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Subduction zone geometry: a mega-earthquake risk indicator

Mega-earthquakes (with a magnitude greater than 8.5) mainly occur on subduction faults where one tectonic plate passes under another. But the probability of such earthquakes does not appear to be even across these zones. In a study published on 25 November 2016 in the journal *Science,* researchers from the University of Oregon and Géoazur laboratory (*CNRS/Université Nice Sophia Antipolis/Observatoire de la Côte d'Azur/IRD*) show that mega-earthquakes mostly occur on the flattest subduction zones. Thus, the Philippines, Salomon Islands and Vanuatu areas would not be favorable to mega-earthquakes, unlike South America, Indonesia and Japan. The discovery of this new indicator should improve earthquake monitoring and seismic and tsunami risk prevention.

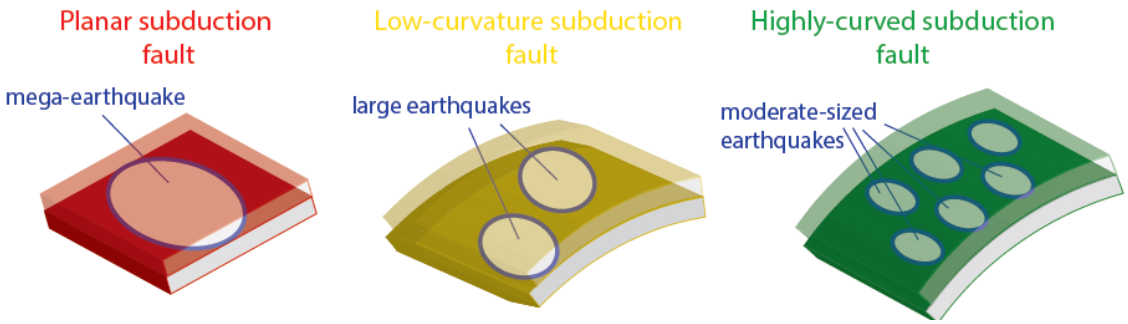
At the point where two tectonic plates converge, an area known as the subduction zone can form where one of the plates passes on top of the other. Rocks do not slide over one another easily and the movement of tectonic plates can be blocked along the entire length of such interaction zones for periods exceeding a thousand years. This 'slip deficit' results in an accumulation of energy, which is released abruptly during earthquakes.

A theory that held sway for many years suggested that mega-earthquakes mostly occurred in subduction zones where plates converged rapidly and those where the subducting plate was relatively young. However, the mega-earthquakes of Sumatra-Andaman in 2004 and Tohoku-Oki in 2011, which generated deadly tsunamis, go against this theory: in the first case, the speed of plate movement is relatively slow (3 to 4 cm per year) and in the second, the Pacific plate that subducts under Japan is more than 120 million years old. A new question therefore arose: can all subduction zones generate mega-earthquakes?

In this new study, the researchers examined another parameter: subduction zone geometry. By comparing the degree of curvature of the subducting plates in great historical earthquakes, they discovered that the maximum magnitude of earthquakes recorded in each subduction zone was inversely proportional to the degree of curvature of the fault. In other words, the flatter the contact between the two plates, the more likely it is that mega-earthquakes will occur.

Earthquakes take place once the energy accumulated as a result of the slip deficit exceeds a certain threshold. The researchers showed that the greater the curvature of the subduction fault, the more this threshold varies along the subduction zone. A heterogeneous threshold produces more frequent earthquakes, but these affect a smaller spatial area and are therefore of lower magnitude. In contrast, a homogeneous rupture threshold over a large portion of a fault has a greater chance of resulting in a simultaneous rupture of the whole blocked zone and, consequently, a greater chance of generating a mega-earthquake.

As a consequence, subduction zones such as the Philippines, Salomon Islands or Vanuatu do not appear likely to generate mega-earthquakes. Others, however, such as Peru, Java or Mexico, which have not seen very large earthquakes over the last 200-300 years, appear to have all the necessary characteristics for a mega-earthquake in the future.



When a subduction plate is flat (left), the rupture threshold is reached simultaneously over the whole zone, which can start mega-earthquakes. On the contrary, when the subduction plate is highly curved, the threshold is more heterogeneous, leading to more frequent, but more moderate, earthquakes.

Picture credit: Quentin Bletery

Bibliography

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Contacts

CNRS Researcher I Anthony Sladen I **Tel: +33 (0)4 83 61 86 86** I sladen@geoazur.unice.fr
Researcher I Quentin Bletery I **Tel: +1 541 968 9190** I qbletery@uoregon.edu (Time difference: Paris -9h)
CNRS Press Officer I Véronique Etienne I **Tel: +33 (0)1 44 96 51 37** I veronique.etienne@cnrs-dir.fr