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Institute of Catastrophe Risk Management

Insurance Implications of Recent Research into the Seismotectonics of Southeast Asia

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INTRODUCTION

With the increasing economic development and prosperity in Southeast Asia comes a burgeoning insurance market, providing financial cover for both property damage and casualties in the event of a major regional earthquake. As insurers consider extending their portfolios to embrace the new opportunities for business growth in Southeast Asia, they will be undertaking their own portfolio risk assessments to ensure that corporate risk management strictures are responsibly followed. The enormous flood insurance losses in Bangkok illustrate the need for prudent and well-informed regional catastrophe risk management.

The main international risk modelling agencies, (RMS, AIR and EQECAT), have a natural commercial focus on established insurance markets where there is a high existing demand for peril models. Accordingly, the model service provided for Southeast Asia insurers is currently rather patchy. Over time, the Global Earthquake Model (GEM) initiative will help to plug the gaps. However, the inertia that accompanies global research projects leaves open a pressing need now for insurers to be updated with actionable technical information that can be used in real-time for making decisions on earthquake underwriting and risk management.

The purpose of this white paper, which is the first of an ICRM series by the author, is to highlight some of the key advances in the understanding of the regional seismotectonics of Southeast Asia, and to assess their insurance implications. Part of the motivation for the selection of this topic, rather than some other earthquake engineering issue, is the establishment in 2009 of the Earth Observatory of Singapore at NTU. One of the broad goals of EOS is to understand the earthquake geology in and around Southeast Asia for reliable long and medium-term forecasts of earthquakes and tsunamis. To fulfil this goal, EOS scientists and colleagues from neighbouring countries integrate geological, geomorphic, geodetic and seismological observations and interpretations.

This is a fine ambitious goal of EOS, befitting an Earth Science institution of increasing international renown and scientific stature, and the focus on medium and long-term forecasting of earthquakes and tsunamis is indeed vital for medium and long-term management of building construction and land usage in the region. For such societal applications, a quasi-deterministic approach to seismic hazard may be sufficient. If a particular fault segment is deemed by seismologists to be very likely to generate a massive earthquake in the next thirty years, then the building codes and coastal land usage policies need to be able to cope with, or adapted for such a scenario.

However, insurers are commercial organizations with a direct short-term interest in the seismic hazard in the next few years. Furthermore, insurers are most interested in areas of high exposure aggregation. Sparsely inhabited areas, or geographical concentrations of the uninsured, are of marginal financial concern. Specifically, insurers require a probabilistic hazard assessment involving the estimation of the annual probability of occurrence of a major earthquake on the regional faults that threaten an insurance portfolio. This requires an analysis well beyond the quasi-deterministic scenario analysis that may be adequate for medium and long-term risk mitigation purposes. In particular, a stochastic model for the temporal occurrence of earthquake activity on a fault is essential for insurance applications.

Part of the epistemic uncertainty inherent in earthquake underwriting is the sudden scientific realization that the likelihood of a major earthquake on a regional fault, or its maximum magnitude, is much greater than hitherto suspected. The reverse may also happen – a fault may be judged less dangerous than previously perceived, perhaps due to some previous geological misinterpretation or statistical exaggeration of partial seismological evidence. But it is the former situation that is far more likely.

There is an adage in the geology of active faulting: absence of evidence is not evidence of absence. Active geoscientific investigation is generally required to locate evidence of fault rupture. Absent such investigation, and the consequent absence of positive evidence, the possibility always exists for fresh evidence to perturb a seismic hazard assessment significantly. There is no tradition for maps of active faulting to indicate to the viewer the associated epistemic uncertainty (Woo, 2011). Blanks on a map may be interpreted as the absence of active faulting – or as an area which has only been partially explored seismotectonically. Progress in studying active faulting in Southeast Asia is serving to reduce this epistemic uncertainty, which will lighten the burden of earthquake underwriting in this region.

Part of the function of this white paper is to translate recent seismotectonics research findings into the probabilistic seismic hazard language most appropriate and relevant for the insurance industry. Out of numerous painstaking observations and measurements accruing from any research programme, it is by no means sure that much should arise that would be of startling revelation to insurers. But as and when great discoveries are made, insurers should be informed and take note. The progress of scientific research is itself a stochastic process, reflecting to some extent the underlying stochastic process of earthquake occurrence. Seismology is an observational rather than laboratory science. Large earthquakes cannot be created in a laboratory, but when they do occur, they add significantly to the overall library of seismological knowledge.

Furthermore, the occurrence of damaging earthquakes tends to loosen the purse strings of funding agencies, encouraging the commissioning of new seismological research. Ex-ante research funding is invariably harder to obtain than ex-post funding. So it was with the great 2004 Indian Ocean tsunami. Fittingly, this report begins with a major seismic hazard study undertaken by the USGS after the 2004 tsunami.

THE USGS HAZARD MAP 2007

The seismological remit of the U.S. Geological Survey (USGS) includes a basic duty to monitor and catalogue earthquakes, first in the USA, then more globally. In addition, the USGS has diversified downstream into the application of such data for undertaking seismic hazard assessments, and casualty analyses. The prime responsibility is in mapping seismic hazard in the USA, but the USGS is engaged in other areas as well. For example, it is to be expected that where US citizens are exposed to significant seismic hazard in the developing world, the United States Agency for International Development (USAID) would be keen to support a collaborative exercise in regional seismic hazard mapping.

The catastrophic tsunami that struck on 26 December 2004 claimed the lives of many citizens from the western world, including several dozens of US citizens. As part of the overwhelming western response to this disaster, USAID funded a USGS Southeast Asia Seismic Hazard Project, which originated after the 26 December 2004 Sumatra earthquake (M9.2). This earthquake generated the tsunami that caused significant casualties and economic losses in Indonesia, Thailand, Malaysia, India, Sri Lanka, and the Maldives. The objective of the USGS study was to develop seismic hazard maps that would assist engineers in designing buildings to resist earthquake strong ground shaking. Future structural damage and societal losses from large earthquakes can be mitigated by introducing seismic hazard provisions in building codes that allow buildings and structures to withstand strong ground shaking associated with anticipated earthquakes.

A feature of any seismic hazard assessment is the method used to deal with epistemic uncertainty associated with disagreement among experts over model parameterization. The USGS seismic hazard maps result from the organization of regional workshop discussions in Indonesia, Thailand and Malaysia to achieve a consensus over input parameters for earthquake sources and ground shaking.

The USGS hazard models and maps were produced at their office in Golden, Colorado, using the methodologies established for producing the United States national seismic hazard maps (e.g. Frankel and others, 2002). A new subduction zone model was developed that considers historical seismicity, paleoseismic investigations, geodetic data, and ground motion studies. Fault maps were compiled and fault parameters were discussed at workshops held in Thailand and Indonesia. In addition, geology and shear-wave velocity maps and a seismic risk analysis were produced for a region surrounding Padang, Indonesia.

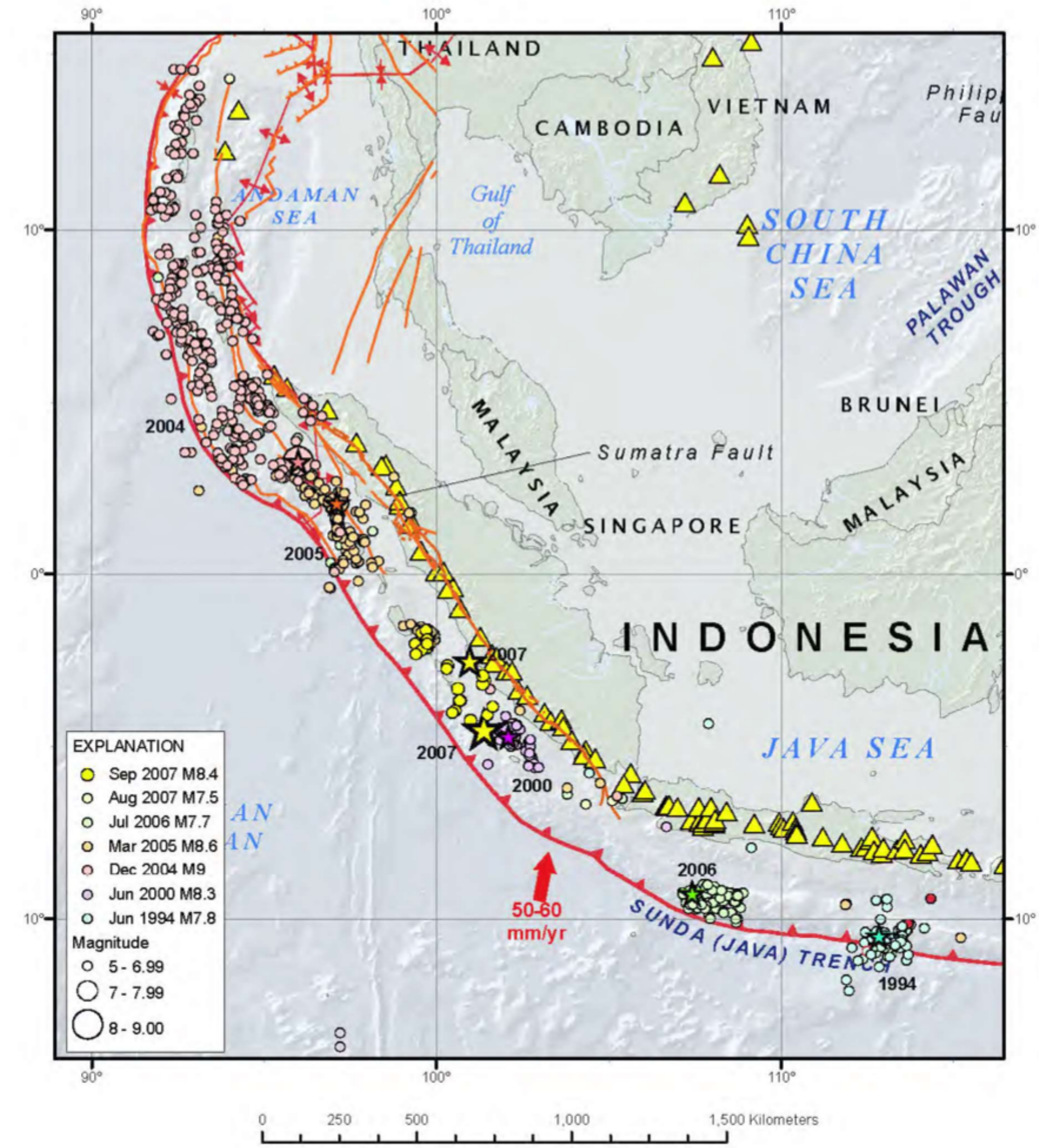

Figure 1. Map of subduction earthquakes (stars and circles) 1994-2007, volcanic centers (triangles), and generalized locations of major crustal faults (orange) and plate boundaries (red). [Source: National Earthquake Information Center (NEIC), USA]

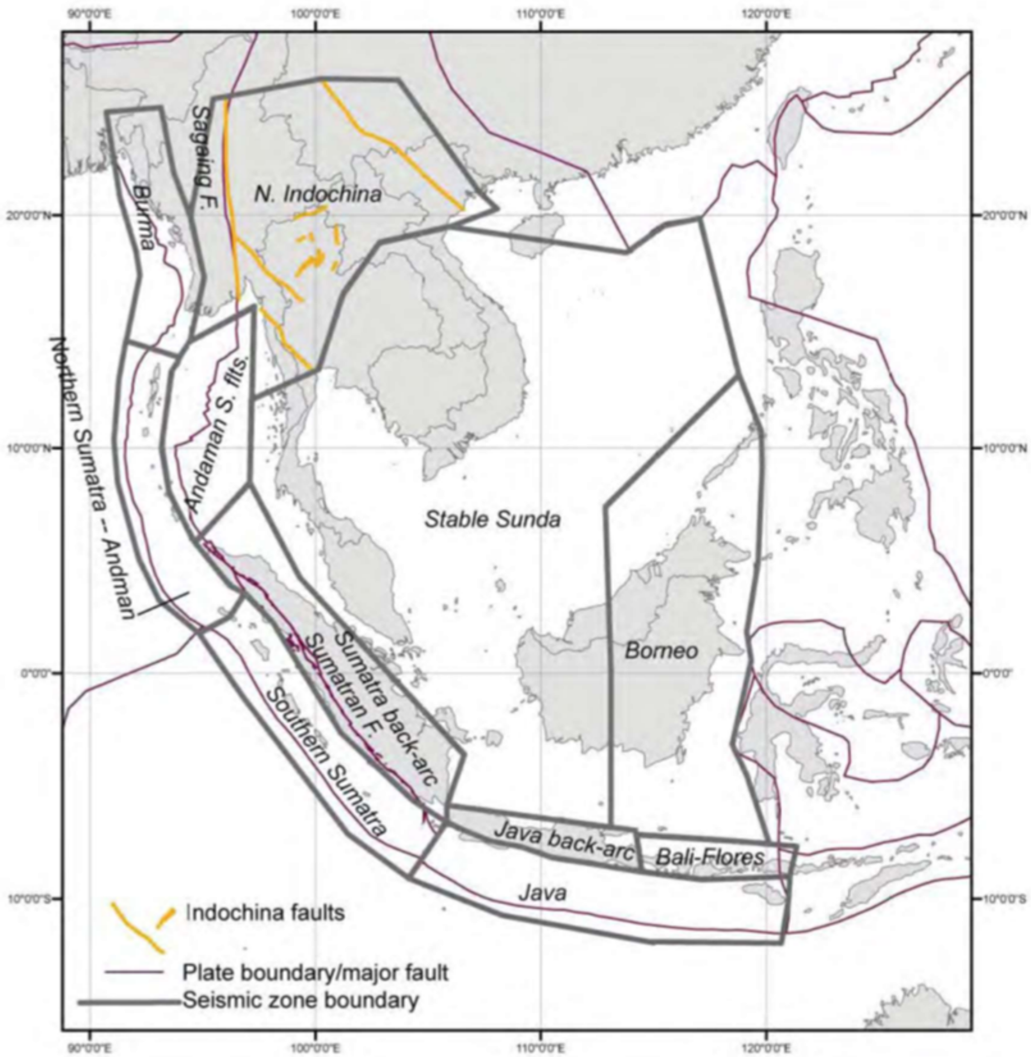

Figure 2. Map of shallow-depth earthquake source zones (labelled) that were considered for the USGS study.

SEISMOTECTONIC REVIEW

The USGS documentation for the Southeast Asia seismic hazard maps summarizes the seismotectonic basis for their hazard model.

Regions of high seismic hazard in Southeast Asia are associated with the subduction process beneath the Indonesian and Philippine archipelagos. The Indonesian island chain is characterized by widespread volcanic activity and earthquake activity resulting from the sliding of the India and Australia tectonic plates beneath the Sunda and Burma tectonic plates. The Sunda subduction zone produces thrust-fault earthquakes on the interfaces between plates, earthquakes within the subducted India and Australia plates that extend down to depths of hundreds of kilometers, intraplate earthquakes within the shallow India and Australia plates, and shallow seismicity within the upper 30 km of the overriding Sunda and Burma plates. Additional crustal faults occur within the Sunda plate well to the north and east of the Sunda subduction zone.

The Northern Sumatra-Andaman zone encompasses offshore northern Sumatra, the Nicobar Island chain, and the Andaman Island chain. In this area, the Indian plate is subducting obliquely beneath the Burma plate. This zone trends nearly north-south as opposed to the nearly east-west trending section of the Sunda subduction zone near the island of Java, here called the Java zone. The estimated rate of subduction is 20 mm/yr to 40 mm/yr, with the higher rates to the south (Rajendran and others, 2007; Socquet and others (2006); and Chlieh and others, 2006).

The Northern Sumatra-Andaman zone last ruptured in the 26 December 2004 Sumatra earthquake (M9.2). The seismic/geodetic model of Chlieh and others (2006), however, shows that some patches of the subduction zone interface between lat. 2° N. and 14° N. apparently did not rupture during the December 2004 mainshock or during the month following the mainshock.

Although the seismological evidence is clear that the Java zone can produce interplate thrust-fault earthquakes with magnitudes approaching Mw8.0, there have been no catalogued earthquakes of Mw8.0 or larger in the Java zone that appear likely to have been due to thrust-faulting on the interface (Newcomb and McCann, 1987) since the mid nineteenth century. Lay and others (1982) and Newcomb and McCann (1987) suggest that this region of the eastern Sunda arc is much less likely to experience great underthrust earthquakes than the western Sunda arc.

Smaller earthquakes are speculated because of weak coupling at the plate interface that may be due to the nature of the older high-density subducting lithosphere beneath the Java zone. Geodetic observations (Simons and others, 2007) are consistent with weak coupling on the subduction interface. The largest earthquake in the Java zone since 1900 was the 19 August 1977 (Mw8.3) earthquake, which was an intraplate earthquake occurring within the subducting Australia plate rather than an interplate earthquake occurring on the thrust interface between the Australia plate and the overriding Sunda plate. The 1977 earthquake produced a destructive tsunami; little or no damage resulted from shaking due to its distance offshore.