Workshop on Advances in Tephrochronology in Southeast Asia

7 - 8 August 2019

Nanyang Technological University, N1.1-B2-01b Teaching Lab

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

EARTH OBSERVATORY OF SINGAPORE

Tephrochronology is a technique that uses discrete layers of tephra (i.e. volcanic ash) to create a chronological framework (Lowe 2011) useful to reconstruct the volcanic history of a given area. Its applications are numerous and there is great potential for expansion in Southeast Asia given the exceptional high density of volcanoes in this part of the world. The goal of this workshop is thus to review the current knowledge about tephrochronologic markers in the region — their composition and ages, to share findings and best practices, and to instigate region-wide collaboration.

Jointly organized by:
Asian School of the Environment, Institute of Advanced Studies and Earth Observatory of Singapore

Organizing committee:
Caroline Bouvet de Maisonneuve, Nur Fairuz Binte Razali, Chris Ong Lay Hiong

Food for thought...

some avenues of research and discussion

The identification and correlation of tephra layers enables reconstruction of the number, timing and magnitude of eruptions that affected a given location. Improving our knowledge of volcanic eruption histories in Southeast Asia is important for a number of factors, the most obvious of which is regional hazards. Southeast Asia hosts ~750 volcanoes (70 of which have erupted in the past century) and is home to a population of ~600 Million. In Indonesia, for example, ~30% of the population lives within 30 km from a Holocene volcano. Another important factor is that Southeast Asian volcanoes are dominantly located close to the equator. Indeed, large volcanic eruptions that occur in equatorial to tropical regions and send ash into the stratosphere have particularly global impacts on climate because the ash and aerosols released propagate into both the northern and southern hemispheres.

143 volcanoes in Southeast Asia have been classified as Large Calderas (41) and Well-Plugged Stratocones (102) by Whelley & al (2015) and thus have or are likely to have produced large explosive eruptions with a Volcano Explosivity Index (VEI) of 5-8. Only 26 of such eruptions have known ages, spanning from 1.2 Ma to 1991 AD. Fewer have geochemical data that can be used for tephrostratigraphic correlations. Consequently, there is a knowledge gap that can be filled through field studies of these numerous volcanoes in combination with studies of marine, lacustrine, and other on-land sedimentary records.

Marine and lake sediments are fantastic archives of meteorological and geological processes (e.g. floods, landslides, volcanic eruptions, earthquakes) and environmental change (e.g. climate and land-use changes). For example, long term hydrological variations are recorded as changes in sedimentology, geochemistry and biological proxies in lacustrine and marine settings. Thus sediments from lakes and oceans provide high resolution palaeoenvironmental data for variations and interactions of the monsoons, El Nino Southern Oscillation, Indian Ocean Dipole, floods and droughts, and human activities. The identification and correlation of tephra layers in these archives enables linking, synchronizing and dating geological or environmental events that impact the local and regional ecology, human and climatic history. Filling the knowledge gap concerning volcanic eruption histories would thus contribute to further developing additional tephrochronologic markers that could help synchronize records over a larger spatial extent, at a greater temporal resolution, and over a greater period of time.

This workshop is an exciting opportunity to share knowledge and findings in order to start filling the identified knowledge gaps, and better define regional marker beds. It is also the opportunity to identify specific research targets that could be undertaken in collaboration, and action items to be revisited during a subsequent workshop. Lastly, it is a chance to train the new generation of Earth scientists and promote the use of tephrostratigraphy in this part of the world.

Programme

Day 1 Wednesday, 7 August 2019

Time	Presenter	Presentation Title
9:00am	Caroline Bouvet	Welcome address
9:30am	Caroline Bouvet	Improving our understanding of Southeast Asian volcanic eruption histories, with an emphasis on Sumatra (Indonesia)
10:15am		***Coffee Break***
10:30am		Discussion & Posters
11:15am	Karen Fontijn	The Value and Limitations of a Detailed Eruptive History at an Indonesian Arc Volcano
12:00pm		***Lunch***
1.15pm		Discussion & Posters
2.00pm	Ruly Setiawan	Linking key archaeological sites using prominent marker beds: Insights from Flores and Java, Indonesia
2.45pm		Discussion & Posters
3:30pm		***Coffee Break***
3.45pm	Ros Muhammad + Iskandar Taib	Dispersal, Reworking and Resedimentation of Distal Young Toba Tuff in Peninsular Malaysia
4.30pm		Discussion & Posters
5.00pm		End of Workshop
6:30pm		***Keynote Speaker Dinner***

Day 2 Thursday, 8 August 2019

Time	Presenter	Presentation Title
9:00am	Mitsuru Okuno	Crater and Caldera Lakes as an Environmental Archive: Case Studies on Eruptive Histories of Volcanoes in the Philippines and Bali (Indonesia)
9:45am		Discussion & Posters
10:30am		***Coffee Break***
10:45am	Chris Newhall	How many eruptions are missing or obscured in the geologic record? Six different perspectives
11:30am		Discussion & Posters
12:15pm		***Lunch***
1.15pm		Lab Tour (3 groups) + Discussion & Posters
3.00pm		***Coffee Break***
3.15pm		Future Perspectives
5.00pm		End of Workshop

Keynote Speakers

Caroline Bouvet de Maisonneuve

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Asst. Prof. Caroline Bouvet de Maisonneuve is a volcanologist with a particular interest for reconstructing eruption histories, magma storage conditions, and eruption mechanisms. She obtained her Ph.D. from the University of Geneva (Switzerland). Her main research interests are magmatic processes occurring just prior to and during an eruption, identifying processes responsible for changes in eruptive behaviour, and cycles of caldera-forming eruptions. She applies a range of tools, such as textural and chemical characterization of whole-rocks and minerals, melt inclusion analyses, numerical modelling, and tephrostratigraphy.

Improving our understanding of Southeast Asian volcanic eruption histories, with an emphasis on Sumatra (Indonesia)

We review the current knowledge about Southeast Asian volcanoes and their eruption histories, and focus on identifying tephrochronologic markers in order to further future paleoclimate and volcanological studies. 41 volcanic edifices in Southeast Asia have been classified as Large Calderas by Whelley & al (2015) and thus have or are likely to have produced large explosive eruptions with a Volcano Explosivity Index (VEI) of 6-8. Unfortunately, only 22 such eruptions have known ages, spanning from 1.2 Ma to 1991 AD, and fewer have geochemical data that can be used for tephrostratigraphic correlations. Volcanic products from different geodynamic regions and different sources can generally be distinguished on major element plots (particularly K_2O versus CaO) of matrix glass composition. However, the distinction of multiple eruptions from a same source requires additional data such as trace element compositions of matrix glass and/or mineral compositions. Biotite, but also magnetite compositions (MgO and TiO_2 contents in particular) appear to be very discriminating. Up to 9 tuffs in addition to the 3-4 Toba Tuffs can be utilized as widespread tephrochronologic markers and span a range from 1.2-1.6 Ma to recent. As only few Holocene major eruptions have been well characterized and dated, many large calderas are still unstudied, and many distal tephra layers are still lacking a source, more tephrochronologic markers can certainly be defined in the future.

Chris NEWHALL

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Dr Christopher Newhall is a volcanologist formerly with U.S. Geological Survey for nearly three decades, studying historical and modern volcanic unrest, and eruptive behavior as recorded in ash layers and minerals. He began his career as a Peace Corps Volunteer in the Philippines and as a PhD student in the Guatemalan highlands, then worked in northern Arizona and at Mount St. Helens, and has been privileged to work on many other volcanoes around the world, including Pinatubo. While working with USGS, Dr Newhall also taught at the University of Washington, and after retiring from the USGS, he led the volcano group of the new Earth Observatory of Singapore.

How many eruptions are missing or obscured in the geologic record?
Six different perspectives

1. Terrestrial volcano-stratigraphers are constantly challenged by missing layers from one outcrop to the next, and sometimes see fresh deposits disappear within just a few years. Ashfall layers are susceptible to bioturbation and surface erosion, and even thick pyroclastic flow deposits in valleys are often removed by channel erosion.
2. Marine tephra stratigraphers find that relatively few of the eruptions known from land are identifiable in marine sediments, and some layers that are found in the marine record are not yet identified on land. For example, Taal Volcano has a rich record of historical and prehistoric eruptions on land, including the latest caldera-forming event ~5600 14C ybp (probable VEI 7). This caldera-forming event has a strong affinity to dark marine tephra layers of similar age found in cores taken from marginal basins around the Philippines. However, more recent Taal eruptions with lower VEIs have not been identified in the top portions of these marine sediments.
   A few years after the 1991 Pinatubo eruption, German and Filipino colleagues found benthic fauna mortality and an intact 1991 ash layer where ash was greater than several cm thick. Where it was less, benthic fauna bioturbated the ash into underlying ooze.
3. Paleolimnologists working in deep freshwater lakes see overturn and oxygenation of bottom waters promote bioturbation, while anoxic waters minimize it. On the floor of Lake Atitlan, Guatemala, sections of finely-stratified (annual?) diatom blooms alternate with sections of homogenized diatom-rich mud, the same material but with the strata fully bioturbated and interpreted as periods with annual overturn.
4. Ice core scientists have identified most of the big sulfate spikes in 19th, 20th & 21st century ice core but some mystery cases remain. One big event in 536 CE remains unidentified, and a big event in 1257 CE was only recently linked to Rinjani (Samalas) volcano in Indonesia.
5. Geomorphologists see ample morphologic evidence for large explosive eruptions --calderas and/or broad pyroclastic fans/aprons – but can't always find distal tephras to match. As just a crude statistic, Whelley et al (2015) identified 143 volcanoes with geomorphic evidence of VEI 5 or larger eruptions, which is far more than identified in any papers we know on Quaternary deep-sea tephras in SE Asia.
6. The Smithsonian Institution's Global Volcanism Program has shown that (a) numbers of REPORTED historical eruptions increase with technological advances and decrease during world turmoil, e.g., WW II; (b) the frequency of eruptions decreases with increasing size, following a power law, and (c) as one goes farther back in history, there is pronounced drop-off from predicted numbers, with smaller eruptions especially poorly recorded. Kiyosugi et al. (2015) estimate that in Japan, roughly 65% of VEI 5 events, 48% of VEI 6 events and 38% of VEI 7 events are missing from geologic records for appropriate time periods.

Despite significant incompleteness in records, combining information from all of these specialties gives us tips on what deposits are likely missing and good topics for new field searches.

Keynote Speakers

Karen Fontjin

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Dr Karen Fontijn obtained her Ph.D from Ghent University, Belgium and spent her post-doc at the Earth Observatory of Singapore and the University of Oxford, UK. As a physical volcanologist, she has worked on various volcanoes in different tectonic settings, from rift volcanoes in Tanzania and Ethiopia, to oceanic and continental arc volcanoes in the Philippines, Indonesia and Chile.

High-resolution tephrostratigraphy at individual volcanoes

Detailed stratigraphic studies of pyroclastic deposits form arguably the best tool to estimate the frequency and magnitude of explosive eruptions at volcanoes where limited or no historical records exist. As such, detailed proximal tephrostratigraphy forms a first-order assessment of potential future eruptive behavior at poorly known volcanoes. In this talk I will highlight some examples of high-resolution stratigraphic records at previously poorly known volcanoes and how they have changed our perception of volcanic hazards and risk at the respective volcanoes.

Most notably, at Agung volcano (Bali, Indonesia), detailed observations of its Late Holocene tephrostratigraphic record using stratigraphic logging, and geochemical and geochronological analyses, have shown that it has an average eruptive frequency of one VEI ≥2-3 eruption per century. The Late Holocene eruptive record is dominated by basaltic andesitic eruptions generating tephra fall and pyroclastic density currents. About 25% of eruptions are of similar or larger magnitude than the 1963AD event, and this includes the previous eruption of 1843AD (estimated VEI 5, contrary to previous estimations of VEI 2). The latter represents one of the chemically most evolved products (andesite) erupted at Agung. In the Late Holocene, periods of more intense explosive activity alternated with periods of background eruptive rates similar to those at other subduction zone volcanoes. I will use the Agung case study to highlight the potential and limitations of detailed stratigraphy at an individual volcano, and how they can be further extended and applied at other arc volcanoes.

Workshop on Advances in Tephrochronology in Southeast Asia, 7- 8 August 2019

Mitsuru Okuno

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Dr Mitsuru Okuno is a Professor at Fukuoka University since 2011. He specializes in radiocarbon dating of tephras using organic matter from paleosols. Apart from extensive research in Japan and South Korea region, he has also worked with PHIVOLCS in Philippines, with Gadjah Mada University in Indonesia.

Crater and caldera lakes as an environmental archive: Case studies on eruptive histories of volcanoes in the Luzon and Bali islands

Lava and tephra (pyroclastic flow and fallout tephra) are hugely disastrous to the vegetation and human society near the vent. Furthermore, explosive eruptions have a greenhouse effect or an umbrella effect in the atmosphere and can affect global climate change. Tephra, as a product of explosive eruptions, is used widely for tephrochronology of tectonic development and for archeological site chronology to provide a time marker over a wide area. Although aeolian loam, humic soil, and peat layers form on land, non-disturbed lake sediments provide an accurate record of environmental changes. Because crater and caldera lakes have a small water catchment area, their sediments can be expected to provide a detailed archive recording the environmental history. This paper introduces the impact of volcanic eruptions and topics of high-precision research based on examples of tephrochronology studies in the Luzon and Bali islands.

At the southern end of Luzon Island, Philippines, co-ignimbrite ash of the Irosin pyroclastic flow deposit, erupted from the Irosin caldera to about 41 cal ka BP, was discovered at the western foot of Mayon volcano. To confirm its wide distribution, we conducted a drilling survey at Paitan Lake, central Luzon. However, we could not reach beyond 40 cal ka BP.

The frequency of caldera-forming eruptions is low, so it can be expected that caldera lake sediments would be preserved for a long time. The Buyan–Bratan caldera in northern Bali, Indonesia, includes Lakes Tamblingan, Buyan, and Bratan. It was previously thought that the volcano had not erupted during the Holocene. Core samples were collected from Lake Buyan and paleoenvironments were reconstructed, but many of the radiocarbon ages were inconsistent with the stratigraphy. Recently, we revealed that lava flowed from Tapak volcano, one of the caldera volcanoes, to about 1.1 cal ka BP and divided Lakes Buyan and Tamblingan. As the scoria layer from Tapak volcano, Batur caldera, and the volcanic ash layers derived from Samalas volcano are not preserved, it is thought that the lake sediments were largely stirred by the inflow of lava.

Keynote Speakers

Ros Fatihah Muhammad

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Dr Ros Fatihah Muhammad is a senior lecturer in the Department of Geology, Faculty of Science at University of Malaya, where she also obtained her Ph.D in 2004. Dr Ros's work involves mainly geomorphological mapping, carbonate karst and speleotherm studies. Ongoing research includes collaborative studies on distribution of YTT and its significance in traditional pottery industry in Peninsular Malaysia.

Dispersal, Reworking and Resedimentation of Distal Young Toba Tuff in Peninsular Malaysia

The 75ka Youngest Toba Tuff (YTT) is found in several locations throughout Peninsular Malaysia, from near the Thai border in the North, to the South China Sea in the East. It is a significant time marker for archeology, and has recently been found to be used as a major component in the manufacture of traditional pottery. The ash is found in distinct horizons within alluvial sediments, ranging in thickness from a few centimeters on the surface and in soil profiles, to over nine meters at river confluences. Deposition at the time of eruption was thought to have been a uniform 10 to 50 centimeters over the entire area of the peninsula, based on YTT ash dispersal modelling.

1. *The current distribution has been shaped by fluvial processes – ash has been removed from areas of high topography, and the thickest deposits are now found accumulated in valleys and low-lying areas within the flood plains of major rivers, mainly at confluences and on river terraces, and, in one location, confined to a valley due to the presence of ridges that could have blocked further downstream transportation. Optically-Stimulated Luminescence on two layers within a same profile may indicate a complex process of resedimentation at 75.5 ± 9.8 and 58.5 ± 7.9 ka. Three facies of deposition are recognized in one location: flood flow, mudflow and slumping*
2. *Grain size distribution and glass shard morphology at different locations reveal varying degrees of reworking. All of the ash found at four locations display the characteristic multi-population trace element glass shard chemistry described by earlier researchers*
3. *At four locations, Population I, II and III shards are abundant while Population IV shards are present but sparse.*

Keynote Speakers

Ruly Setiawan

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Ruly Setiawan is a geoscientist at Centre for Geological Survey, Geological Agency of Indonesia. His research focuses on tephrostratigraphy, volcanology and geoarchaeology. He is particularly interested in hominin evolution and dispersal in SE Asia. His concern is to establish a regional tephrostratigraphic framework and to find potential stratigraphic isochrons for synchronising environmental and archaeological records. In the last few years, he worked with archaeologists and vertebrate paleontologists in Flores, Timor and Java.

Linking key archaeological sites using prominent marker beds: Insights from Flores and Java, Indonesia

Tephra layers preserved in archaeological sequences can contribute to determine the age of archaeological materials, understanding palaeoenvironmental changes, and correlation of widespread archaeological sites. Recent study in the So'a Basin, a ~200 km^2 depression in central Flores, has documented numbers of ignimbrites and silicic ash layers throughout the Ola Bula Formation. Large assemblages of stone artefacts and vertebrate fossils as well as some hominin remains have been identified in fluvial and volcaniclastic deposits spanning between c. 1 million to 650,000 years ago. By combining sedimentary facies analysis, tephrostratigraphy, geochemical analysis, and new chronological data, this study has improved the chronostratigraphic framework of the basin; recognised numbers of volcanic marker beds, further aiding in reconstructing the basin fill history and connecting several important archaeological sites; and provide new information about the timing of hominins settlement and fauna turnover.

Further research will focus on identifying tephra deposits that potentially act as inter-islands and/or regional markers to link hominin-bearing sites and help to answer regarding the timing of hominin dispersal and evolution across Indonesia archipelago.

Posters

Author	Organisation	Poster Title
Abd. Hafidz	Institut Teknologi Bandung	The role of tephra layers in correlation of Lake Towuti core data
Aditya Pratama, S.T., M.T.	Institut Teknologi Bandung	Eruptive History at the Ijen Crater, East Java, Indonesia
Ajab Singh & Ashok K. Srivastava	Sant Gadge Baba Amravati University	Lithological, geochemical and depositional attributes of YTT ashes, Purna alluvial basin, Central India
Amelia Sasmita, Hamdi Rifai, Rizaldi Putra, Marcus Phua, Steffen Eisele, Francesca Forni, Caroline Bouvet de la Maisonneuve	Universitas Negeri Padang	Identification of Magnetic Minerals in the Peatlands cores from Lake Diatas West Sumatera, Indonesia
Catherine Lit	University of the Philippines Diliman	Composition of marine sediments and tephra in the Sulu Sea, Philippines
Ella Destari Ningsih, Rizaldi Putra, Caroline Bouvet de la Maisonneuve, Marcus Phua, Steffen Eisele, Francesca Forni, Jeffrey Oalmann, Hamdi Rifai	Universitas Negeri Padang	Identification of Magnetic Mineral Forming Elements in Peatland Alahan Panjang West Sumatera Indonesia, Section DD Rep B 693 Using XRF (X-Ray Flourescence)
Faraz Sya'bana	Universitas Gadjah Mada	Tephrostratigraphy of Lautan Pasir Caldera-Forming Eruption Products: Reconstruction of The Youngest Caldera of Bromo-Tengger Volcanic Complex
Forni.F, Eisele S., Phua M. Oalmann J.A,, Hamdi, Putra R., Bouvet de Maisonneuve	Asian School of the Environment	Geochemistry of proximal deposits of quaternary calderas in Sumatra: building a database for tephrostratigraphic correlations
Hamdi Rifai, Caroline Bouvet de la Maisonneuve, Jeffrey Oalmann, Francesca Forni, Steffen Eisele, Marcus Phua, Rizaldi Putra, Rizki Nurul Fajri, Muhammad Riyan Fadila, Nur Aisyah, Amelia Sasmita, Pika Aafriyeni, Ella Destari Ningsih	Universitas Negeri Padang	Magnetic Properties of Volcanic Ashes from West Sumatra
Jeffrey Oalmann, Philip Kyle, Nels Iverson, and Caroline Bouvet de Maisonneuve	Earth Observatory of Singapore	Preliminary LA-ICP-MS Analyses of the INTAV Reference Glasses for Tephrochronology
Marcus Phua, Caroline Bouvet de Maisonneuve, Steffen Eisele, Francesca Forni, Hahjung Chin, Fairuz Razali	Asian School of the Environment	Unravelling the eruptive history of volcanoes in Sumatra, Indonesia using tephrostratigraphy
Muhammad Riyan Fadila, Hamdi Rifai, Rizaldi Putra, Caroline Bouvet de la Maisonneuve, Francesca Forni, Steffen Eisele, Marcus Phua	Universitas Negeri Padang	Magnetic mineral properties of pre- and post caldera lava from maninjau, western sumatra
Mutiara Effendi, S.Si, M.T	Center for Geological Survey of Indonesia	Late Pleistocene Caldera-Forming Eruption Masurai in Merangin, Sumatra, Indonesia : Eruption History Event Based on Pyroclastic Density Currents Deposit Stratigraphy
Nur Aisyah, Hamdi Rifai, Caroline Bouvet de la Maisonneuve, Jeffrey Oalmann, Francesca Forni, Steffen Eisele, Marcus Phua, Rizaldi Putra	Universitas Negeri Padang	Scanning Electron Microscope (SEM) Imaging and Analysis of Magnetic Minerals of Lake Diatas Peatlland Section DD REP B 693

Posters

Author	Organisation	Poster Title
Pika Afriyeni, Hamdi Rifai, Caroline Bouvet de la Maisonneuve, Francesca Forni, Steffen Eisele, Marcus Phua, Rizaldi Putra	Universitas Negeri Padang	Identification of Magnetic Minerals in Peatland at The Section of DD REP B 693 Lake Diatas Using XRD (X-Ray Diffraction)
Purnama Sendjaja, ST. MT	Center for Geological Survey of Indonesia	Volcanic Stratigraphy and Potential Hazards of the Colo Volcano, Central Sulawesi, Indonesia
Radya Aulia Rahman & Haryo Edi Wibowo	Universitas Gadjah Mada	Tephra Stratigraphy of Kukusan Scoria Cone within Ijen Caldera Complex, East Java, Indonesia
Rina Zuraida	Center for Geological Survey of Indonesia	Three tephra layers from offshore of North Bali
Rizaldi Putra, Hamdi Rifai, Caroline Bouvet de la Maisonneuve, Francesca Forni, Steffen Eisele, Marcus Phua, Rizki Nurul Fajri, Muhammad Riyan Fadila, Nur Aisyah, Amelia Sasmita, Pika Aafriyeni, Ella Destari Ningsih	Universitas Negeri Padang	Identifying tephra layers in sedimentary record using magnetic susceptibility measurement
Rizki Nurul Fajri, Rizaldi Putra, Caroline Bouvet de la Maisonneuve, Marcus Phua, Steffen Eisele, Francesca Forni, Hamdi Rifai	Universitas Negeri Padang	Analyzing Magnetic Susceptibility and Elemental Composition of Rocks and Soil around Danau Diatas, West Sumatra, Indonesia
Enrera, Rochelle E.	University of the Philippines Diliman	Newly discovered calderagenic units of Irosin caldera: implications on its eruptive history
Steffen Eisele, Marcus Phua, Hamdi, Amelia H.L Ying, Fairuz N.Razali, Caroline Bouvet de Maisonneuve	Asian School of the Environment	The potential of cryptotephra in a volcanic environment – A case study from Western Sumatra, Indonesia

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Directions to
Tephrochronology Workshop 2019

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