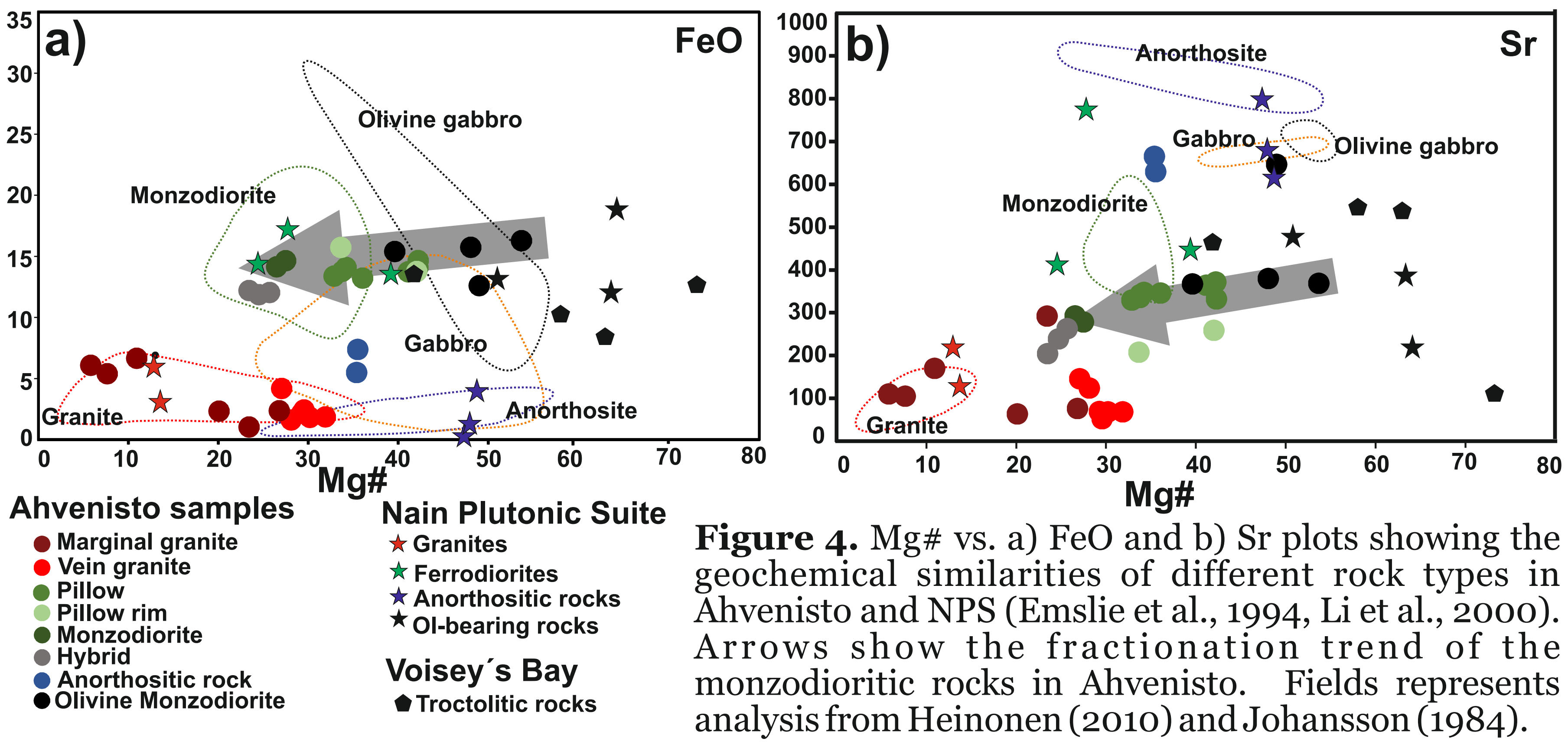

Figure 4. Mg# vs. a) FeO and b) Sr plots showing the geochemical similarities of different rock types in Ahvenisto and NPS (Emslie et al., 1994, Li et al., 2000). Arrows show the fractionation trend of the monzodioritic rocks in Ahvenisto. Fields represents analysis from Heinonen (2010) and Johansson (1984).

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