EARTH OBSERVATORY OF SINGAPORE

2017 ANNUAL REPORT

EARTH OBSERVATORY OF SINGAPORE

conducts fundamental research on earthquakes, volcanic eruptions, tsunamis and climate change in and around Southeast Asia, toward safer and more sustainable societies

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Director's Message

This annual report marks the Earth Observatory's first decade.

At the onset, we conceived of a regional research and educational institution aimed at conducting basic geohazards research, headquartered on the campus of an up-and-coming university, NTU Singapore.

Did we move significantly toward these goals during our first ten years? Are we contributing to making Southeast Asian societies safer and more sustainable? Are we likely to play a premier role in meeting the challenges posed to Southeast Asian societies by climate and sea-level change, volcanic eruptions, earthquakes, tsunamis, and river hazards?

This year's annual report helps answer these questions by focusing on the Observatory's work with colleagues in one of our neighbouring countries, Myanmar. We hope you will find that the work we have begun there demonstrates that research organisations, government agencies, universities, and private entities within our region can work together to understand geohazards. We offer you a glimpse of how the knowledge we are producing, and the youngsters we are educating, are improving our region's ability to adapt to natural hazards.

Professor Kerry Sieh, **Director**

Focus on Myanmar

Home to more than 50 million people, Myanmar is shaped like a giant kite with a long tail that sweeps down along the Andaman Sea.

Beneath the surface, invisible dangers affect Myanmar's growing population, making it one of the most earthquake-prone countries in the world. In the north, mountain ranges mark the northeast limit of the Indian tectonic plate, which has been colliding with the southern edge of the Eurasian plate for tens of millions of years. It is this interaction that has helped push up the Himalayan Mountains and the Tibetan Plateau in the far north of the country.

To the east, the Shan Plateau rises high above the central Myanmar basin. Ribbed with mountain ranges and broken hills, it hides a 700-kilometre-wide system of active faults, creating hazards we know little about. Extending north to south, the 1,500-kilometre-long Sagaing Fault splits Myanmar in half, running below the economic centre of Mandalay, through the new capital of Nay Pyi Taw, alongside the thriving metropolis of Bago, and to the west of the country's largest city, Yangon. When set into motion, strike-slip faults like this one tear the earth apart when slabs of crust slide sideways against each other.

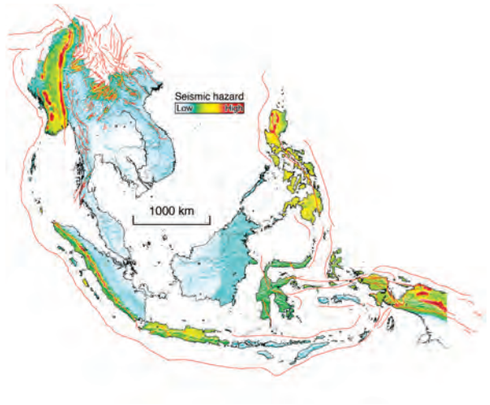
Digging up data

Scientists at the Earth Observatory of Singapore have been locating, analysing, and assessing seismic faults of Myanmar and adjacent regions to better understand their potential hazards. Professor Kerry Sieh and his team are collecting data from satellites high above the earth, surveying the ground with instrument-carrying drones, monitoring ground-motion information gathered by seismic stations, and even digging deep below the ground in search of clues left by past events, a technique known as paleoseismology.

In one project, Research Fellow Dr Xuhua Shi led a team that used fault geomorphology and paleoseismology to investigate sections of the Jinghong Fault, one of the primary faults crossing the China-Myanmar border on the Shan Plateau. They tracked fault-related ridges, valleys, and surface offsets there, dug trenches, and examined sediments deformed by past earthquake ruptures. From this information, they mapped the northeast reach of the fault in detail, locating where geomorphic surfaces and sediments had change, and determining the rate of fault movement and return time for strong earthquake events. From their research, Prof Sieh's team estimated that the last major quake took place there between 500 and 1,000 years ago, and estimated a recurrence rate of about 1,000 years.

Making maps

Information from paleoseismological excavations, along with data from a variety of other sources, provided the foundation for a second project led by Research Fellow Dr Chan Chung-Han. He was tasked with developing high-quality probabilistic seismic-hazard maps for all of Southeast Asia, using uniform assessments and reliable data to replace current resources, which rarely matched well across national borders.

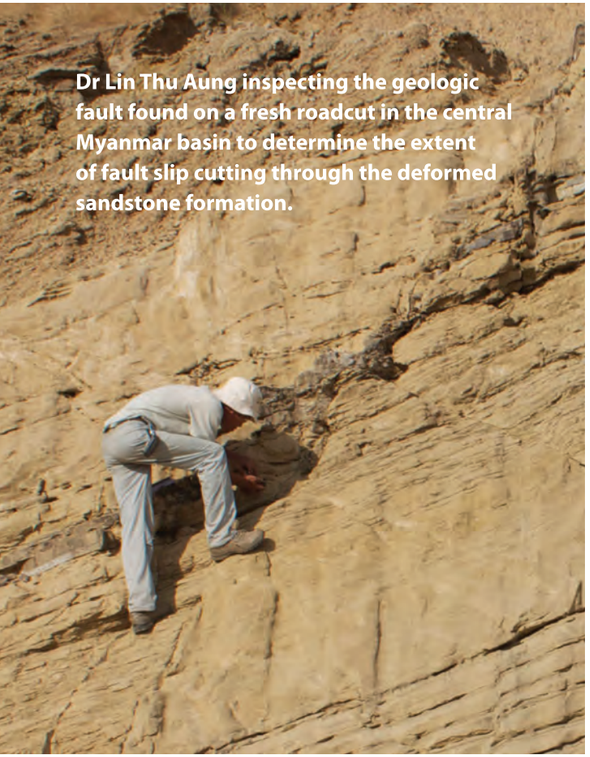


Proposed seismic hazard map showing high hazard levels along some major active faults in Southeast Asia, based on seismological and geological research by the Earth Observatory.

Dr Chan tested different approaches for seismic hazard evaluation by comparing analytical expectations to damage caused by actual events. His team analysed that information to identify best-fitting models, and then used those models to develop a new set of hazard maps.

In Myanmar, the team's surveys showed high hazard levels along the Sagaing Fault, which runs under many of the most populated areas of the country, but has a short earthquake recurrence interval. Equally pressing, Dr Chan found, were threats to the more numerous low- and moderate-hazard areas of the region. In these areas, smaller events happening more often were likely to have devastating effects on vulnerable populations: Even a small earthquake in an unprepared area can have catastrophic consequences.

The team also developed new ways of assessing whether earthquakes might trigger tsunamis, a constant worry for a country made up of hundreds of islands and with thousands of kilometres of coastline. One way they're addressing these concerns is by partnering with temblor.net, an online platform that integrates information on natural hazards from around the world and makes them available to scientists and the general public.



Dr Lin Thu Aung inspecting the geologic fault found on a fresh roadcut in the central Myanmar basin to determine the extent of fault slip cutting through the deformed sandstone formation.

Finding faults

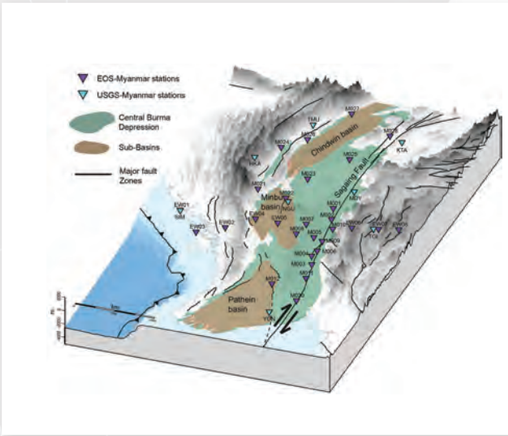
For the past decade, Professor Paul Tapponnier's team has been working with colleagues from Myanmar to map active faults across the country and find the trace of large earthquakes in the past. When two recent earthquakes shook central Myanmar, his team used social media videos to analyse damage from ground motion. They found that patterns of ground motion during these two events were very different from one another, revealing complexities in forecasting seismic hazards for Southeast Asia.

Last year, the team also looked closely at an active fault that extends beneath the Yangon metropolitan area. Using a new model to reinterpret the old data, they determined that the earthquake that occurred in 2017 was sourced from the same fault system that shook the region in 1927 and 1970. The epicentre of the 1970 earthquake was only a few kilometres from the western bank of the Yangon River, on the Irrawaddy Delta. The thick, soft sediments there, and the active fault hidden beneath the Delta, adds additional risk for local communities, since the spongy soil is likely to amplify any ground motion from earthquakes near the city.

Building networks

Working farther north, Assistant Professor Shengji Wei and his team spent much of the year installing 29 broadband seismometers in the central Myanmar region. These instruments measure ground motion and detect the presence of seismic waves. Along with eight seismometers put in place by the U.S. Geological Survey, the installations together create a network of 37 stations, each providing continuous data, and all feeding information to the new Myanmar National Seismic Network. When the real-time software detects the presence of an earthquake above magnitude 1.5, it automatically determines the event's coordinates, magnitude, and origin time.

Using the waveform records of local and distant earthquakes, researchers can determine the structure below the seismic station, geometry and locking status of the fault, existence of secondary faults, and even the possibility of an earthquake triggering a tsunami. Between August and September of 2017, more than 300 local events were detected, expanding knowledge of the area and adding valuable information for both local and global study.



Map showing the topography, simplified geological units, major faults, and seismic stations in Myanmar.

Working in Myanmar with a collaborator from the University of Mandalay, Dr Wang Yu (at left) records conditions at a GPS site in Pui Oo Lwin, a hill town east of Mandalay, on the Shan Plateau.

Creating new models

Associate Professor Emma Hill's team has begun looking in detail at data recorded by 24 continuous-GPS (cGPS) stations in the Myanmar-India-Bangladesh-Bhutan (MIBB) network. The team also had access to nine new cGPS sites installed in central Myanmar in 2017. Each station works by continuously gathering location information from satellites. Computer models based on this data allow researchers to detect both long-term changes and sudden shifts in the Earth.

Hill's team — led by Research Fellows Drs Eric Lindsey and Wang Yu, along with Research Associate Dr Lin Thu Aung — also revisited existing survey benchmarks across Myanmar, remeasuring each to detect ground movement. With this information, they created maps and models designed to pinpoint areas of underground instability and strain.

The work of Hill's team in modelling the tectonic makeup of Myanmar also takes into account the seasonal monsoon rains, which cause flooding, land loss, and ground subsidence (sinking land) due to the water's massive weight. These pressures interfere with efforts to gather data by overwhelming signals from small tectonic events. Working with visiting students from several countries, however, the team is using space-based gravity observations to correct the signals, so they can see long-term tectonic trends without interference from monsoon rains.

In another study, the team processed data from Japanese satellites to find an increase in long-term subsidence rates around Yangon. While the city itself remains fairly stable, communities located beyond the reach of the municipal water-distribution system are using significant amounts of groundwater, exacerbating the problem of soils caving in and lands sinking.

Paleoseismology workshop participants learn about earthquake field research in eastern Myanmar along the 2011 Nam Ma Fault rupture.

Sharing knowledge

In Myanmar, our researchers have learnt much from local and regional experts, but they've also shared knowledge and techniques with colleagues and communities. In March of this year, Observatory scientists held a paleoseismology training workshop on the plate-boundary Sagaing Fault, focusing on the giant earthquakes generated by the Fault in the past 2,000 years. During this workshop, an international team of experts taught students from Myanmar, Thailand, Taiwan, and the USA the essential field skills of studying active faults and prehistoric earthquakes, including generating high-resolution digital maps using aerial photos taken by drones.

The goal of the course was to equip students with new skills and knowledge, and to empower them to conduct fundamental geological research in their own countries. In this way, as in so many others, the Earth Observatory of Singapore continues to work toward building the resources needed to safeguard the health, safety, and economic potential of Southeast Asia.

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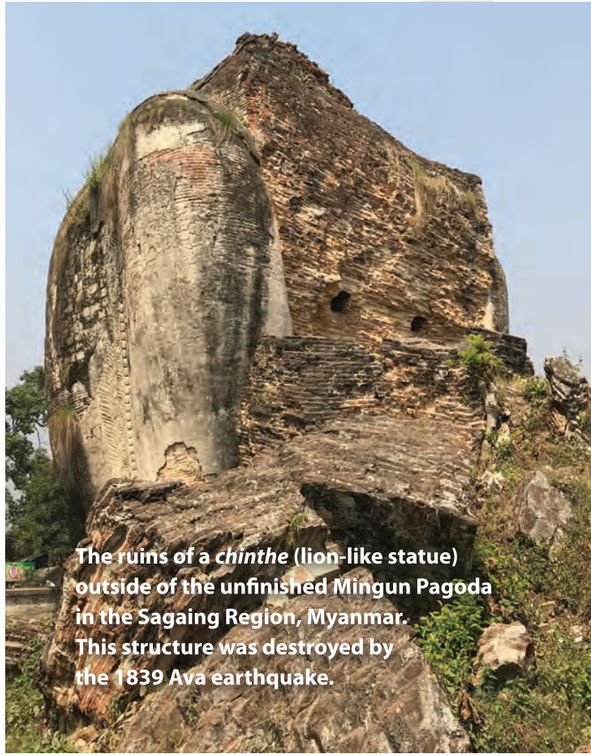

The ruins of a *chinthe* (lion-like statue) outside of the unfinished Mingun Pagoda in the Sagaing Region, Myanmar. This structure was destroyed by the 1839 Ava earthquake.

Other Research Projects

Our research extends across our dynamic planet, from monitoring haze in Sumatra to studying volcanoes in Papua New Guinea.

read more earthobservatory.sg/annualreport2017/research/otherprojects

Publications

The online list contains all publications authored by researchers at the Earth Observatory between April 2017 and March 2018.

read more earthobservatory.sg/annualreport2017/research/publications

Research Map

Our scientists travel the world to conduct fundamental research on geohazards. Find out where our researchers have been in the past year.

read more earthobservatory.sg/annualreport2017/research/map

Applied Projects

The Applied Projects Group integrates scientific research with public policy, working with communities, businesses, and government agencies to address issues related to geohazard risks.

In 2017, team members met with the government disaster-management agency in Bangkok to discuss Thailand's tsunami safety and education efforts. Together, they focused on the challenges of maintaining the complex network of tsunami early-warning towers along the Andaman coast. In addition, the Phuket government has adopted the Group's new disaster-training plans for schools, which helps students learn to stay safe in earthquakes and tsunamis.

This year, team members also continued their study in Uttarakhand state, northern India, developing earthquake hazard parameters used to conduct risk assessments. Using results from 40 soil-probe samples, the Applied Projects team has begun creating a digital elevation model from aerial imagery, and will soon publish a research manuscript with their findings.

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Community Engagement Office

The Community Engagement Office builds the identity of the Earth Observatory of Singapore within and beyond the scientific community.

The Office communicates science through various channels, including the institutional blog, where research findings and commentaries are publicised. The Office also participates in conferences, exhibitions, and panel discussions, and hosts high-profile guests, visiting scientists, and schools for tours and events. Short videos featuring EOS research is another way the Office shares the work of Observatory scientists.

Partnerships are also integral to the Office's outreach plans. This year, the team worked with colleagues from France and Indonesia to promote the second MIRAGE marine expedition, organised the premiere of the documentary 'Haze: It's Complicated', produced by the Art+Media team, and reached out to industry partners and research institutes.

In the coming year, the Community Engagement Office plans to increase visibility, expanding communication and outreach across the scientific community and deepening relationships with local and global partners.

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earthobservatory.sg/annualreport2017/outreach/communityengagement

Philanthropy Office

The Office of Philanthropy supports the Earth Observatory of Singapore through advancement initiatives that provide financial investment, strengthen strategic alliances, and promote institutional priorities.

The Philanthropy Office launched the ambitious agenda of creating a campaign to help ensure the Observatory's financial security in perpetuity. To achieve funding goals, the Office implemented an integrated infrastructure designed to incorporate best practices for institutional advancement. In addition, the Office created a grants administration unit to provide support for Observatory researchers and allow for the integration of additional investment streams.

In 2017, the Office of Philanthropy cultivated a number of significant funding opportunities that will provide impactful support for the Centre for Geohazard Observations, scholarships, geohazard research, and special projects. Through the growth of the Office of Philanthropy, the Earth Observatory of Singapore is well positioned to attain a sustainable, high-quality geohazards programme for generations to come.

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Technical Office

The Technical Office manages all major field instruments and networks conducted by the Earth Observatory of Singapore throughout Asia.

It oversees the Observatory's data centre, and works closely with governments and research agencies across the globe.

The Technical Office achieved two major targets this year: setting up a 30-station permanent broadband seismic network in Myanmar, and conducting new airborne LIDAR surveys in Nepal and Myanmar.

Carried out in collaboration with Myanmar's Department of Meteorology and Hydrology and the Myanmar Earthquake Committee in Yangon, the new seismic stations have helped form the backbone of the Myanmar Seismological Network. The airborne LIDAR studies mapped geomorphological signatures of past earthquakes along the Himalayan frontal thrust in Nepal and the Sagaing Fault in Myanmar.

In 2017, the Technical office also continued its work of maintaining seismic and GPS networks monitoring volcanoes in Indonesia and the Philippines.

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Asian School of the Environment

The Asian School of the Environment (ASE) at Nanyang Technological University is an interdisciplinary school that trains future leaders to face Asia's biggest environmental challenges.

ASE students working toward PhD and Bachelor of Science degrees work closely with internationally renowned researchers at the Earth Observatory of Singapore and beyond.

This year's cohort of fourth-year undergraduates is ASE's first group of graduating students. As part of their assessment, they had to present Final Year Research Projects demonstrating their ability to apply knowledge and concepts learned during their undergraduate years to future areas of research. Ninety per cent of these final-year students secured employment before graduation.

In 2017, ASE students participated in several international workshops, attending the Japan–East Asia Network of Exchange for Students and Youth Programme, becoming Youth Advocates for the United Nations, and taking part in the University Scholars Leadership Symposium. They also moderated talks by National Geographic explorers Joel Sartore and Arthur Huang, and hosted a visit by explorer Mike Horn.

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Impact

Accomplishments and Honours

Kerry Sieh, Director
Fellow of the American Association for the Advancement of Science

Paramesh Banerjee, Technical Director
President of the Asian Seismological Commission

Sabrina Smith, Community Engagement Director
ArtScience Museum International Advisory Board

Benjamin Horton, Principal Investigator
Intergovernmental Panel on Climate Change (IPCC) review editor

Shi Xuhua, Research Fellow
AXA Fellowship

Priyamvada Nanjundiah, PhD Student
Asia Oceania Geosciences Society 2017 Best Student Poster Award

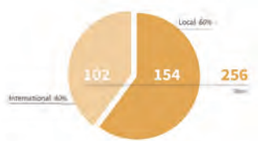
Lee Wen-Chien, Li Weiran, Fabio Manta, Deepa Mele Veedu, and Stephen Pansino, PhD Students
Dr Stephen Riady Geoscience Scholars Fund 2017

Full accolades are listed at earthobservatory.sg/annualreport2017/impact

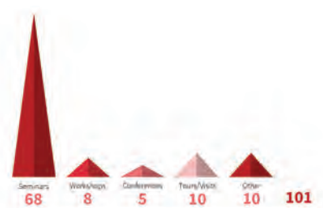
We expanded our reach

Online Engagement

Media Mentions



Workshops, Seminars, and Other Outreach Events



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