Pressure influence on Ar solubility in tholeiite melt

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In a recent paper, Sarda and Moreira (2002) have shown that degassing of Mid-Ocean Ridge tholeiite occurs via vesiculation followed by variable vesicle loss. Noble gas concentration data record this in the form of vesicles-melt binary mixing hyperbolae, in diagrams such as the $^{4}He/^{40}Ar$ versus ^{40}Ar plot where Ar concentration is a proxy for vesicle abundance.

We have modelled this using equilibrium vesiculation described by Henry's law, plus gas–melt mixing equations. The modelling suggests that Henry's solubility constants for noble gases differ from those measured in the laboratory at 1 atm pressure. The Ar solubility should be about 7 times lower.

One possibility is Ar solubility to decrease with increasing pressure due to melt compression. Here, I show that, assuming an exponential decrease allows a correct fit of the recently published high-pressure Ar data of Schmidt and Keppler (2002). This assumes Henry's law holds at high pressure following:

$C=Sf$

where C is Ar concentration in melt, S Ar solubility and f Ar fugacity. Differentiating the above equation relative to pressure yields the differential equation to be integrated:

where γ is the fugacity coefficient, Z gas compressibility, P pressure, and k the constant of the solubility exponential decrease. I used the Redlich-Kwong equation of state to calculate γ and Z for Ar at all pressures. I found a value of about 2 GPa^{-1} for k.

The model used by Sarda and Moreira (2002) can be adapted for vesiculation at constant, high pressure. If this is followed by a pressure decrease down to eruption affecting *only* gas volume without re-equilibration between gas and melt, then, the formulas of Sarda and Moreira (2002) are valid provided the solubility constant keeps its high pressure value. An Ar solubility decreased by a factor of 7 corresponds to a pressure of about 1 GPa (close to 30 km).

This model is too simple, as re-equilibration between gas and melt must occur in reality. However, it shows that vesiculation under ridges probably occurs at a depth of some tens of kilometres during magma ascent to the oceanic floor.

References:

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Cenozoic volcanism in Sikhote Alin, Russia: Transition of magma type associated with backarc opening

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Introduction

The attention will be paid to magmatism in the North Sikhote Alin, one of the backarc region, simply because that region was attached to the NE Japan arc. In order to document the magmatic activity more comprehensively, the analyses will cover the whole region of the North Sikhote Alin, although previous works focused solely on the coastal range about changing ages and geochemistry.

Result and Discussions

K-Ar ages and major/trace element compositions were obtained from 71 fresh lavas from the northern Sikhote Alin, Far East Russia, in order to document the secular variation in volcanism and upper mantle processes during backarc opening. This region is distinct in that it was the home of the NE Japan arc sliver before the opening of the Japan Sea backarc basin. Also, the distribution of lavas from the coastal region to the inner continent is the characteristic feature of this region. North Sikhote Alin can be divided into two volcanic province, that is, the East Sikhote Alin (ESA) along the Japan Sea coast, the West Sikhote Alin (WSA). The volcanic activity in the north part took place between 40-25 Ma and 20-5 Ma, and was a marked hiatus volcanism during 25-20 Ma, which is synchronous to the period of the major opening event in the Japan Sea backarc basin. It should be stressed that the volcanic activity during the pre-opening stage occurred in the entire ESA along Japan sea, whereas no volcanism in the WSA. Such an arc-like signature may suggest the location of this region before the formation of the backarc basin. On the other hand, the volcanism during 20-5 Ma exhibits spot-like signatures appeared throughout.

Summary

All lavas erupted in the ESA during 40-25 Ma have compositions typical of subduction magmas, which marked secular variation in lava chemistry, the ESA implied to be formed a arc before the opening. During 20-5 Ma, intraplate-type lavas with typical hotspot magma compositions typifies the Sikhote Alin volcanism and may be caused by mantle upwelling beneath the Cenozoic intraplate basalt province in the northeast Asia.