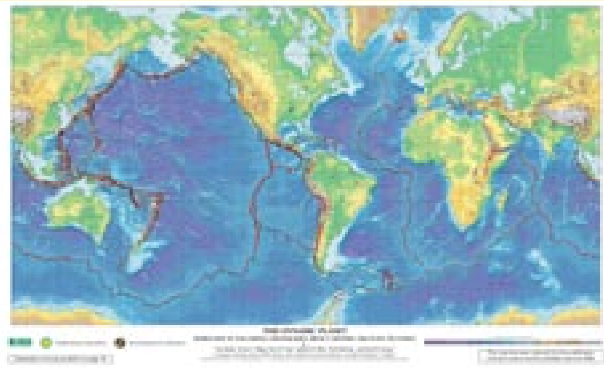
This Dynamic Planet

The following pages are a special poster pullout featuring the front of the USGS map, "This Dynamic Planet."

About "This Dynamic Planet"



This map shows many of the features that have shaped — and continue to change — our dynamic planet. Most new crust forms at ocean ridge crests, is carried slowly away by plate movement, and is ultimately recycled deep into the earth — causing earthquakes and volcanism along the boundaries between moving tectonic plates. Oceans are continually opening (for example, Red Sea, Atlantic) or closing (for example, Mediterranean). Because continental crust is thicker and less dense than thinner younger oceanic crust, most does not sink deep enough to be recycled and remains largely preserved on land. Consequently, most continental bedrock is far older than the oldest oceanic bedrock.

The earthquakes and volcanoes that mark plate boundaries are clearly shown on this map, as are craters made by impacts of extraterrestrial objects that punctuate Earth's history, causing some catastrophic ecological change. Over geologic time, continuing plate movements, together with relentless erosion and redeposition of material, mask or obliterate traces of earlier plate-tectonic or impact processes, making the older chapters of Earth's 4,500-million-year history increasingly difficult to read. The recent activity shown on this map provides only a present-day snapshot of Earth's long history, helping to illustrate how its present surface came to be.

The map is designed to show the most prominent features when viewed from a distance, and more detailed features upon closer inspection. The back of the actual "This Dynamic Planet" map zooms in further, highlighting examples of fundamental features, while providing text, timelines, references and other resources to enhance understanding of this dynamic planet. Both the front and back of the map illustrate the enormous recent growth in our knowledge of planet Earth. Yet, much remains unknown, particularly about he processes operating below the ever-shifting plates and the detailed geological history during all but the most recent stage of Earth's development.

The complete and full-sized version of "This Dynamic Planet" will be available from the USGS in the summer of 2006.

Legend

Volcanoes — Data from Global Volcanism Program, Smithsonian Institution, Washington, D.C.; accessed at http://www.volcano.si.edu/world/summary.cfm, March 16, 2005

- Erupted A.D. 1900 through 2003
- Erupted A.D. 1 through 1899
- Erupted in Holocene time (Paste 10,000 years), but no known eruptions since A.D. 1
- Uncertain Holocene activity and fumarolic activity

Impact Craters — Data from University of New Brunswick, Planetary and Space Science Centre, Earth Impact Database; accessed at http://www.unb.ca/passc/ImpactDatabase/. October 23, 2003 (also see Grieve, 1998). Geologic age span: 50 years to 2,400 million years. Crater diameter indicated below

- <10km
- 10 to 70 km
- >70 km (shown at actual map scale)

Notable Events — Numbers next to a few symbols — of many thousands shown — denote especially noteworthy events, keyed to correspondingly numbered entries in tables found on the back of the map. These numbered events have produced devastating natural disasters, advanced scientific understanding or piqued popular interest. They remind us that the map's small symbols may represent large and geologically significant events.

- 5 Volcanoes
- 9 Earthquakes
- 25 Impact craters

Plate Tectonics

Divergent (sea-floor spreading) and transform fault boundaries — Red lines mark spreading centers where most of the world's volcanism takes place; thickness of lines indicates divergence create, in four velocity ranges. White number is speed in millimeters per year (mm/yr) from DeMets and others (1994). The four spreading-rate ranges are <30 mm/yr; 30-59 mm/yr; 60-90 mm/yr; and >90 mm/yr. Thin black line marks the plate boundary, whether sea-floor spreading center or transform fault. On land, divergent boundaries are commonly diffuse zones; therefore, most are not shown. The only transform faults shown on land are those separating named plates.

Plate motion — Data from Rice University Global Tectonics Group. Length of arrows is proportional to plate velocity, in millimeters per year. These approximate rates and directions are calculated from angular velocities with respect to hotspots, assumed to be relatively fixed in the mantle (see plate motion calculator at http://tectonics.rice.edu/hs3.html).

Plate convergence — More accurately known than "absolute" plate motion, convergence data are shown by arrows of uniform length showing direction and speed, in millimeters per year relative to the plate across the boundary. Data from Charles DeMets (University of Wisconsin at Madison, written commun., 2003) and Bird 2003)

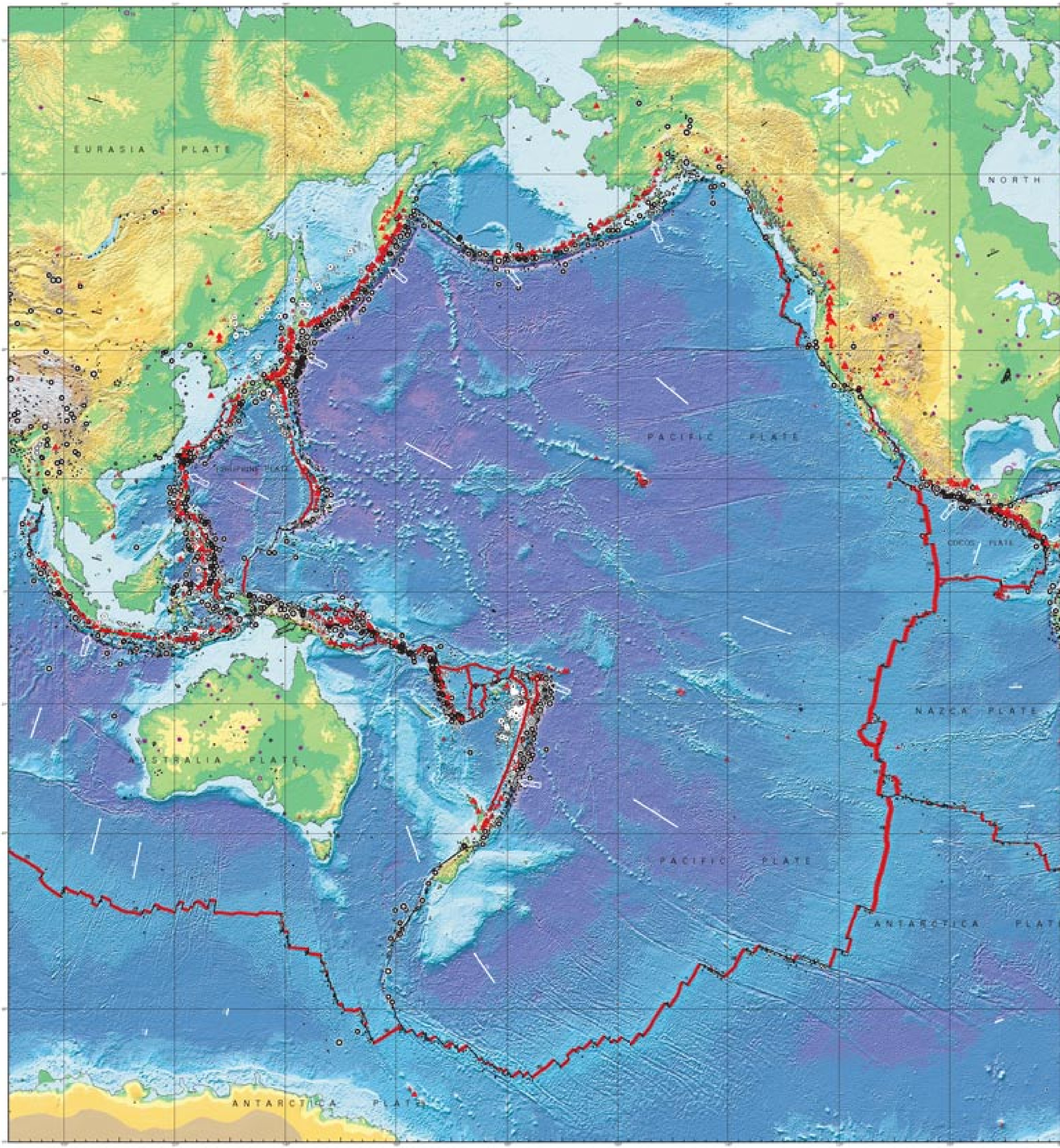
Earthquakes — Data from Engdahl and Villaseñor (2002). From 1900 through 1963, the data are complete for all earthquakes >6.5 magnitude; from 1964 through 1999, the data are complete for all earthquakes >5.0 magnitude. Most location uncertainties <35 km. Eleven more recent major or great earthquakes (magnitude >7.7) have been added for completeness through 2004; data from USGS National Earthquake Information Center at http://neic.usgs.gov/, accessed January 4, 2005. An epicenter is the surface location of the first rupture on an earthquake fault. Symbols shown represent epicenters. For earthquakes larger than about magnitude 7.0, the size of the rupture zone, which can extend hundreds of kilometers from the epicenter, is larger than the symbols used on this map

Depth to earthquake, in km	Magnitude of earthquake			
	5.0–5.9	6.0–6.9	7.0–7.9	≥8.0
<60	•	•	○	○
60–300	•	•	○	○
>300	○	○	○	○
Global average occurrence[1]	1319/yr	134/yr	17/yr	1/yr

[1]Earthquakes of magnitude <5 (not shown on map) are much more frequent, with ~13,000/yr in the 4.0–4.9 range alone. Data from USGS National Earthquake Information Center.

Earthquakes that occurred from 1750 to 1963 within stable plate interiors on continents — Data from A.C. Johnston (Center for Earthquake Research and Information, University of Memphis, written, commun., 2002). Even though these epicenters do not meet the precise location criteria of Engdahl and Villaseñor (2002), they are plotted here to remind readers of the potentially hazardous earthquakes that are distant from known plate boundaries. Size of symbol proportional to earthquake magnitude

Notable pre-1900 earthquakes — Nos. 1,2,3,6 and 7



Smithsonian Institution

Naval Research Laboratory

THIS DYNAM

WORLD MAP OF VOLCANOES, EARTHQUAKES

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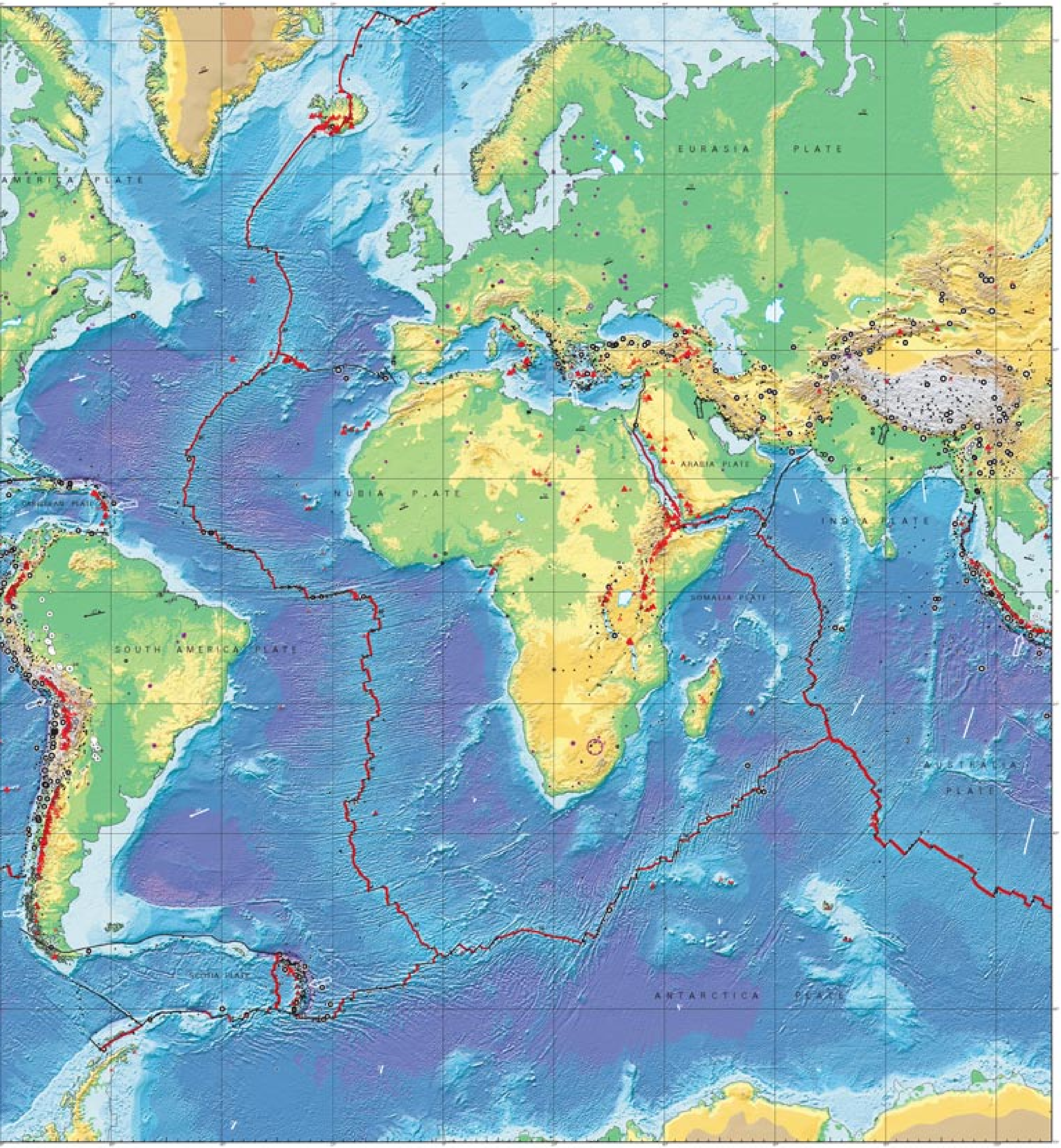
Explanation of map symbols on page 17.



MIC PLANET

S, IMPACT CRATERS, AND PLATE TECTONICS

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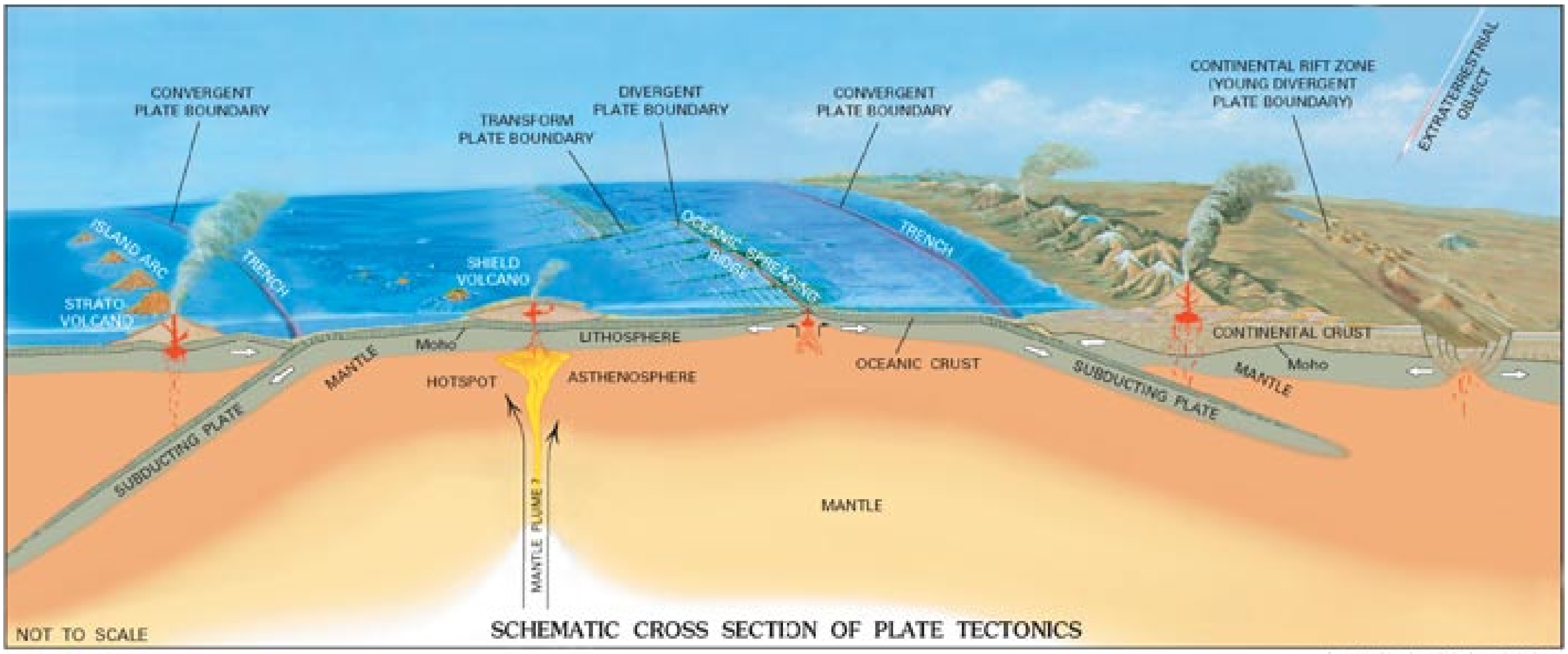
This map has been reduced for this publication.
Full size version will be available summer 2006.



José F. Vigil and Robert I. Tilling

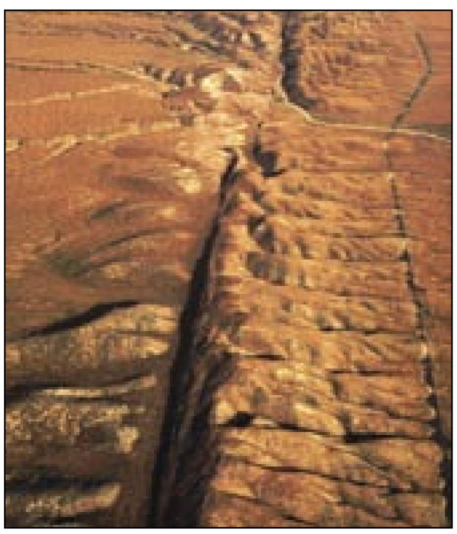
Earthquake Basics

The Fundamentals and Terminology of Earthquake Science

An **earthquake** is a sudden movement of the Earth's crust caused by the abrupt release of pressure that has accumulated over a long time. The energy it releases can be generated by a sudden dislocation of segments of the crust; by a volcanic eruption; or by human activities, such as mining, oil extraction and filling reservoirs. Most destructive earthquakes are caused by dislocations of the crust. The crust may first bend, and then, when the stress exceeds the strength of the rocks, break and "snap" to a new position.

The Earth is formed of several distinct layers that have very different physical and chemical properties. The outer layer, which averages about 22 miles in thickness, consists of about a dozen large, irregularly shaped, brittle **plates** on top of a pliable inner layer. These plates are constantly moving, their edges sliding over, under, away from or past each other. Most earthquakes occur at the boundaries where the plates meet.

All earthquakes occur along faults, which reflect zones of weakness in the Earth's crust. A **fault** is a fracture in the Earth's crust where two blocks of the crust have slipped with respect to each other. Even if a fault zone has recently experienced an earthquake, there is no guarantee that all the pressure has been relieved. Another earthquake could still occur within a short period of time. Many of the most active faults are deep within the crust and are not visible at the surface, especially where the plates are colliding with each other.



Aerial view of the San Andreas Fault slicing through the Carrizo Plain in the Temblor Range east of the city of San Luis Obispo, Calif. Photo: Robert E. Wallace.

The **hypocenter** of an earthquake is the location beneath the surface where the rupture of the fault begins. The **epicenter** of an earthquake is the location directly above the hypocenter on the surface of the Earth. The **focal depth** of an earthquake is the depth from the Earth's surface to the hypocenter. The location of an earthquake is commonly described by the geographic position of its epicenter and by its focal depth.

Measuring Earthquakes

When an earthquake occurs, vibrations called **seismic waves** are generated. These waves travel outward from the source of the earthquake along the surface and through the Earth at varying speeds depending on the material through which they move. The vibrations produced by earthquakes are detected, recorded and measured by instruments called **seismographs**. By responding to the motion of the ground surface beneath it, a seismograph creates a zigzag line called a **seismogram** that reflects the changing intensity of the vibrations. From the data expressed in seismograms, scientists can estimate how much energy was released and determine the time, the hypocenter and the type of faulting of an earthquake.

Magnitude verses Intensity

The severity of an earthquake can be expressed in several ways. The **magnitude** of an earthquake describes its size. Most magnitude computation procedures (sometimes referred to as the **Richter scale**) measure the amplitude of various seismic waves. The **moment magnitude** is a measure of the physical dimensions of the zone that ruptured in the earthquake (i.e., the area of the fault that ruptured) times the amount of offset, and that too can be estimated from data processed by modern seismographs. [See "Measuring Magnitude" page 25.]

In general, each earthquake has one preferred magnitude, but each person who feels or observes a quake can describe its intensity at their location. The **intensity** is an observation of how strongly a shock was felt at a particular location.

To quantify the effect or intensity of an earthquake, scientists use the **Modified Mercalli Intensity Scale**. While magnitudes are expressed as Arabic numbers and in theory have no upper or lower limits, intensity is expressed in Roman numerals I-XII. Evaluation of earthquake intensity can be made only after eyewitness reports and results of field investigations are studied and interpreted. (Was it barely felt, did it knock dishes off shelves, destroy poorly constructed buildings or destroy almost all buildings?)

Although magnitude is an important factor in the effect of an earthquake, earthquakes of large magnitude do not necessarily cause the most intense surface effects. An earthquake's destructiveness depends on many factors: magnitude, focal depth and local geologic conditions, as well as the distance from the epicenter, the population density, and the design and construction types of buildings and other structures. The combination of these factors is often what determines the difference between slight damage and catastrophe.

Compiled by Steve Vandas with assistance from Diane Noserale. Much of the information was obtained from the USGS publication "Earthquakes" by Kaye M. Shedlock and Louis C. Pakiser.