Differentiation history of Hubert Miller Seamount basalts, Amundsen Sea, South Pacific

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Summary Rock samples from Marie Byrd Seamounts were dredged for the first time during R/V Polarstern expedition ANT-XXXIII/4 in spring 2006. The seamounts form a group of 8 submarine volcanic edifices located in the southern Amundsen Sea between 68°-72°S and 112°-132°W off the shelf of Marie Byrd Land. Basalts dredged at the flanks of the Hubert-Miller-Seamount belong to the alkali basalt – trachybasalt differentiation series. Cumulates including Ti-augites are proof for an additional more Si-undersaturated phase of magmatism, xenocrysts of oligoclase indicate shallow magma plumbing of higher degrees of differentiation. Igneous clasts with sub-greenshist metamorphic overprint are indications for flank collapses. However, samples of yet uncertain origin are (1) Sisaturated coarse crystalline igneous clasts (dykes incl. lamprophyric texture) some with metamorphic overprint and (2) quartzsandstones and litharenites with grains of deformed quartz as well as light mica which require continental crust as source rocks.

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Introduction

The Marie Byrd seamounts are located in the southern Amundsen Sea between 68° and 71°S and 112° and 132°W off the shelf of Marie Byrd Land (Fig. 1).

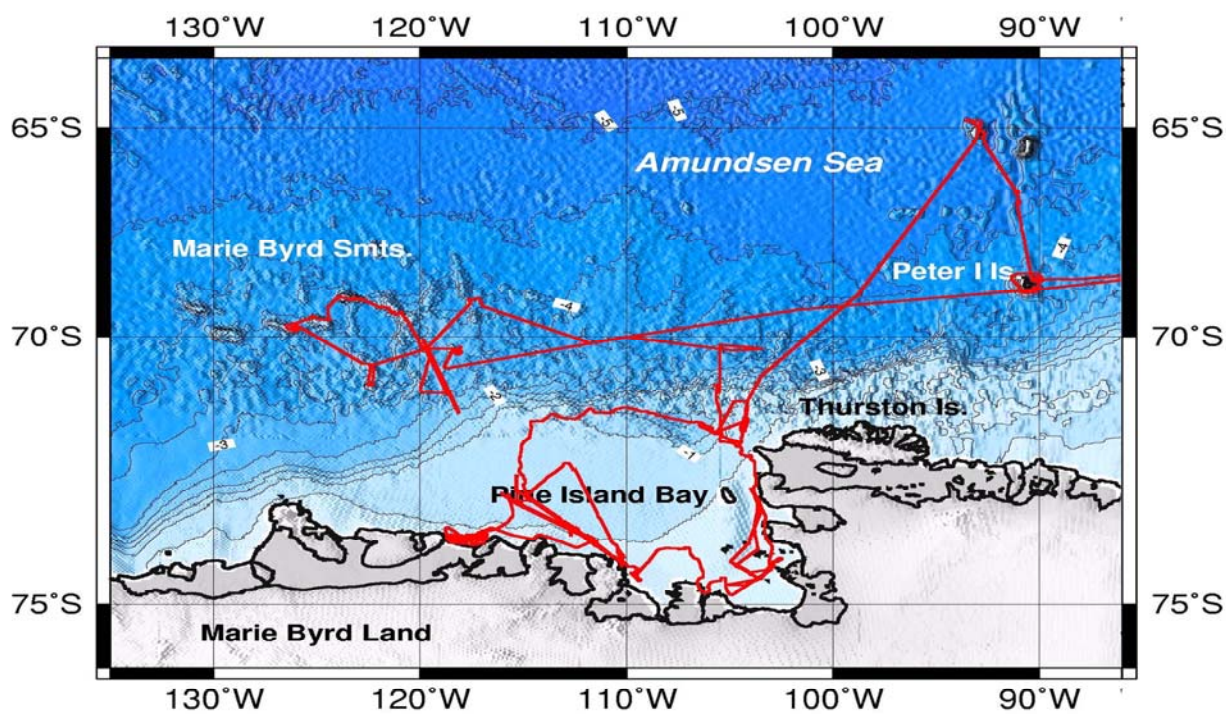

Figure 1. Cruise plot of expedition ANT-XIII/4

During two expeditions with R/V N.B. Palmer (1996) and F.S. Polarstern (ANT-XVIII/5a, 2001) only two out of almost 20 seamounts had been mapped (Fig. 2). The individual volcanic edifices rise up to 3,000 m above the seafloor from abyssal plain depths of 3,500 – 4,000 m. They are volcanoes with steep flanks and flat plateaus within 1,000 – 1,500 m water depth, indicating subaerial activity, followed by subsidence accompanied by erosion. Volcanic cones 200 m in heighth proof a second post-erosional volcanic phase. Until 2006, rock samples were not recovered from the Marie Byrd Seamounts. Their origin and geological history still remained enigmatic.

The Hubert Miller Seamount

A bathymetric mapping and hard rock sampling program with chain bag dredges was performed during F.S. Polarstern expedition ANT-XXIII/4 in spring 2006. It focused on the Hubert Miller Seamount which is one of the larger seamounts within the Marie Byrd Seamount Volcanic Field (Fig. 3). This seamount is NW-SE orientated, extends for 75 x 50 km and exhibits a characteristic flat plateau at 2,400 m above seafloor and 1,600 – 1,200 mbsf.

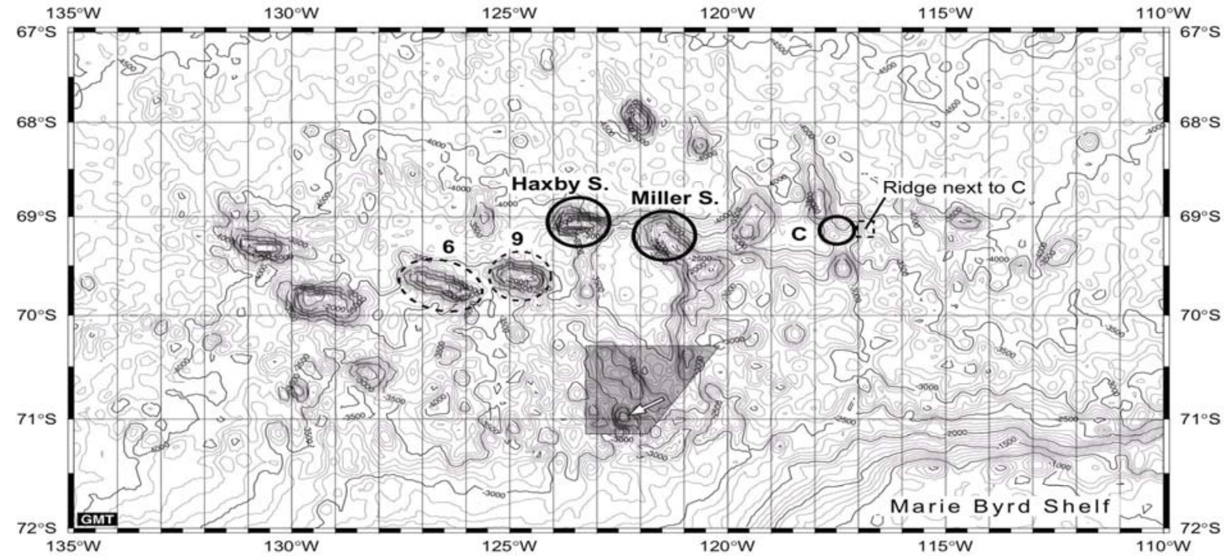

Figure 2. Position of the Hubert Miller Seamount within the Marie Byrd Seamounts

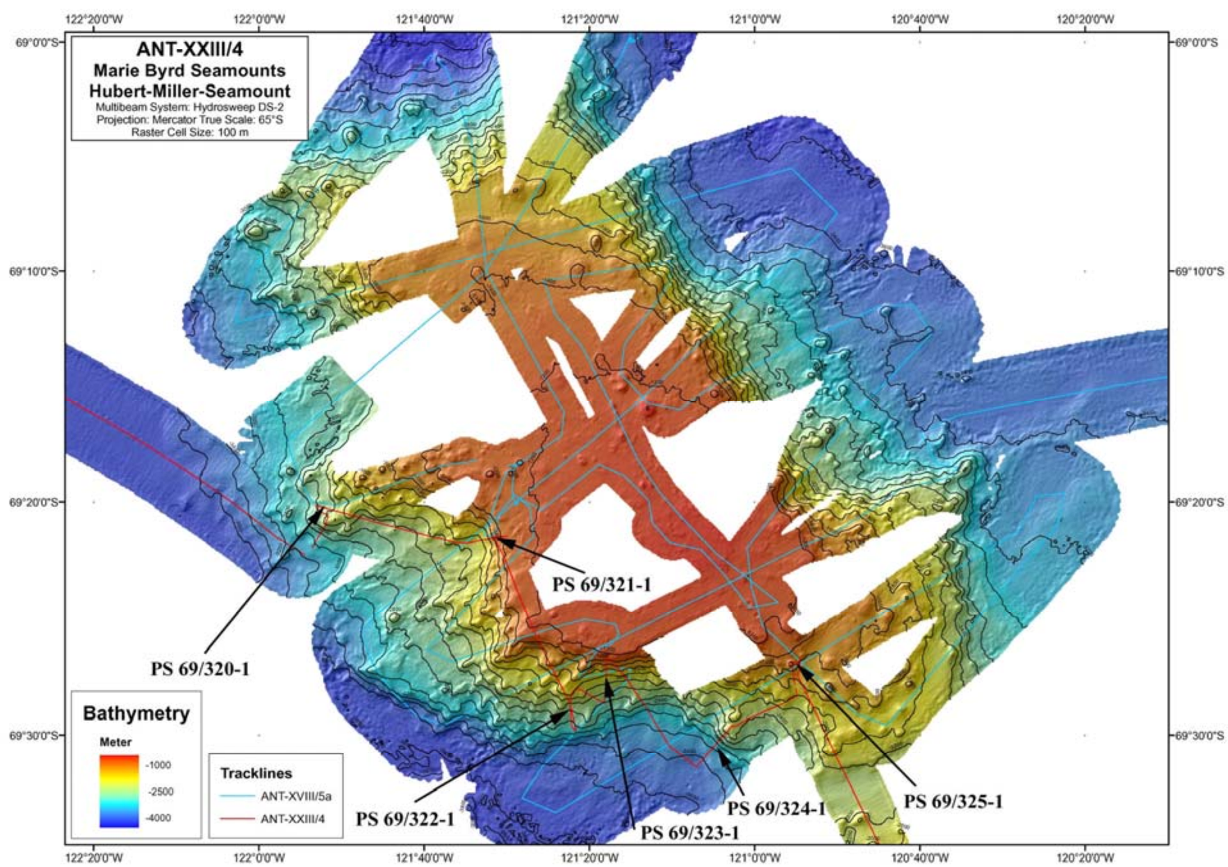

Figure 3. Location of dredge sites at the Hubert Miller Seamount

Small parasitic cones are only well preserved at the flanks. At six locations close to the edge of the plateau and at steep flanks of the seamount sampling of in-situ basaltic rocks was attempted. At only four dredge sites in-situ volcanic material was collected aside from igneous fragments of uncertain origin as well as drop stones of variable abundance.

Petrology and mineral chemistry

Petrographically four groups of dredged clasts can be distinguished:

Group I: basaltic volcanics (alkalibasalts to trachybasalts)

Group II: coarse crystalline (sub)volcanics with Si-saturated composition)

Group III: igneous clasts with metamorphic overprint

Group IV: sedimentary rocks (quartz-sandstones and litharenites with clats of deformed quartz as well as plagioclase, light and dark mica); clasts of group IV are not subject of this paper.

Group I

The slightly SiO_2-saturated alkalibasalts on Hubert-Miller-Seamount are poorly- to non-vesicular, with olivine, plagioclase and oxides as solidus phases. Some exhibit an irregular intersertal texture with several vol.-% of completely iddingsitized and goethite covered olivine (high-T oxidization). This indicates subaerial turbulent extrusion of a low viscosity magma. Some samples contain mm-sized tachylitic schlieren in crystalline matrix formed by Ti-magnetite, olivine and plagioclase, indicating mixing of differentially tempered magmas. Viscous laminar flow is indicated in some alkalibasalts as well as more strongly developed the more common olivine-free trachybasalts with fluidal textures due to subparalelly oriented plagioclase laths. Plagioclase crystals in the alkalibasaltic suite occur as matrix laths (0.1 mm), micro-phenocrysts (0.2 – 0.6mm), macro-phenocrysts (1 – 2mm) and cm-sized xenocrysts (Fig. 5a). The mineral chemistry was determined by electron microprobe analyses (Tab. 1). As expected, the An-contents decrease with decreasing size and are lower by almost 10 mol-% in trachybasalts. Macro-phenocrysts are of labradorite composition. The micro-phenocrysts show zoning as well and are of intermediate andesine composition. Groundmass plagioclase laths are andesines to oligoclases. Some rare plagioclase xenocrysts were determined as oligoclase. A xenocrystic core of An35 in a trachybasalt is as low as the matrix minerals indicating magma mixing. Equally low An-contents are exhibited by zoned xenocrystals in olivine-bearing alkalibasalts. This is proof for more highly differentiated cooler plumbing systems within the volcanic structure of the Hubert Miller Seamount.

Table 1: An contents of plagioclase phases in alkalibasalt – trachybasalt differentiation series of Hubert Miller Seamount

An-content	Macro-phenocrysts core	Macro-phenocrysts rim	Micro-phenocrysts	Matrix
Alkalibasalt	69 – 60	60 – 54	64 - 51	52 – 39
Trachybasalt	62 – 51 (35)*	52 - 40	52 - 43	42 – 30

* xenocrystic core

Augitic clinopyroxene is less common and occurs as matrix constituent in the trachybasalts, as individual xenocrysts (Fig. 5b) as well as titanaugite with hourglass structure (< 3% TiO_2) in xenoliths (Fig. 5c). This is evidence for upper intrusive levels of more highly undersaturated magma episodes within the history of Hubert-Miller-Seamount.

Group II

Coarse grained igneous clasts are rare and heterogeneous in mineralogy. One is a basaltic lamprophyre with leucocratic matrix that is heavily overgrown by late stage phlogopite, indicating volatile-rich phase at subvolcanic levels. On the contrary, an olivine-phyric basaltic sample with epidotized matrix contains pseudomorphic replacement of olivine by chlorite and oxides, as well as vein-fillings of a calcite-epidote-quartz assemblage. This is indicative of subgreenschist metamorphism. If these are not dropstones these rocks represent hydrothermally altered subsurface fragments that may be exposed due to flank collapse.

Group III

(Sub)volcanics with amphibole-plagioclase dominated recrystallisation textures also represent fragments of the metamorphic (here: greenschist-fazies) core of the volcanic structure.

Geochemistry

Nineteen samples were analysed for their major-, minor- and selected trace element contents. They form three groups:

- Chem-Group I: slightly *hy*-normative (high-Al) basalts, ("alkali-olivine"basalt to trachybasalt)
- Chem-Group II: basaltic-andesites, subvolcanic rocks, some lamprophyric, some with (sub-) greenschist facies overprint
- Chem-Group III: sedimentary rocks of rhyolitic (78-90 wt.-% SiO2) and rarely dacitic composition ~ 70 wt.-% SiO2)(quartz-dominated sandstones and litharenites, respectively); these are not discussed within this paper.

Chem-Group I:

The generally *hy*-normative basalts form a sequence of alkalibasalts to trachybasalts (SiO_2 44 – 52 wt.-%). They are on average of more intermediate composition exhibiting a higher degree of differentiation then those from intracontinental volcanic fields, such as in the Central European igneous province. The mafic rocks (SiO_2 <46 wt.-%) contain 5-4 wt.-% MgO; the intermediate ones 3 - <1wt.-%. Equally low are Ni and Cr-contents of 80 – 23 ppm and < 60ppm respectively. Alumina is generally high with 16.5 – 18.5 wt.-% equal to those in „high-alumina-basalts"; Fe_2O_3 total decreases (14 - 11 wt.-%) with increasing SiO_2-content as does Ti (3.8 - 1,9 wt.-%). Even more compatible is Sr,

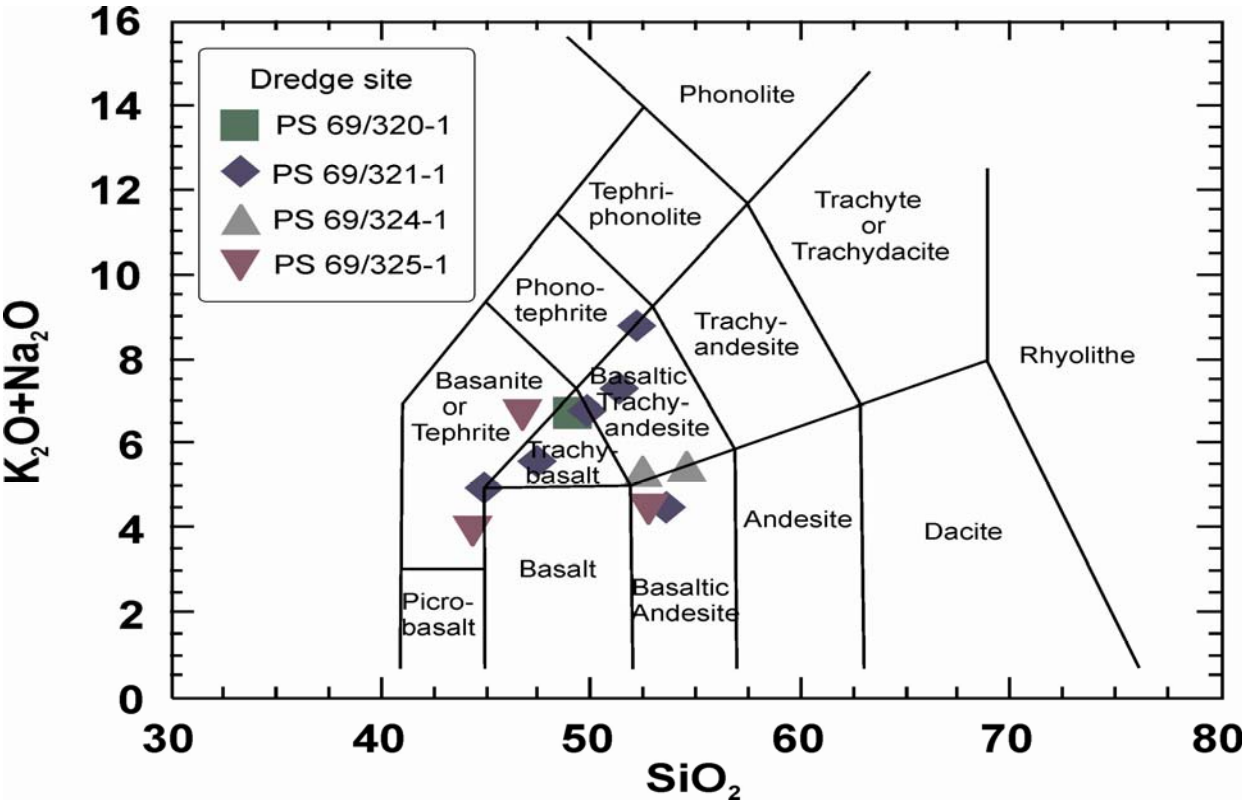

Figure 4. Total alkali-silica diagram showing the nomenclature of Hubert Miller Seamount basalts after Le Maitre et al. (2002).

decreasing from 800 ppm to 230 ppm. Zr, Nb und Y are incompatible throughout the differentiation processes. The data support the observations that olivine, plagioclase and the spinel phase as solidus phases controll the fractionation processes leading to trachybasalts.

Chem-Group II

The altered dike samples and metamorphically overprinted, recrystallized sub-volcanics are characterized by low alkali contents at 8 wt.-% higher SiO_2-contents and only minor differences in degree of differentiation (MgO < 7 wt.-%, Cr <200 ppm), Al_2O_3-contents vary between 16 - 18 wt.-%. As they were dredged at several localities they seem to be genetically related to the volcanic structures and may be either products of a hidden sub-alkalic igneous phase of the seamount or due to secondary alteration processes by igneous and/or metamorphic fluids.

Summary

Basaltic rock samples dredged from the Hubert Miller Seamount form a slightly hy-normative alkalibasalt-trachybasalt-differentiation series. They are on average of more intermediate composition exhibiting a higher degree of differentiation then those from intracontinental volcanic fields, such as in the Central European igneous province. Magma-mixing as common process is indicated by amorphous schlieren of heterogeneous crystallinity within most samples. Zoned xenoliths of oligoclase are indication for crustal magma plumbing systems of higher degree of differentiation that had not equilibrated during ascend of the basaltic magmas. Xenoliths of Ti-cpx – plagioclae cumulates indicate that the seamount experienced an igneous phase of higher Si-undersaturation. In the total-alkali-silica diagram a second smaller group of samples clusters in the field of sub-alkalic basaltic andesites. They comprise coarse crystalline clasts of most likely dikes that may exhibit (1) a lamprophyre character due to late stage mica overgrowth, or (2) a sub-greenshist alteration or (3) greenschist metamorphic overprint. These rocks from the volcanic core being exposed at several dredge sites implicate flank collapses, assuming that these samples are not dropstones. Quartz-sandstones with deformed quartz grains as well as the additional presence of biotite and muscovite (next to plagioclase) require continental crust as source area for these clasts, which are assumed to be dropstones.

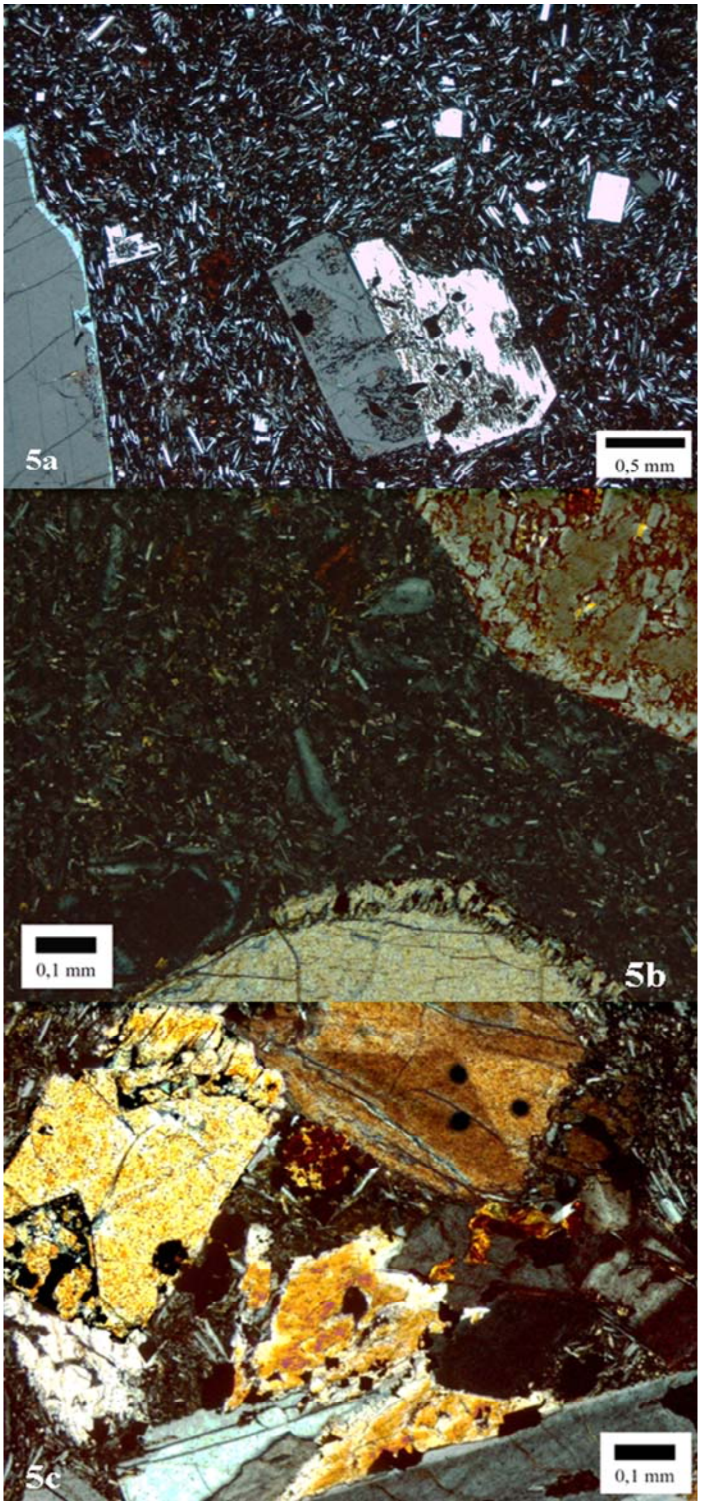

Figure 5. Thin section under crossed polarized light of sample PS 69/321-1-3; (a) plagioclase phenocrysts and matrix laths, (b) clinopyroxene xenocrysts with overgrowth, (c) xenolith of titanium-augiteplagioclase intergrowth.

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