T10: Non-polar ice cores

Characterization of individual insoluble particles in ice core

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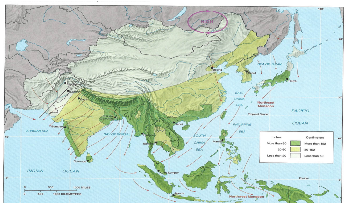
Introduction

The main purpose of this study is to identify individual particles contained in an ice core and trace their sources by the combined use of quantitative energy-dispersive electron probe X-ray microanalysis (ED-EPMA), which is also known as low-Z particle EPMA, and attenuated total reflectance FTIR (ATR-FTIR) imaging. It is capable of characterizing different minerals and their isomorphs even on single particle basis. Totally 606 individual insoluble particles from the ice core collected in the East Rongbuk from Mt. Qomolangma (Everest) were characterized. The particles in four samples, sample A-D, collected from different depths were classified into 17 particle types based on their morphology, elemental concentrations, and molecular species and/or functional groups of individual particles available from the two analytical techniques.

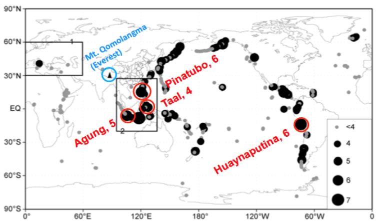
Samples

Sampling site: The East Rongbuk glacier located on the northern slope of Mt. Everest (28°03′ N, 86°96′ E, 6518 m asl)

Summer, wet monsoon blowing from the Indian ocean generated by the low pressure on the continent



Winter, dry monsoon blowing from the continent by the high pressure on the continent



- windward sources such as the Thar and Sahara desert, and other arid regions contribute to the aerosols trapped in the Mt. Everest snowfall.

Geographical distributions of volcanoes.
The size of dot represents the value of Volcanic Explosivity Index (VEI).
The two boxes represent the two most likely source regions of the volcanic eruptions to Mt. Qomolangma area. (Xu *et al.*, 2009)

Measurement and analysis

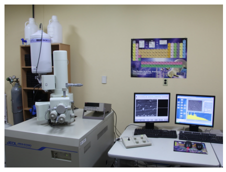
- *Low-Z particle EPMA using SEM/EDX*

❖ SEM-EDX (Scanning Electron Microscopy–Energy Dispersive X-ray Spectrometry)
  - Individual Particle Analysis:
    - shape and size: secondary / backscattered electron images
    - chemical composition: X-ray spectrum

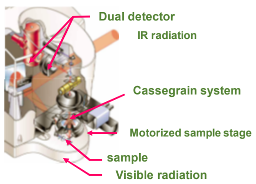
❖ Ultra-thin window EDX for low-*Z* elements detection (C, N, O, F)

❖ Metallic collecting substrates for minimizing charging effects (Ag or Al)

- Jeol JSM-6390 SEM
- Oxford Link SATW ultrathin window EDX detector
- The detector resolution: 133 eV for Mn Kα X-rays
- 10 kV accelerating voltage
- 0.5 nA beam current
- Oxford INCA Energy software
  : X-ray spectra and elemental maps



- *ATR-FTIR imaging*

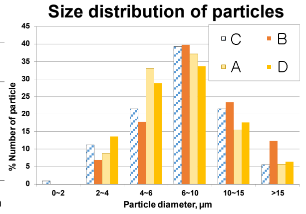


- Perkin Elmer Spectrum 100 FT-IR spectrometer interfaced to Spectrum Spotlight 400 FT-IR microscope
- Image pixel size = 1.56 μm
- Spectral resolution = 8 cm^{-1}
- Scan per pixel = 32
- Individual Particle Analysis
  - location: optical image
  - functional groups, molecular species, and crystal structure: IR spectra

Sample	Depth interval (m) Top	Bottom	Estimated bottom age[a]	No. of Particles	Event[b]
A	10.23	10.40	1991.9	224	Pinatubo, 1991.4.2 - 9.2
B	26.71	26.85	1965.8	144	Taal, 1965.9.28 - 9.30 / Agung, 1963.2.18 - 1964.1.27
C	90.91	91.09	1611.0	110	-
D	91.90	92.00	1601.0	128	Huaynaputina, 1600.2.17 - 3.6

a. Hong *et al.*, 2009
b. Smithsonian Institution

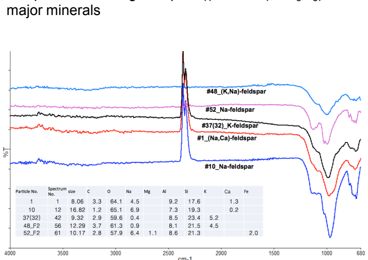
Size distribution of particles



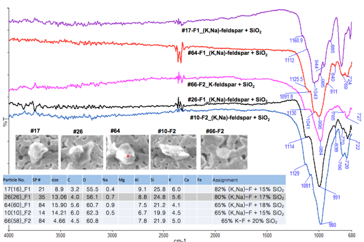
Results

Typical EPMA data and ATR-FTIR spectra of particles

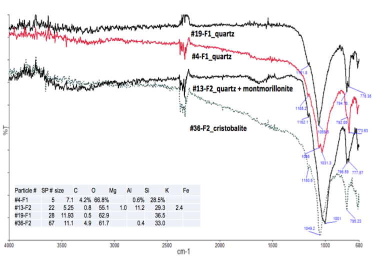
Representative ATR spectra 5 individual particles of sample **A** containing feldspars ((Na,K,Ca)$AlSi_3O_8$) as major minerals



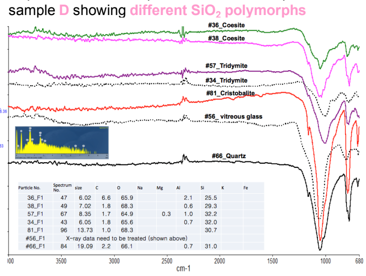
Representative ATR spectra of and elemental concentrations of 5 individual particles of sample **B** those show the coexistence of feldspars ((Na,K,Ca)$AlSi_3O_8$) and SiO_2 (felsic materials) where silica content is less than 20% indicating presence of volcanic basalt.



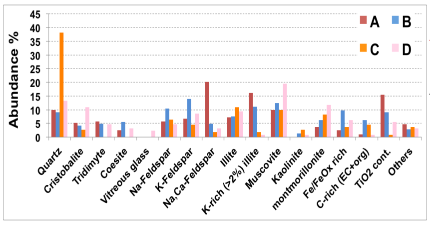
Representative ATR spectra and elemental concentrations of 4 individual particles of sample **C** showing SiO_2 polymorphs. **No tridymite and coesite were observed.**



Representative ATR spectra of 7 individual particles of sample **D** showing different SiO_2 polymorphs



Relative abundance and characteristics of specific samples



A: Na,Ca-Feldspar (plagioclase) / Ti-containing

B: Cristobalite, Tridymite, Coesite / K-containing minerals

C: Quartz (major), Cristobalite (minor) / Montmorillonite, Kaolinite

D: Vitreous glass, Muscovite / Montmorillonite

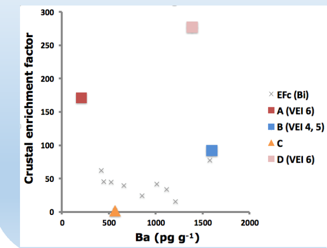
Volcanic ashes of Huaynaputina

- andesites to dacitic pumices (SiO_2 wt% from 57-67.8)
- high K-content (Oliver *et al.*, 1996)

Our study reveals that the possibility of encountering a SiO_2 particle to that of a feldspar particle in this sample is 34% and 16%, respectively. The possibility ratio of SiO_2: Feldspar particle is 34:16 or 68: 32 which might be correlated with the reported wt% of andesite to dacite mineral in bulk volume of Huaynaputina volcanic rock. However, when this bulk mineral is dispersed as single particles due to volcanic activity possibility of encountering SiO_2 and feldspar particles may remain similar.

Moreover, this sample encounters a large number of particles majoring in K-containing minerals i.e. K-feldspar, muscovite and illite. This results is consistent with the before mentioned report saying the enrichment of K-content observed in bulk mineral analysis of Huaynaputina volcanic rock.

- *ICP-SFMS (Inductively Coupled Plasma-Sector Field Mass Spectrometry)*
  - Element 2 (X-cone), Thermo Scientific
  - Apex-HF/ACM membrane desolvation unit, Elemental Scientific Inc.



References

Oliver, R., Vatin-Rerignon, N., Goemans, P., Keller, F. (1996) Third ISAG. 609-612. / Hong, S., Lee, K., Hou, S., Hur, S.D., Ren, J., Burn, L.J., Rosman, K.J., Barbante, C., Boutron, C.F. (2009) Environ. Sci. Technol. 43, 8060-8065. / Xu, J., Kaspari, S., Hou, S., Kang, S., Qin, D., Ren, J., Mayewski, P.A. (2009) Chinese Sci. Bull. 54, 1411-1416. / Fei, J., Zhang, D., Lee, H. (2016) Adv. Meteorol. 2016, Article ID 3217038 / Smithsonian Institution, Retrieved from http://www.volcano.si.edu