Asperities

Background page to accompany the animations on the website: IRIS Animations

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Introduction

What is an asperity?

An asperity (is an area on a fault that is stuck or locked. In the Earth, tectonic earthquakes are caused by slip along a fault plane, where two rock bodies are in rigid contact. The friction along the fault plane is not uniform in strength, so overall movement involves slip on one or more asperities, or "stuck patches" where the friction is highest. Most of the energy that is released by earthquakes comes from the patches that become "unstuck."

More About Asperities*

Total fault offset accumulates through time in an uneven fashion, primarily by movement on first one, and then another section of the fault. The portions of the fault that produce great earthquakes can remain "locked" and quiet for one hundred or more years, while the strain is building up; then, in great lurches, the strain is released, producing a great earthquake.

Asperities, which may be caused by roughness, or protrusions on the fault, act like welded contacts between the sides of the fault. Younger faults have rougher surfaces with more asperities. As a fault repeatedly ruptures, the asperities can be worn down, creating fault gouge and smoothing the fault. The gouge material often decomposes to a fine clay and forms a thin layer which "greases" the fault for easier sliding. Fluids can also facilitate slip by reducing the normal stress on the fault.

The San Andreas Fault is actually a fault system that is more than 800 miles long and the seismically active portion extends to depths of at least 10 miles within the Earth and ranges from a few hundred feet to a mile or more wide. It doesn't slip all at once, but rather, earthquakes jump around on it as local asperities break. On some stretches of some faults, however, such as around Hollister on the Calaveras fault, date movement occurs primarily by constant repeated creep events rather than by sudden earthquake offsets. In historical times, these creeping sections have not generated earthquakes of the magnitude seen on "locked" sections.

The dynamics of fault rupture are complex, but general fault behavior can be explained with a simple model in which slip promotes fault weakening.

Fault slip occurs in three stages:

1) initiation of sliding on a small portion of the fault,
2) growth of the slip surface, and
3) termination of slip and fault healing. Earthquakes occur on preexisting faults operating in a "stick- slip" mode. Earthquakes are "slip" episodes; they are followed by periods of no slip ("stick"), during which elastic strain increases away from the fault. Although some growth of the fault may occur with each earthquake, we can generally assume that for large earthquakes (M>6) the faulting process primarily involves repeated breaking of the same fault segment rather than creation of a new fault surface."

Asperity Quakes Compared to Chopstick Breaks

Most earthquakes happen on faults. The process that causes them is similar to what happens if you bend a chopstick until it breaks.

Comparing the multiple asperities along a fault zone with the multiple failures of a bamboo chopstick:

Regional compression and extension are acting on the "fault zone" (plate tectonics is acting on fault zones; hands are acting on the chopstick)

There is a build-up of stress (hold the tips of the chopstick with the tips of your fingers and feel the stress build up as elastic energy is stored in the chopstick). If you release the energy before the chopstick breaks, it will return to its pre-stressed shape.

Knowledge of the rate of strain buildup allows one to "forecast" that it (the chopstick or the fault) will break. But it is difficult to predict the time and place where it will breaks next.

The weakest zones will break first.

One may hear some precursors (weakest asperities breaking).

There is elastic deformation and brittle failure.

There is elastic rebound as the stored energy in the deformed material is released, the material rebounds to its previous shape.

Sound waves generated by the breaking chopstick can be compared to the compressive seismic waves (P waves) of an earthquake.

Bottom line: Tectonic earthquakes will occur anywhere within the earth where there is sufficient stored elastic strain energy to drive fracture propagation along a fault plane. Most boundaries do have such asperities and this leads to a form of stick-slip behaviour. Once the boundary has locked, continued relative motion between the plates leads to increasing stress and therefore, stored strain energy in the volume around the fault surface. This continues until the stress has risen sufficiently to break through the asperity, suddenly allowing sliding over the locked portion of the fault, releasing the stored energy. This energy is released as a combination of radiated elastic strain seismic waves, frictional heating of the fault surface, and cracking of the rock, thus causing an earthquake.

*From "Can Earthquakes be Predicted?" by Michelle Kathleen Hall-Wallace

Vocabulary

Asperity—literally "roughness. It is an area on a fault that is stuck or locked. A type of surface roughness appearing along the interface of two faults. Physics the elastically compressed region of contact between two surfaces caused by the normal force

Elastic strain—Earthquakes are caused by the sudden release of energy within some limited region of the rocks of the Earth. The energy can be released by elastic strain, gravity, chemical reactions, or even the motion of massive bodies. Of all these the release of elastic strain is the most important cause, because this form of energy is the only kind...

Fault plane—The plane along which the break or shear of a fault occurs. It is a plane of differential movement, that can be vertical as in a strike slip fault or inclined like a subduction zone fault.

Fault zone—Since faults do not usually consist of a single, clean fracture, the term fault zone is used when referring to the zone of complex deformation that is associated with the fault plane.

Strain—Strain is defined as the amount of deformation an object experiences compared to its original size and shape. For example, if a block 10 cm on a side is deformed so that it becomes 9 cm long, the strain is (10-9)/10 or 0.1 (sometimes expressed in percent, in this case 10 percent.) Note that strain is dimensionless.
Learn more: **http://www.uwgb.edu/DutchS/structge/stress.htm**

.**Stress**—Stress is defined as force per unit area. It has the same units as pressure, and in fact pressure is one special variety of stress. However, stress is a much more complex quantity than pressure because it varies both with direction and with the surface it acts on.
Learn more: **http://www.uwgb.edu/DutchS/structge/stress.htm**

Tectonic earthquake—an earthquake that is due to the movement of the tectonic plates. Tectonic earthquakes will occur anywhere within the earth where there is sufficient stored elastic strain energy to drive fracture propagation along a fault plane. Other earthquakes can be caused by blasts.