

# GC BRIEFING

*An update from Global Research & Development: Portfolio Management*

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## SPATIAL AND TEMPORAL EARTHQUAKE CLUSTERING: AN OVERVIEW OF EQECAT'S PERSPECTIVE

*The recent major earthquakes that have occurred in Chile (February 2010), New Zealand - Canterbury (September 2010), New Zealand - Christchurch (June 2011) and Tohoku (March 2011) have raised questions such as: Do earthquakes of major intensity cluster around the world? Have there been other, previous series of major earthquakes around the world? Are other major earthquakes more likely to occur in the very near future, if so where? These are all very challenging questions. This briefing begins to answer some of them.*

*This briefing presents a summary of the white paper recently released by EQECAT, Spatial and Temporal Earthquake Clustering: Part 1 – Global Earthquake Clustering. It is EQECAT's first paper about both spatial and temporal clustering of mega-thrust earthquakes (1). This briefing is presented for general interest and should not be viewed as an endorsement of EQECAT's views.*

*The paper reports that the statistics on giant earthquake occurrences show that the historical temporal clustering of these earthquakes on a global scale cannot be attributed to chance. However, the physical processes producing this global temporal clustering are unknown.*

*The paper indicates that, on a global scale, effects of giant earthquakes are likely transmitted over large distances through post-seismic relaxations and strain transfer mechanisms in the deep ductile layers of the Earth. The transmission happens in relatively short time intervals. On the other hand, global temporal earthquake clustering appears not to be related to shallow co-seismic effects of elastic earth properties associated with near-field and far-field stress models.*

*If the current earthquake cycle of mega-thrust earthquakes, which started in 2004 with the December 24, 2004 9.1 Mw Andaman-Nicobar (Sumatra) earthquake, follows the one that occurred between 1950 and 1965, then we may expect that the cycle is only half complete. The largest earthquake in the current cluster has yet to occur.*

## Summary

Table 1 chronologically lists the world's largest mega-thrust events with magnitudes greater than 8.5 Mw, according to the U.S. Geological Survey (USGS).

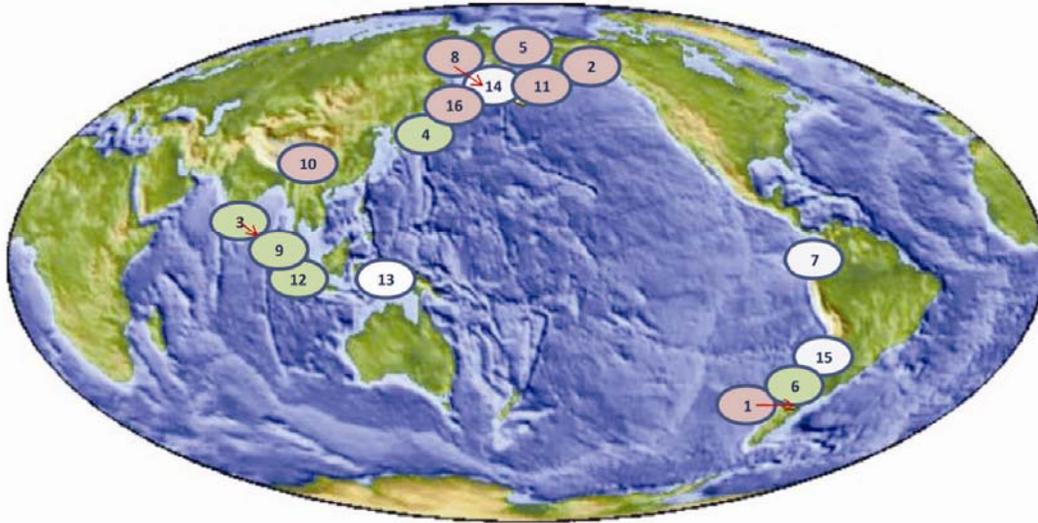
**TABLE 1: THE WORLD'S LARGEST EARTHQUAKES SINCE 1900 (≥8.5 Mw)**

USGS_ID	Year	Magnitude	Earthquake	Region
7	1906	8.8 Mw	Ecuador	
15	1922	8.5 Mw	Chile-Argentina Border	
14	1923	8.5 Mw	Kamchatka	
13	1938	8.5 Mw	Banda Sea	Indonesia
10	1950	8.6 Mw	Assam	Tibet
5	1952	9.0 Mw	Kamchatka	
11	1957	8.6 Mw	Andreanof Islands	Alaska
1	1960	9.5 Mw	Chile	Chile
16	1963	8.5 Mw	Kuril Islands	
2	1964	9.2 Mw	Prince William Sound	Alaska
8	1965	8.7 Mw	Rat Island	Alaska
3	2004	9.1 Mw	Sumatra	Indonesia
9	2005	8.6 Mw	Sumatra	Indonesia
12	2007	8.5 Mw	Sumatra	Indonesia
6	2010	8.8 Mw	Chile	Chile
4	2011	9.0 Mw	Honshu	Japan

Source: USGS, Guy Carpenter & Company, LLC

The locations of these earthquakes are shown in Figure 1 (Page 3) by using the USGS identification number assigned to each earthquake in the table. The colors indicate different time periods of occurrence.

**FIGURE 1: LOCATIONS OF THE WORLD'S LARGEST EARTHQUAKES SINCE 1900 ALONG THE PACIFIC RING OF FIRE (USGS)**



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Source: USGS, Guy Carpenter & Company, LLC

## Mega-thrust Earthquakes

The December 24, 2004 Andaman-Nicobar (Sumatra) earthquake/tsunami has been referred to as the first “global” earthquake. The label is appropriate in terms of the number of lives lost, the number of countries affected and the global effort required for recovery. The moment magnitude 9.1 Mw earthquake and its tsunami caused the death of approximately 280,000 people. This earthquake was the largest to occur worldwide in 40 years.

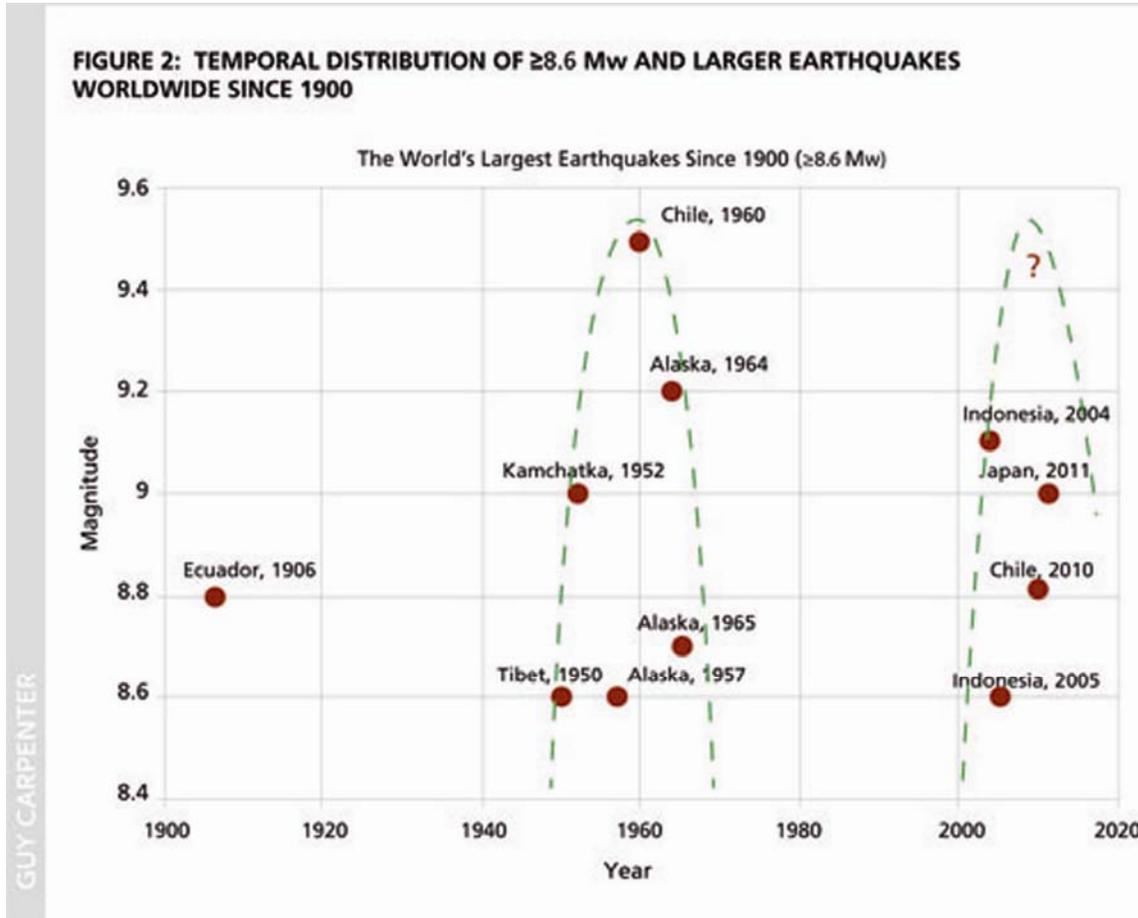
The previous earthquake of similar magnitude was the 9.0 Mw Good Friday, Alaska earthquake of March 27, 1964. Both of these earthquakes are members of a class of “giant” earthquakes, which are only those earthquakes with magnitudes 9.0 Mw and greater.

On a worldwide scale, while earthquakes on the order of 8.0 Mw occur on average once per year, giant earthquakes of 9.0 Mw and greater occur far less frequently.

The Andaman-Nicobar earthquake was only the fourth giant earthquake to be recorded since 1900. The probability of such an earthquake occurring in any given year is about 4.6 percent, or about once every 22 years.

## Temporal Global Earthquake Clustering

Figure 2 shows the temporal chart of the mega-thrust earthquakes since 1900. The data show dramatic spikes in the global occurrence of these earthquakes. Clusters are schematically indicated by the green dashed curves.



Source: Bufe, C.G., and D.M. Perkins (2005). "Evidence for a Global Seismic-Moment Release Sequence", *Bulletin of the Seismological Society of America*, Vol. 95, pp. 833-843.

The 1964 Alaska earthquake was the last giant earthquake in a cluster of three that began in 1952 with the 9.0 Mw mega-thrust earthquake off the Kamchatka Peninsula, Russia in the northwestern Pacific Ocean. The second earthquake in this sequence was the 9.5 Mw Valdivia, Chile earthquake, which is the largest earthquake ever recorded by modern seismograph networks.

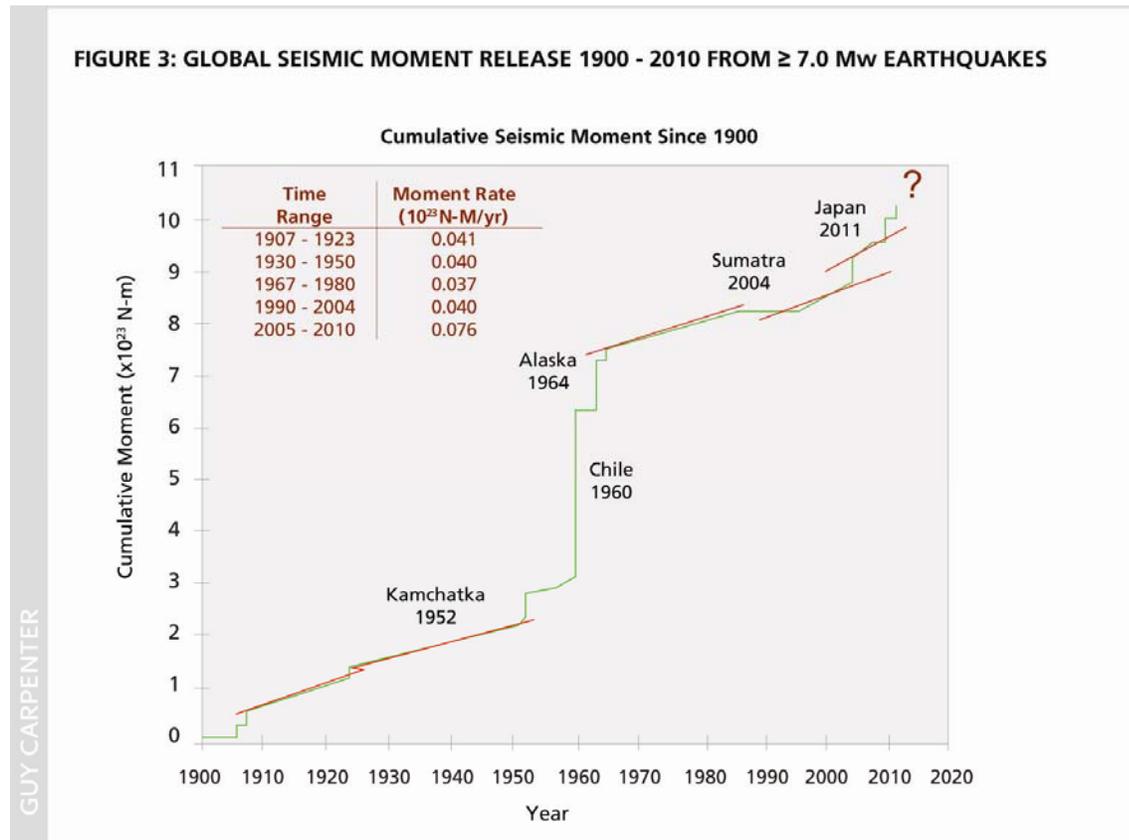
There is not enough knowledge to fully understand the global effects and physical connectedness of megathrust earthquakes. While classical seismological models based on elastic Earth properties have been developed and applied very successfully to model local and regional seismic sources, these models breakdown at global scales due to the immense distances involved.

Nonetheless, empirical evidence over the last seven years suggests that rare, giant earthquakes of magnitude near 9.0 Mw and greater may cluster temporally over time periods of perhaps 15 years. The low annual probability of these earthquakes of 4.6 percent per year makes it highly unlikely that the temporal clustering occurs on a random basis.

Since the 2004 9.1 Mw Andaman-Nicobar (Sumatra) earthquake, both the 8.8 Mw Maule, Chile and 9.0 Mw Tohoku-oki, Japan earthquakes have occurred over a short time span of seven years.

Formal statistical analyses have shown the time period between 1952 and 1964 as being highly significant in the context of global earthquake occurrence. The 15-year time interval between the years 1950 and 1965 contains seven of the nine greatest earthquakes occurring before 2005. That is also statistically significant with only a 0.5 percent chance of being a random occurrence. Other random simulation tests suggest that the outbreak of giant earthquakes between 1950 and the mid-1960's, and the 36-year period of global quiescence that followed, were highly unusual, and not easily relegated to chance.

The clustered periods of mega-thrust earthquakes stand out even more if the magnitudes of the earthquakes are transformed into seismic moment and accumulated since 1900 as shown in Figure 3.



Source: Ammon, C.J., T. Lay, D.W. Simpson (2010). "Great Earthquakes and Global Seismic Networks", *Seismological Society of America*, Vol. 81, pp. 965-971., Update by Paul C. Thenhaus, Kenneth W. Campbell and Dr. Mahmoud M. Khater

It is easy to see that the huge increases in global seismic moment release correspond to the periods containing the clustered occurrence of giant earthquakes.

Recent research shows that deep seismic tremor activity is triggered on some fault zones by the wave passage effect. The deep tremor activity persists long after the surface waves have passed. Over time, the resulting deep stresses can propagate up-dip to shallow fault levels which would serve to trigger shallow large earthquakes.

The most viable mechanism may be post-seismic viscoelastic strains that develop in the deep ductile layers of the Earth, for example, the asthenosphere. These very deep layers react slowly to induced strains but are capable of transmitting stresses over long distances during time periods of years to decades and can influence regional tectonic stressing rates. More speculatively, perhaps, global strains generated by oscillations of the Earth caused by these giant earthquakes serve to stress other large faults that are critically stressed in other regions of the world. It is possible that more than one mechanism is responsible for the observed global correlation among giant earthquakes.

**Note:**

1. Paul C. Thenhaus, Kenneth W. Campbell and Dr. Mahmoud M. Khater, "Spatial and Temporal Earthquake Clustering: Part 1 – Global Earthquake Clustering," EQECAT, October 14, 2011. <http://www.eqecat.com/pdfs/global-earthquake-clustering-whitepaper-part-1-2011-10.pdf>

Should you have any questions, please contact any member of the Global Research & Development: Portfolio Management team listed below.

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