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IEM POSITION DOCUMENT 2005

Approved by IEM Council

POSITION PAPER ON ISSUES RELATED TO EARTHQUAKE

Note: IEM Position Documents are approved by the IEM Council and express the views of the Institution on a specific issue. The purpose of this document is to provide objective, authoritative background information to persons interested in issues with IEM's expertise, particularly in areas where such information will be helpful in drafting sound public policy.

EXECUTIVE SUMMARY

The safety of building structures in Malaysia affected by seismic waves emanating from earthquakes in, and close to, Sumatra has always been of concern to the general public. The issue has recently been brought back in the spotlight after the large 26 December 2004 earthquake which triggered tsunami that caused a number of fatalities. Although there were no other fatalities among occupants staying in buildings, there were a few reported cases of building swaying and structural and non-structural defects in the form of cracks. In general, occupants have expressed fear for their safety particularly those residing in highrise buildings. A Position Paper Committee from IEM was set up to look into these issues and to subsequently arrive at a common stance on proposals for mitigation policy and guidelines on earthquake safety aspects for consideration and acceptance by the Government of Malaysia.

This position paper aims to recommend reasonably effective measures to address safety issues of building structures in Malaysia. Besides addressing issues related to effects of earthquake on buildings, the position paper also proposes initiatives and actions to be undertaken by the Institution of Engineers, Malaysia (IEM) in conjunction with other professional bodies in respond to these issues.

IEM has a direct interest and concern with regards to this issue, and its present position and proposed courses of action are as stated below.

In the short term, IEM is recommending these initiatives:

1. Urging for the need of more seismic monitoring stations in Malaysia.
2. Exhorting for the setting up of instrumentation for measuring seismic response of buildings.
3. Undertake seismic vulnerability studies of existing important buildings or structures, particularly in high risk areas.
4. Review of current Engineering Design & Construction Standards and Practices.
5. Suggest for the design of highrise buildings to cater for long period vibration. In addition, site specific ground motions are required for consideration in the design of highrise structures of seven (7) storeys and above. This range of building's height is found to be particularly vulnerable to the effects of earthquake [22].

In the long run, IEM is recommending these courses of actions by various players and stakeholders in the local engineering industry:

1. Develop or adopt a suitable code of practice with necessary modification for the construction industry with regards to seismic design after the review.

2. Sensitive and Important structures (e.g., hospital, BOMBA, police stations, importance bridges, dams, power supplies structures, telecommunication structures, etc) shall be checked for vulnerability when exposed to seismic ground motion.
3. Introduction of earthquake engineering education curriculum in the universities and other tertiary institutions of higher learning.
4. Sourcing of substantial rolling research fund for earthquake engineering research and also to include monitoring and risk assessment works.
5. Continuing education for practicing engineers is required in the areas of earthquake engineering in line with the call from the Board of Engineers Malaysia.

THE POSITION PAPER COMMITTEE

A position paper committee on issues related to Earthquake was established on 19 April 2005 by the Institution of Engineers, Malaysia (IEM), with Ir. Dr. Ch'ng Guan Bee as its chair. The members of the IEM Position Paper Committee have been appointed based on their cross representation of the local construction engineering academia and industry. They are as follow:

1. Ir. Hee M.C.	IEM Council
2. Ir. Lee Weng Onn	IEM Council
3. Ir. Dr. Jeffrey Chiang	IEM Structure Representative
4. Ir. Dr. Sooi Took Kong	Representative from Universities
5. Ar. Andy Gan Khai Fatt	Representative from PAM
6. Mr. Low Kong Chiew	Director, Seismology Department
7. Assoc Prof. Dr. Azlan Adnan	Representative from Universities
8. Ir. Teo Ching Wee	REDHA
9. Prof. Dr. John Kuna Raj	Dept. of Geology, Univ Malaya

10. Ir. Liew Shaw Shong	IEM Geotechnical Representative
11. Ir. Elias Ismail	CIDB

1.0 THE ISSUES

1.1 Recent earthquakes in Sumatra, resulting in tremors felt, have heightened concerns to Malaysians, especially those occupants residing in highrise buildings.

1.2 Existing Building By-laws or codes of practices do not have legislations and guidelines to address the effects of earthquake-induced vibration to building structures.

1.3 Hence there is a lack of sustainable solutions to overcome safety concerns related to effects of earthquakes emanating from Indonesia.

2.0 BACKGROUND

2.1 The global statistics has shown that the fatalities caused by effects of earthquakes stands at the rate of approximately 12,000 deaths a year. In the last century alone there were approximately 2.2 million deaths due to earthquakes. This figure constitutes about 49.3 % of the total death toll caused by natural hazards all over the world in the 20th century. In terms of regional breakdown, 85.5% of deaths were from the Asia Pacific region alone.

2.2 The earth crust is made up of at least 12 separate lithosphere consisting of the crust and the more rigid part of upper mantle over the Asthenosphere. At the interface of these tectonic plates, there are three

(3) types of interactions that can cause earthquakes. These three (3) types of interactions are:

(a) Divergent boundary
(b) Convergent boundary
(c) Transform boundary

2.3 In Sumatra, the types of plate boundary that cause earthquakes, posing direct vibration threat to Malaysia are of the last two types (viz., items 2.2 (b), and 2.2 (c)). The convergent boundary at Sumatra is of subduction zone, capable of generating major earthquakes of large magnitude measured over 9.0 on the Richter's scale. In addition, the frequencies of earthquake occurrence in Indonesia, as recorded over the past 10 years were high (in numbers of a few thousands).

2.4 In Malaysia, there were a total of 46 events of earthquake occurrences, originating from Indonesia that were felt in Malaysia over the last decade out of the thousands of events occurred and recorded in Indonesia. The above number of events did not account for felt aftershocks. In Sabah and Sarawak, there were a total of 30 events, which occurred over the period from 1874 to 2005. The intensities felt ranged from magnitudes I to VII (Mercalli Intensity Scale, see Appendix).

2.5 A total of twelve (12) strong motion seismic monitoring stations were set up in Malaysia in 2004. Five (5) of them are situated in Peninsular Malaysia, while the remaining seven (7) are sited in East Malaysia.

2.6 A seismic hazard assessment carried out in Malaysia in 2004 has shown that a peak ground acceleration (PGA) of 50 gals (for 500 years return period) has been determined for 'before Aceh's event' (26 Dec 2004), and a PGA value of 100 gals has been ascertained for 'after Aceh's event'.

2.7 It was also noted that the earthquake characteristic that has affected the structures here was of that with a long period of vibration. Due to the long distance traverse by the seismic wave (or far field effect), the short period vibration characteristic has been filtered out. When a fault ruptures, seismic waves are propogated in all directions, causing the ground to vibrate at frequencies ranging from about 0.1 to 30 Hertz. Buildings vibrate as a consequence of ground shaking; damage takes place if the building cannot withstand these vibrations. Compression and shear waves mainly cause high frequency (>1 Hertz) vibrations which are more efficient then low frequency waves in causing low buildings to vibrate. Rayleigh and Love waves mainly cause low-frequency vibrations which are more efficient than high-frequency waves in causing tall buildings to vibrate. Because amplitudes of low frequency vibrations decrease less rapidly than high-frequency vibrations as distance from the fault increases, tall building located at relatively great distances (60 miles) from a fault are sometimes damaged (Hays, 1981).

2.8 A preliminary study on soil samples of five cities in the West coast of Peninsular Malaysia by University Technology Malaysia (UTM) has shown that the average local soil amplification ranges from 1.4 to 3.6. The study implies that the local soil effect could not be neglected.

2.9 Two other factors that need to be considered are building configuration and structural types. These are factors that need special attention especially for building designs in earthquake zone areas. Building failures in past recorded earthquakes around the world have shown the importance of these factors, in terms of structural integrity.

2.10 Ductility design for earthquake loads is another important consideration. Normally, it is preferred to ensure that the joints of a structural frame (such as beam-column connections) be of sufficient ductility so as to allow movement under earthquake forces, without joint failure. In low to moderate earthquake zones, partial ductility design may be the solution, in order to justify costs and effort.

2.11 Due to the nature of building design and usage, some external and internal features of buildings (such as wall claddings and services piping) can fail, be disrupted or even collapse due to effects of earthquake, causing hazards to users or general public.

2.12 It is said that a building is only as strong as the ground on which it is founded on. Hence, the issue of ground and slope stability may also be of some concern in the face of earthquake tremors. On the earthquake induced sinkholes, only one major case has been reported, near Kampar in the Kinta Valley area. This was an ex-mining area with loose sand tailings underlain by limestone bedrock. The geological predisposition was ‘ripe’ for the popping-up of sinkholes, and the earthquake tremor provided the ‘triggering’ factor. Earthquake tremors could be one factor among others in triggering the sinkholes. On the earthquake-induced landslide and ground settlement (liquefaction), there is no official historical record so far induced by the tremors, but the risk could not be neglected.

3.0 RECOMMENDATIONS

3.1 The proposed stance by the IEM Position Paper Committee affects the following:

(a) Existing built environments – how safe are the existing building structures under the effect of earthquake tremors from neighbouring countries?

(b) Feasibility of new and proposed built environments (e.g., property development) – what are the cost implications to developers and house buyers?

(c) Existing and future practices on design and construction of structures – how would the extra costs incurred be charged by designers and builders?

3.2 The IEM Position Paper Committee has decided to recommend measures on issues related to effects of earthquake tremors on building safety, for consideration and acceptance by the Government of Malaysia. These measures are presented in Items 3.3 and 3.4, as short and long term course of actions.

3.3 Recommended short term measures

3.3.1 Setting up more seismic monitoring stations in Malaysia

(a) There is an urgent need to increase the number of seismic monitoring stations in the country.

(b) The current five numbers of seismic monitoring stations in peninsular Malaysia should be increased to at least one (1) station per state so that sufficient data could be gathered for better decisions making in the future.

3.3.2 Setting up building acceleration instrumentation devices

(a) This instrumentation is needed to be installed on the building to obtain the acceleration at different storey height.

(b) It is recommended in ACI code that such devices have to be installed on at least three positions of highrise structures, i.e. at the base, at mid-level, and at the top, in order to obtain accurate and reliable readings of the building response.

3.3.3 Undertake seismic vulnerability studies of existing important buildings or structures, particularly in high risk areas.

(a) This involves the application of appropriate seismic vibration measuring devices to the structures so as to record the site effects due to earthquake to a certain degree of accuracy.

(b) Attention needs to be given to heavy architectural cladding on the façade of the buildings.

3.3.4 Review of current engineering design and construction standards and practices

(a) One of the immediate tasks that can be carried out by IEM and other professional bodies is to review the current practices and design standards on buildings in the country. This is essential as the current standards do not address the possible vibration forces, principally due to earthquake.

(b) Once reviewed, comments and/or suggestions raised should be tabled to the proper authority for further actions, such as to draft and incorporate new earthquake design guidelines into the current national standards.

3.3.5 Suggest for the design of highrise buildings to cater for long period of vibration. In addition, site specific ground motions are required for consideration in the design of highrise structures of seven (7) storeys and above. This range of building's height is found to be particularly vulnerable to effects of earthquake [22].

(a) This suggestion should be taken up by a national Technical Committee, looking into the drafting and development of design guidelines of building structures under earthquake loadings.

(b) Expert opinions need to be sought out, particularly from local and international researchers on these issues.

3.4 Recommended long term measures

3.4.1 Develop or adopt a suitable code of practice for the construction industry

(a) Proper guidelines and code of practice are needed for the design engineers as a long term solution.

(b) These documents are proposed to be updated and revised in every five (5) years, when new findings are evident.

3.4.2 Sensitive structures shall be checked for vulnerability when exposed to seismic ground motion

(a) Other infrastructures like bridges, transmission towers, dams and other residential buildings shall be checked for vulnerability.

(b) The Street, Drainage and Buildings Act requires buildings of over 10 years old and over five (5) storeys in height to have periodic inspection. The inspection is proposed to include earthquake vulnerability checks.

3.4.3 Introduction of earthquake engineering education curriculum in the Universities and other tertiary institutions of higher learning

(a) Earthquake engineering should be taught as a subject in universities in the future.

(b) Alternatively, it can be an extension or continuation to the university's general engineering study on dynamic analysis of rigid bodies, structural frames and foundation subsoils.

3.4.4 Sourcing of substantial rolling research fund for earthquake engineering research and also to include monitoring and risk assessment works. Research and development constitutes an important part of mitigation of earthquake engineering programme.

(a) Possible sources of such funding include IPRA grants (via university research), CIDB research or study grants (via CREAM).

3.4.5 Continuing education for practicing engineers is required in the areas of earthquake engineering in line with the call from the Board of Engineers Malaysia to equip local engineers with the skills and knowledge to tackle potential hazards and problems arising from earthquake effects on buildings.

IEM strongly recommends that the proposals outlined above be considered and implemented by the Government of Malaysia as early as possible so as to mitigate and to improve on building safety due to effects of earthquake in the country.

In the short and long term measures, the following recommendations in terms of rankings and proposed agencies involved are made in Table 4.1 below:

Table 4.1 : Short and Long Term Measures – Top Three Priorities

Clause	**Action by Government**	**Agency Involved**	**Short Term Action Priority**	**Long Term Action Priority**
3.3.1	Yes (minor)	Kajicuaca	2	
3.3.2	No (new)	Kajicuaca/JKR/ MLA	1	
3.3.3	Yes (minor)	JKR/ IEM/ CIDB	3	
3.3.4	Yes (minor)	JKR/ IEM / MLA /CIDB		
3.3.5	No (new)	JKR/ MLA/ IEM		
3.4.1	Yes	JKR/ CIDB/ IEM/ SIRIM		3
3.4.2	Yes (little effort)	Related Stakeholders (BOMBA, Police stations, power transmission structures, etc)		1
3.4.3	No (new)	MOSTI/ MOHE/ IEM		
3.4.4	No (new)	CIDB/ MOSTI/ JKR/ MOHE		2
3.4.5	Yes (little effort)	IEM/ BEM/ MOHE		

Legend :

Ranking Scale – Scale 1 : Most Priority, Scale 5 : Least Priority
MLA – Ministry of Local Authority and Housing
MOHE – Ministry of Higher Education
JKR – Jabatan Kerja Raya Malaysia, Ministry of Works
MOSTI – Ministry of Science and Technology Innovation
IEM – Institution of Engineers Malaysia
BEM – Board of Engineers Malaysia
CIDB – Construction Industry Development Board

4.0 CONCLUSION

The IEM Position Paper Committee has outlined its recommendations to alleviate the concerns raised by the engineering profession and the general public in Malaysia, with regards to issues related to effects of earthquake on building structures. Useful general background information is also provided to educate and to inform the public on earthquake-related matters. It is hoped that the recommendations put forward herein are accepted by all stakeholders particularly the Government of Malaysia for further action as soon as possible, for the well-being and safety of the public at large.

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APPENDIX 1 : GEOLOGICAL BACKGROUND

1.0 Earthquakes occur when there is a sudden release of the energy stored in elastically strained rocks; this usually occurring along fault planes where there is relative movement of the blocks on either side. These displacements are mainly found along tectonic plate boundaries where there is intermittent movement of the plates past each other. Four main impacts are associated with earthquakes; the first being surface rupture which involves cracking or displacement of the ground surface and occurs when earthquakes have shallow foci (<30 km depth). When surface rupture occurs on the sea or ocean floor, tsunamis can be generated and represent the second hazard. The third hazard is ground shaking which refers to the vibrations or tremors felt at the ground surface during the passage of seismic waves which radiate out from the earthquake focus at the time of displacement. Changes to physical properties of subsurface earth materials during the passage of seismic waves also occurs and can give rise to ground failure (the fourth hazard) as liquefaction and landslides.

2.0 According to the theory of plate tectonics, the outermost layer of the earth or lithosphere is some 70 to 150 km thick and can be separated into seven large tectonic plates, as well as a number of smaller ones. The tectonic plates are all moving relative to one another and slide under, past, or away from, each other at convergent, transform, and divergent, plate boundaries respectively (Fig 2).

3.0 Peninsular Malaysia, located within the Eurasian tectonic plate, is considered to be an aseismic area; there being an absence of not only moderate to large magnitude, historical earthquakes but also geological and/or seismological evidence suggesting recent tectonic events (Gobbett & Tjia, 1972). Induced earthquakes of moderate magnitude (<5.5 Richter Scale) in the vicinity of the Kenyir Dam between 1984 and 1988, however, suggest that some parts of the Peninsula are not truly aseismic in nature (Shu, 1989; Raj, 1994).

4.0 The Peninsula is located close to a major convergent tectonic plate boundary off the west coast of Sumatra Island, where the Indo-Australian tectonic plate with oceanic crust is subducting beneath the Eurasian tectonic plate with continental crust. Along this subduction zone, earthquakes of small to large magnitudes (>9.0 Richter Scale) have, and will continue to be, generated with foci located along a broad zone that dips some 60^o towards the northeast. Extending throughout the western side of Sumatra Island furthermore, is the active right-lateral Sumatran Fault Zone, along which earthquakes of similar magnitudes are also generated (Sun & Pan, 1995).

5.0 Although several hundreds of earthquakes, including aftershocks, have occurred in, and close to, Sumatra Island, in the past decade, only some 46 events of ground shaking (Mercalli Intensity Scale <VI) have been reported in Peninsular Malaysia (Ramli, 1986, Lee, 1993). There have also been recent reports of subsidence and sinkholes in Perak State following large magnitude (>8.0) earthquakes on 26/12/2004 and 28/03/2005 off the west coast of Sumatra (Raj, 2005a. 2005b).

6.0 In Sabah and Sarawak, historical and instrumental seismicity records show the presence of several earthquake epicentres that reflect their present-day tectonic setting (Yjia, 1983). On-shore Sabah, the epicenters mark earthquakes of moderate magnitude (<6.0) that are mostly found in, and close to, the Dent and Semporna Peninsulas, where they demarcate a broad zone of mainly shallow foci between the Sulu Trench and Sulu Volcanic Arc (Lim, 1985). Further east, close to Philippines and Sulawesi, there are epicentres of several, moderate to large magnitude (>6.0) earthquakes that mark the complex tectonic setting where a number of micro-tectonic plates are being squeezed between two convergent boundaries. Epicenters in central and north Sabah mark shallow earthquakes that define an approximately north-northeast trending belt centered around Ranau, whilst epicenters in the Labuk Bay area appear to be related to major north to north-northeast trending faults. Epicenters in the South China Sea, to the west of Sabah and Sarawk, may represent renewed fault movements here, whilst other epicenters, particularly those in Sarawk, show no clear relationship with the tectonic setting (Lim, 1986; Raj, 1996).

7.0 In view of the tectonic setting, more than 50 cases of ground shaking (up to Mercalli Intensity Scale VIII) have been reported in Sabah, especially in the Ranau and Lahad Datu areas where surface rupture and ground failure has also occurred. Substantial damage to buildings has also been reported as on 26 July 1976 in the Tawau and Lahad Datu areas, and on 26 May 1991 in the Ranau area (Lim, 1977; Lim & Godwin, 1992). Along the northern and eastern coasts of Sabah, ground shaking can be also be attributed to seismic waves generated by earthquakes in the Celebes and Sulu Seas as well as in Sulawesi and the Phillipines, though there are no well documented reports of tsunami (Raj, 2005c).

Table 1: Mercalli Intensity Scale To Depict Severity of Ground Shaking (Association of Bay Area Governments, 2003)

Description of Shaking Severity		Summary Damage Description	Full Description
I.			Not felt. Marginal and long period effects of large earthquakes.
II.			Felt by persons at rest, on upper floors, or favorably placed.
III.			Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.
IV.			Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV, wooden walls and frame creak.
V.	Light	Pictures Move	Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.
VI.	Moderate	Objects Fall	Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken (visibly, or heard to rustle).
VII.	Strong	Nonstructural Damage	Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.

VIII.	Very Strong	Moderate Damage	Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
IX.	Violent	Heavy Damage	General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. (General damage to foundations.) Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluvial areas sand and mud ejected, earthquake fountains, sand craters.
X.	Very Violent	Extreme Damage	Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.
XI.			Rails bent greatly. Underground pipelines completely out of service.
XII.			Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

Masonry A: Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.
Masonry B: Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.
Masonry C: Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces.
Masonry D: Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

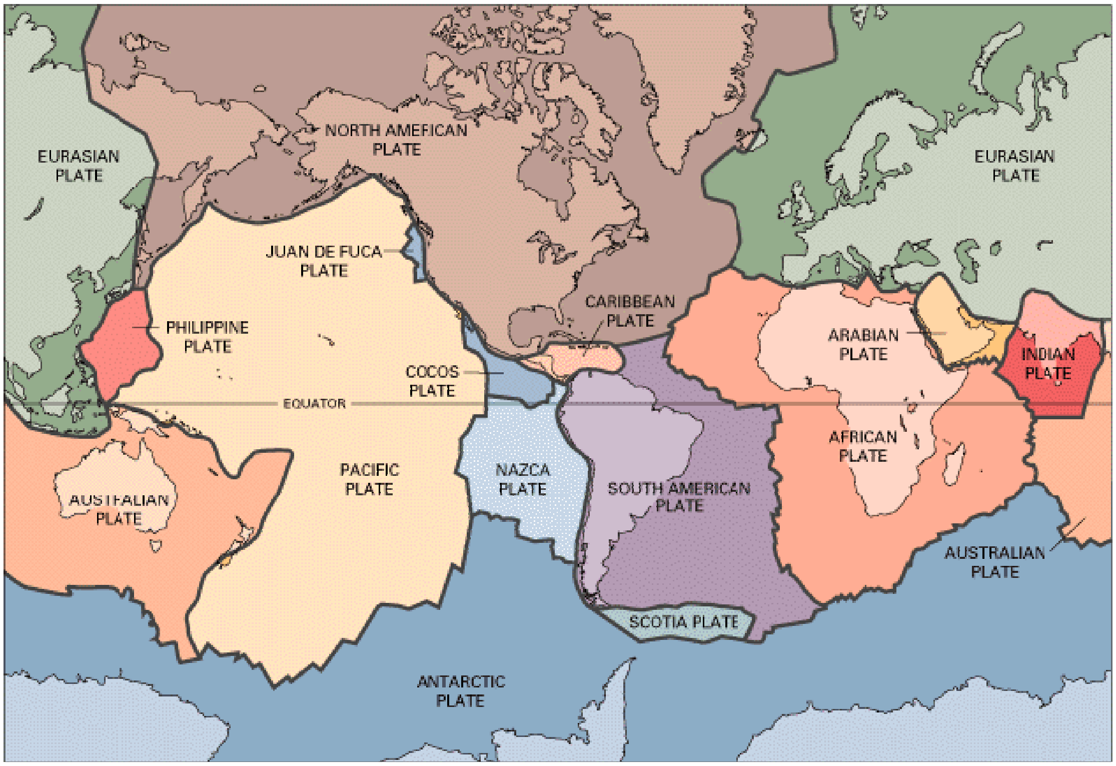

FIG. 1: MAJOR TECTONIC PLATES

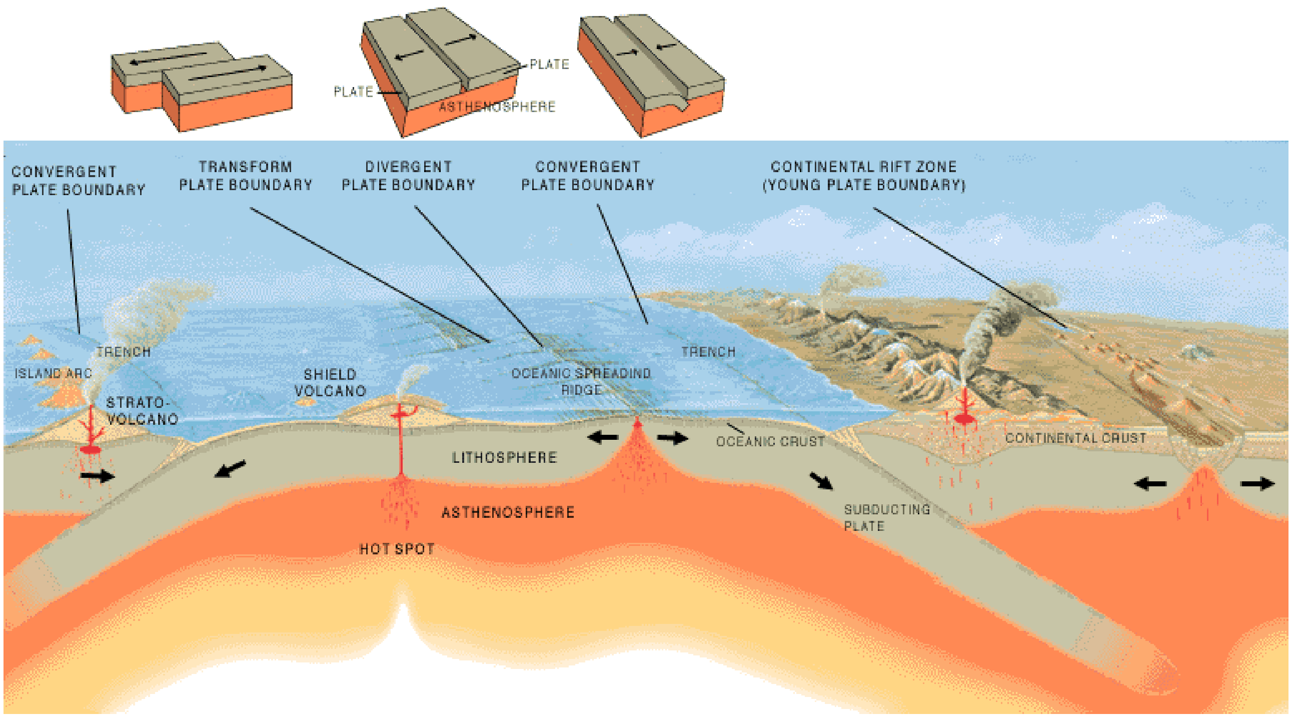

FIG. 2: TECTONIC PLATE BOUNDARIES

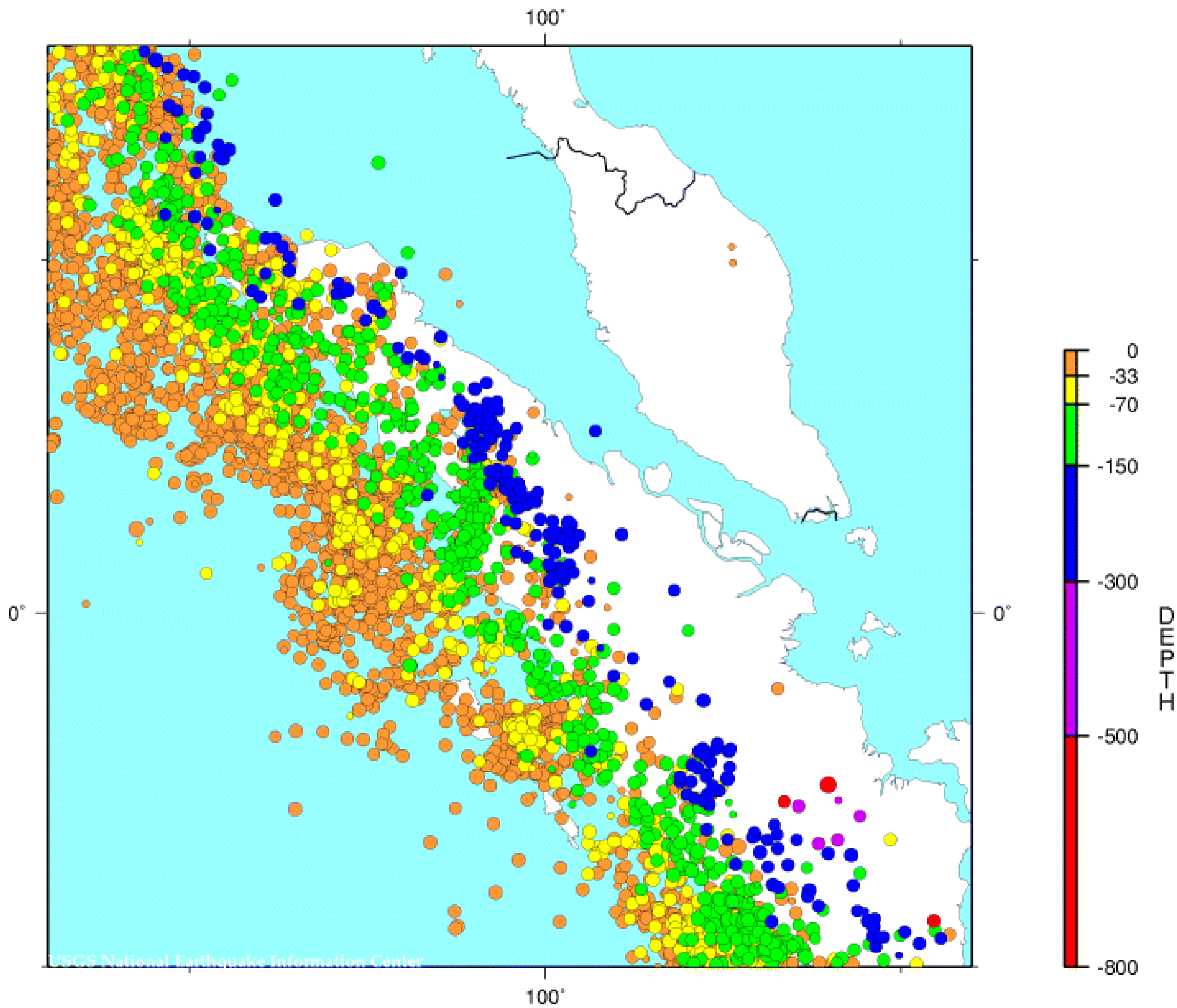

FIG. 3: EARTHQUAKE EPICENTRES (1973 - PRESENT)
http://neic.usgs.gov/

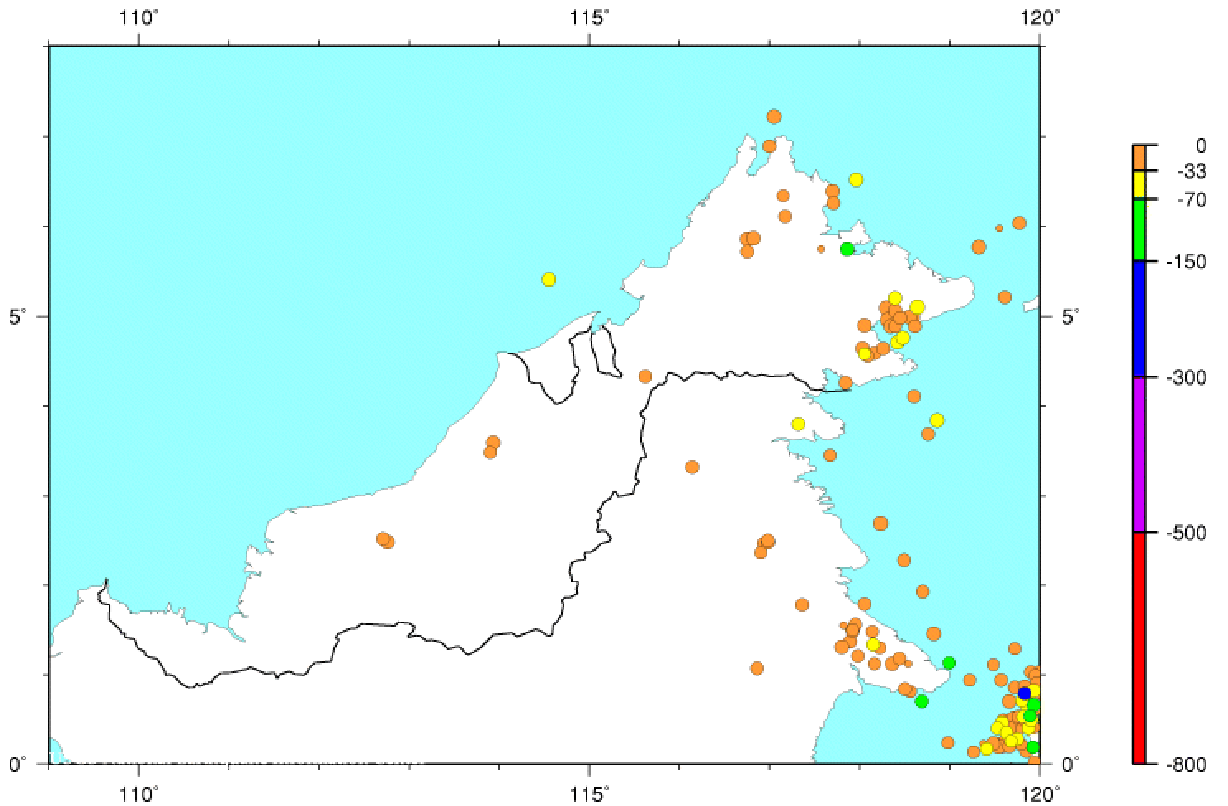

FIG. 4: EARTHQUAKE EPICENTRES (1973 - PRESENT)
http://neic.usgs.gov/