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Subject title Geochemical characteristics and U-Th diesquilibria of the latest eruptions in the Ulleung Island, Korea

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Major and trace elements and U-Th disequilibria from ten whole rock samples of the Ulleung Island were examined; major elements from two xenoliths were also examined. All of the samples for whole rock analyses are duplicated. Major element compositions were determined by XRF (Philips PW 2400); trace elements including U and Th were analyzed by a quadrapole type inductively coupled plasma mass spectrometer (ICP-MS: Agilent 7500cs). Analytical errors for trace element analyses were below 2% (1SD) except Li (3.0%), Be (6.3%), Y (2.2%) and Lu (2.4%). The $^{238}U/^{234}U$, $^{232}Th/^{230}Th$ ratios were measured by an isotope-dilution technique using a TIMS (Finngan MAT 262).

Both xenoliths are identified as nepheline-bearing monzonites (Pl=47-49%; Or=43-45%; Ne=7.7-8.0%) by the CIPW norm calculation. Two types of volcanic rocks are identified based on the TAS diagram: two trachyandesites (SiO_2 = 55.7-56.7 wt%; K_2O+Na_2O= 9.9-11.2 wt%) and eight phonolites (SiO_2 = 57.7-60.2 wt%; K_2O+Na_2O= 12.6-14.1 wt%).

Trace element concentrations are normalized by primitive mantle (McDonough and Sun, 1995) and generally show high LREE/HREE ratios (i.e. La/Yb=19.36-26.88), depletions in Sr, Ba, Eu and B and slight enrichment of Li. The REE patterns with negative Sr, Ba, and Eu anomalies and concave upward curvature between Gd (MREE) and Lu (HREE) indicate that the crystallization of feldspar and amphibole has predominated in the magma system. These patterns are consistent with the occurrence of feldspar and kaersutite phenocrysts in the analyzed rock samples.

The $^{238}U/^{230}Th$ disequilibria of all samples are plotted on the left side of the equiline, implying the Th excess. Most ratios lie between 0.630-0.656 for $^{230}Th/^{232}Th$ and 0.695-0.716 for $^{238}U/^{232}Th$ except for an extra-caldera phonolite sample, yielding $^{230}Th/^{232}Th$=0.407 and $^{238}U/^{232}Th$=0.389 which are attributed to an older eruption age.

Major and trace element concentrations show five eruptive cycles: (1) the extra-caldera phonolitic lava (347), (2) high-Al_2O_3 phonolitic pumice (N5P) and lava (N5T), (3) the trachyte-phonolite pumices (N4, N3 and N2GR), (4) phonolitic pumices (N2BR and N2BL), and (5) the dome-forming trachyandesite lava (343) and scoria (342). Sample 347 is distinguished by generally high concentrations of trace elements, high

Gd/Eu ratio, and low $^{238}U/^{232}Th$ and $^{230}Th/^{232}Th$ ratios. Samples N5P and N5T are characterized by highly evolved pattern of trace elements (e.g. Th/Ba=0.003-0.0003) and high-Al_2O_3 concentration (20.2- 20.4 wt%; the others=18.8-19.0 wt%). Among five phonolitic pumices of N4, N3 and N2 (N2GR, N2BR and N2BL), older samples of N4, N3 and N2GR tend to decrease in SiO_2, K_2O, CaO, P_2O_5, Ba, Sr and Eu concentrations, but increase in most of other elements. However two samples N2BR and N2BL show somewhat opposite trend.

The $^{238}U/^{232}Th$ and $^{230}Th/^{232}Th$ ratios can be subdivided: (1) high $^{230}Th/^{232}Th$ ratios (>0.71) for samples 343 and 342, (2) relatively higher $^{238}U/^{232}Th$ ratios for N5P and N5T, and (3) low $^{238}U/^{232}Th$ ratios and $^{230}Th/^{232}Th$=0.7-0.71 for N4-N2BL. Despite the narrow range of $^{230}Th/^{232}Th$ ratios among five samples N4-N2BL, $^{230}Th/^{232}Th$ ratios of N4, N3 and N2GR are slightly higher than those of N2BR and N2BL, supporting different major and trace element behaviors between these two groups.

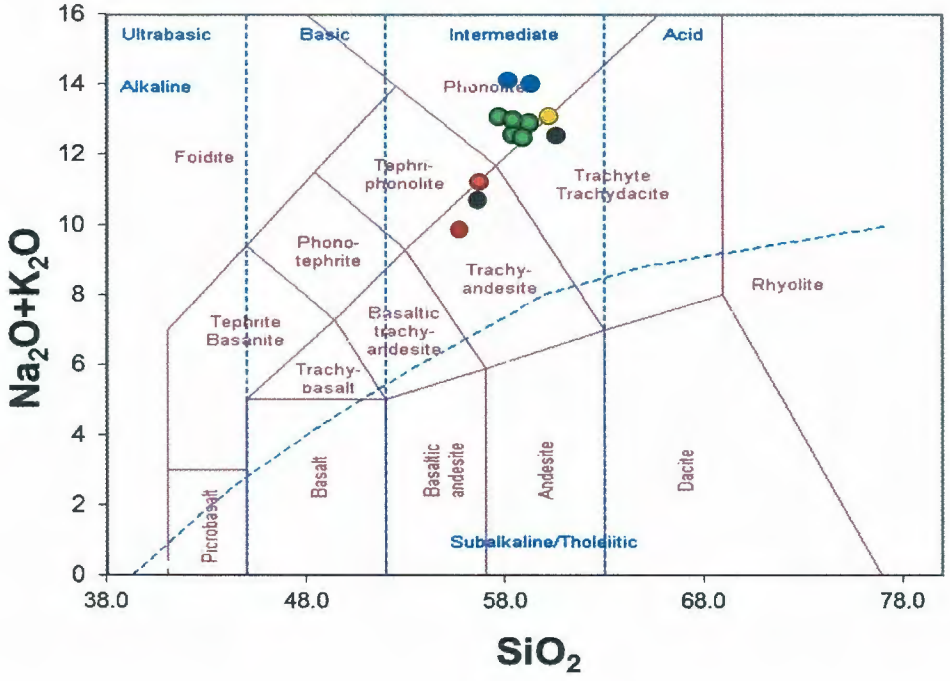

Figure 1. TAS diagram for the 12 rock samples from the Ulleung Island. Black dots are the two xenolith samples; the blue ones are N5T and N5P; the green ones are N4, N3, N2GR, N2BR and N2BL; the yellow one is 347; and the red ones are 343 and 342.

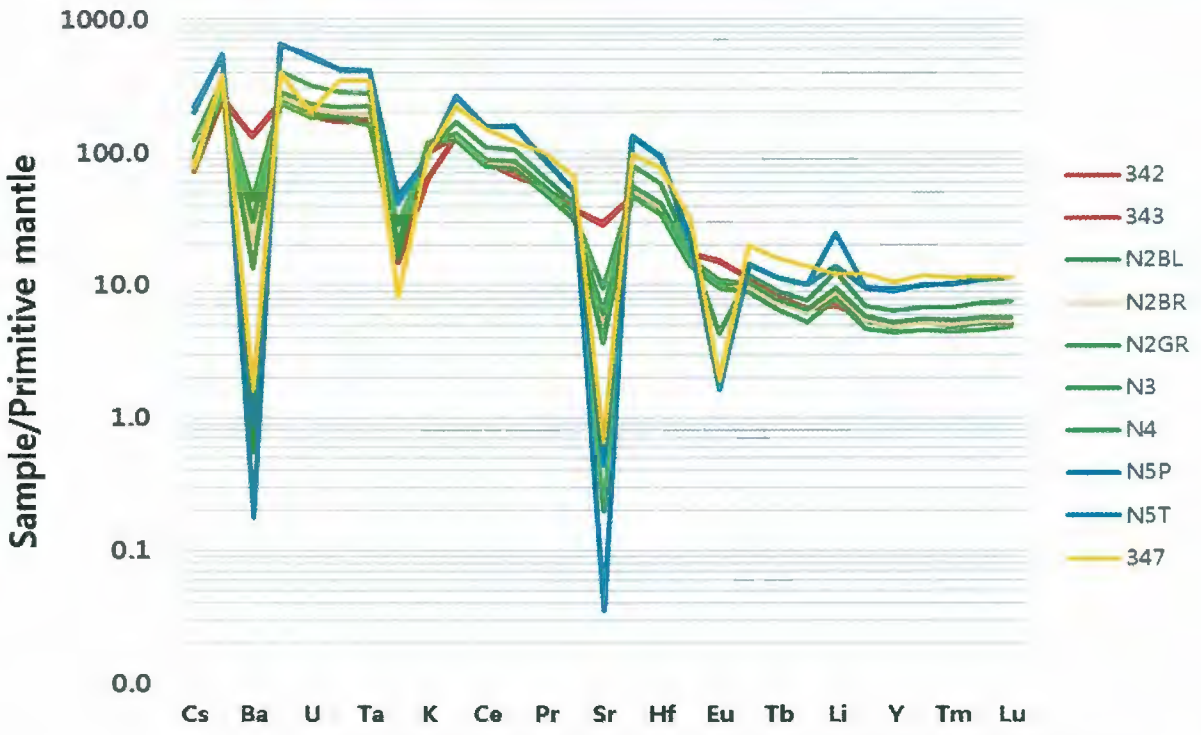

Figure 2. The primitive mantle normalized (Sun and McDonough, 1995) trace element patterns for the Ulleung Island volcanic rocks.

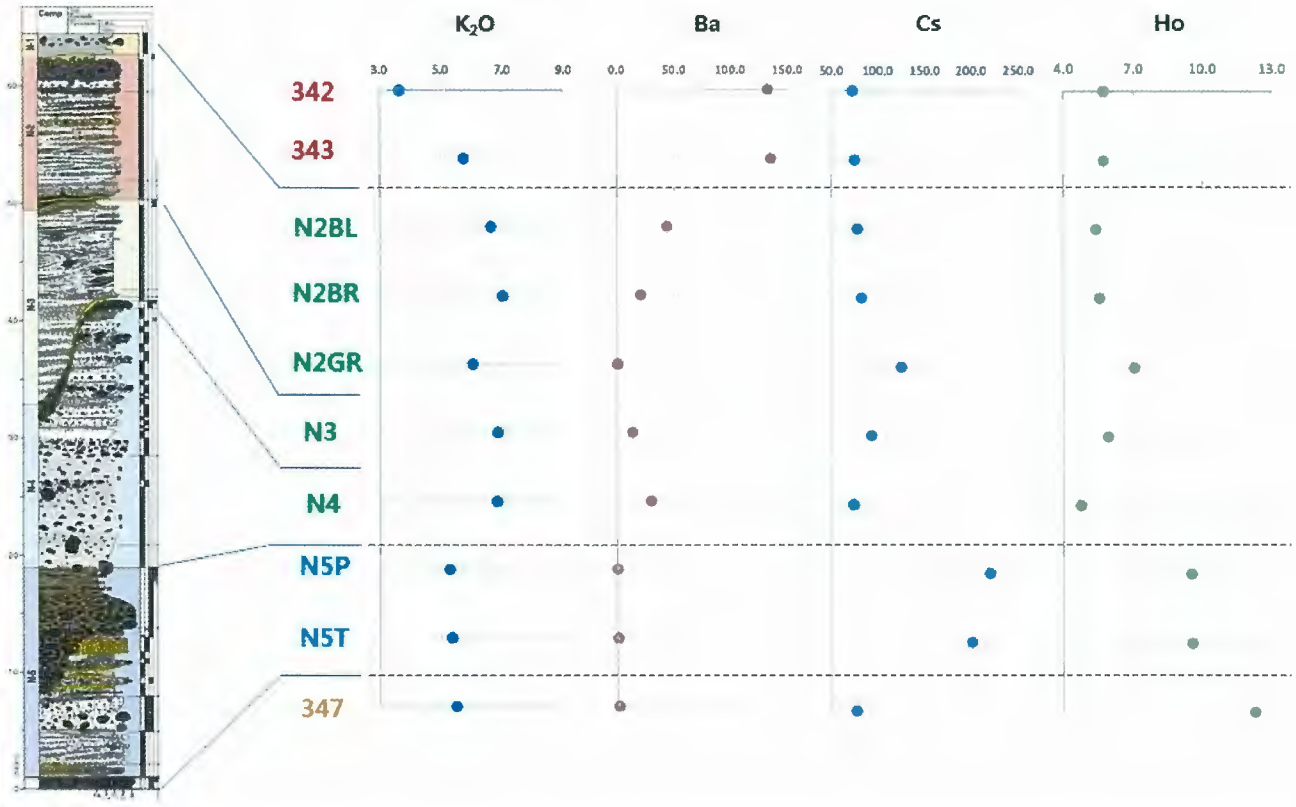

Figure 3. Some of major (K_2O) and trace element (Ba, Cs, Ho) concentrations in the stratigraphic order. The sedimentary log is from Kim et al. (2014). The pattern of SiO_2 is similar with that of K_2O; those of CaO, TiO_2, P_2O_5, Sr, and Eu with Ba; those of Al_2O_3, Na_2O, MgO, MnO, Li, Be, Rb, La, Ce, Lu and HFSE with Cs; and those of the others with Ho.

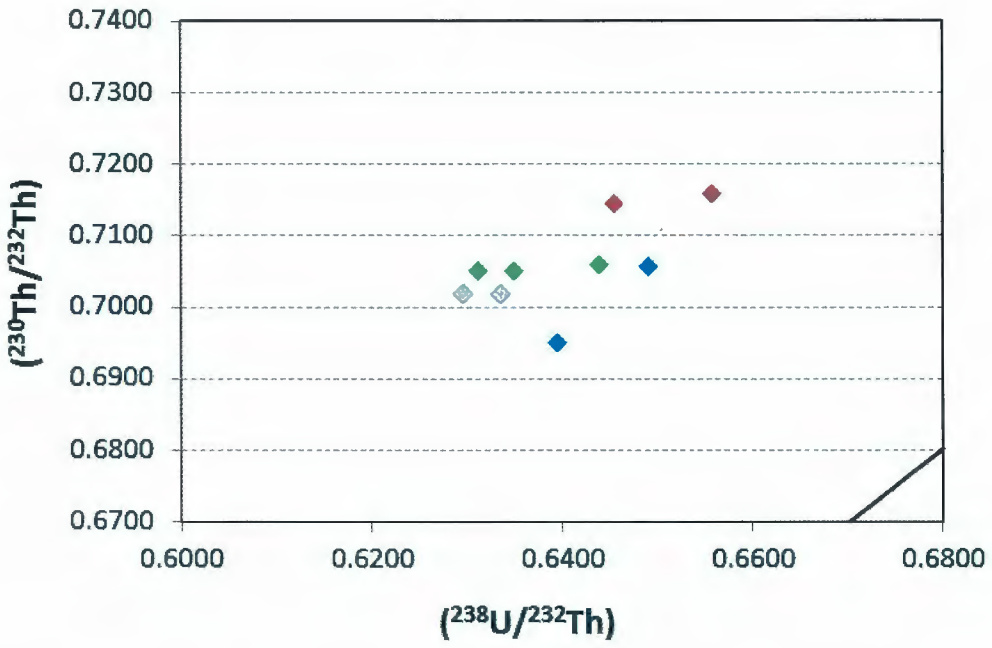

Figure 4. The U-Th equiline diagram for the samples: red (343, 342), green (N2GR, N3, N4), white (N2BR, N2BL), and blue (N5T, N5P). The bold line is the U-Th equiline. Note that the data of 347 (0.389, 0.407) is out of this diagram.