EARTHQUAKE PARAMETERS INCLUDING STRONG EARTHQUAKES

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Summary

The main parameters of an earthquake source are introduced. In addition, the problem of locating earthquake zones is discussed, different magnitude scales are represented and the seismic source model known as Earthquake Focal Mechanism is presented. Common publications of seismic data such as bulletins and catalogues are considered as comprehensive sources of information.

Special attention is given to design parameters destined for use in engineering applications and in anti-seismic protection. The perspectives of seismic parameterization are outlined.

1. Introduction

For earthquake information to be useable for scientists and engineers it needs to be expressed in the form of specific physical parameters. The main parameters of earthquake source are the location of focus, origin time and magnitude of an earthquake, whose waves arrive at the times measured on each seismogram. These and other parameters of an earthquake can be determined from the wave data recorded by seismograph stations. The point of origin of an earthquake is called its focus or hypocenter. The hypocenter of an earthquake is the point on a fault where an earthquake starts. Epicenter is the point on the Earth's surface above the hypocenter. The first arrivals of seismic waves are used to determine earthquake location. The coordinates of the epicenter are given in units of latitude and longitude. The latitude is the number of degrees north (N) or south (S) of the equator and varies from 0 at the equator to 90 at the poles. The longitude is the number of degrees east (E) or west (W) of the prime meridian which runs through Greenwich, England. The longitude varies from 0 at Greenwich to 180 and E or W shows the direction from Greenwich.

2. Locating an Earthquake

Phase readings and preliminary earthquake locations are provided by operators of seismic stations, national networks, and other agencies preparing seismic bulletins. When data from more than one observatory are available, an earthquake's epicenter may be estimated from the epicentral distances indicated by the times of travel of the P and S waves from source to recorders in a minimum of three locations. Once an earthquake's distance from several stations is known, the quake's focus may be determined.

The depth of earthquake focus is measured relative to sea-level or the mean elevation of the seismic stations which provided primary data for the earthquake location. The most obvious indication on a seismogram that a large earthquake has a deep focus is the small amplitude, or height, of the recorded surface waves and the uncomplicated character of the P and S waves. Although the surface-wave pattern does generally indicate that an earthquake is either shallow or may have some depth, the most accurate method of determining the focal depth of an earthquake is to read a depth phase recorded on the seismogram. The depth phase is the characteristic phase pP-a P wave reflected from the surface of the Earth at a point relatively near the hypocenter. At distant seismograph stations, the pP follows the P wave by a time interval that changes slowly with distance but rapidly with depth. This time interval, pP-P (pP minus P), is used to compute depth-of-focus tables. Using the time difference of pP-P as read from the seismogram and the distance between the epicenter and the seismograph station, the depth of the earthquake can be determined from published travel-time curves or depth tables.

Another seismic wave used to determine focal depth is the sP phase—an S wave reflected as a P wave from the Earth's surface at a point near the epicenter. This wave is recorded after the pP by about one-half of the pP-P time interval. The depth of an earthquake can be determined from the sP phase in the same manner as the pP phase by using the appropriate travel-time curves or depth tables for sP.

3. Earthquake Magnitude and Intensity

Charles F. Richter, an American seismologist, introduced in the 1930's the concept of earthquake magnitude. His original definition held only for California earthquakes occurring within 600 km of a particular type of seismograph. His basic idea was ranking empirically of the earthquake's inherent size or magnitude by using the distance from a seismograph to an earthquake and observing the maximum signal amplitude recorded on the seismograph. Originally the Richter Scale could be applied only to the records from the Woods-Anderson instruments. Presently, instruments are carefully calibrated with respect to each other. Thus, Richter's magnitude scale was then extended to observations of earthquakes of any distance and of focal depths ranging between 0 and 700 km. Because earthquakes excite both body waves, which travel into and through the

Earth, and surface waves, which are constrained to follow the natural wave guide of the Earth's uppermost layers, two magnitude scales evolved - the m_b and M_S scales.

The standard body- or surface-wave magnitude formula uses logarithm of the amplitude of ground motion (in microns); divided by the corresponding period (in seconds); and a correction factor that is a function of distance between epicenter and station and focal depth of the earthquake. There are many variations of these formulas that take into account effects of specific geographic regions, so that the final computed magnitude is reasonably consistent with Richter's original definition.

Earthquakes with magnitude of about 2.0 or less are usually call microearthquakes; they are not commonly felt by people and are generally recorded only on local seismographs. Events with magnitudes of about 4.5 or greater - there are several thousand such shocks annually - are strong enough to be recorded by sensitive seismographs all over the world. Great earthquakes, such as the 1964 Good Friday earthquake in Alaska, have magnitudes of 8.0 or higher.

National and regional agencies are faced with the problem of making magnitude estimates from the data of their own stations, closely to those listed by international agencies. The general procedure is to adopt a measure of wave motion derived from available seismograms, and to fit a calibration function to magnitude data from an external agency for a set of events recorded at both levels. When this has been done, the derived formula becomes available for subsequent internal use.

In the course of the joint General Assembly of the IASPEI the Subcommission on Magnitudes of the Commission on Practice held a number of discussions on the current status of magnitude determinations, and on the nomenclature to be used in future publications. The increasing use of telegraphic communication and computer processing has made it necessary to express magnitude information within the constraints of the upper-case alphabetic character set, without using subscripts. The following system is therefore recommended. The principal conclusions are summarized below in Tables1. and 2.

Code	Type of Magnitude scale
MWA	Local magnitude from Wood-Anderson seismographs, as defined by Richter (1935)
M	Unified magnitude, as defined by Gutenberg and Richter (1956)
Mb	Magnitude determined by body waves in general
Ms	Magnitude determined by surface waves in general
MLH	Magnitude from horizontal surface waves
MLV	Magnitude from vertical surface waves
MLRV	Magnitude from vertical component of Rayleigh waves
MLRH	Magnitude from horizontal component of Rayleigh waves
MLQ	Magnitude from Love waves
MPV	Magnitude from P phase (vertical)
MPH	Magnitude from P phase (horizontal)

MPPV	Magnitude from PP phase (vertical)
MPPH	Magnitude from PP phase (horizontal)
MSV	Magnitude from S phase (vertical)
MSH	Magnitude from S phase (horizontal)
MB'	Body-wave magnitude converted from ML
ML'	Surface-wave magnitude converted from MB
MBN	Body-wave magnitude for near earthquakes
MLG	Magnitude determined from Lg (Sg) waves at distance < 10°
Md	Magnitude determined from the duration of earthquake signal
Mw	Magnitude determined from the seismic moment

Table 1. Codes of magnitudes scales

Magnitude diapason	**Class**
M > 8	Great
7 < M < 7.9	Major
6 < M < 6.9	Strong
5 < M < 5.9	Moderate
4 < M < 4.9	Light
3 < M < 3.9	Minor
M < 2.9	Micro

Table 2. Magnitude classes

Intensity scale describes how much shaking was experienced at a site, based on interviews and examination of structures and is not an instrumental determination. The Intensity Scale differs from the Richter Magnitude Scale in that the effects of any one earthquake vary greatly from place to place, so there may be many Intensity values measured for one earthquake. Each earthquake, on the other hand, should have just one Magnitude, although the several methods of estimating it will yield slightly different values. The Modified Mercalli Intensity Scale (Table 3) is commonly used in the United States.

The Modified Mercalli intensity levels range from not felt (I) to total destruction (XII). In contrast, magnitude represents the energy released in the earthquake and is not what you feel in the event. . Alternative scales have been developed in both Japan and Europe for local conditions. The European (MSK) scale of 12 grades is similar to the abridged version of the Mercalli. The same earthquake will feel very different at different locations. For each earthquake, we have one magnitude but a map of intensities with different intensities at different sites. Bigger earthquakes will have larger areas of damage and higher maximum intensities. How large an area of a particular level of shaking (say, VII -- where old buildings begin to be damaged) is produced by any earthquake will depend both on the magnitude of the event and on how quickly the waves attenuate with distance.

I.	Not felt. Marginal and long-period effects of large earthquakes
II.	Felt by persons at rest, on upper floors, or otherwise favourably placed to sense tremors

III.	Felt indoors. Hanging objects swing. Vibrations like passing of light trucks. Duration can be estimated.
IV.	Vibration like passing of heavy trucks (or sensation of a jolt like a heavy ball striking the walls). Standing motorcars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV, wooden walls and frames creak.
V.	Felt outdoors; direction may be estimated. Sleepers wakened. Liquids disturbed, some spilled. Small objects displaced or upset. Doors swing, open, close. Pendulum clocks stop, start, change rate.
VII.	Difficult to stand. Noticed by drivers of motorcars. Hanging objects quiver. Furniture broken. Damage to weak masonry. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices. Waves on ponds; water turbid with mud. Small slides and caving along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged
VIII	Steering of motorcars affected. Damage to masonry; partial collapse. Some damage to reinforced masonry; none to reinforced masonry designed to resist lateral forces. 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.	General panic. Weak masonry destroyed; ordinary masonry heavily damaged, sometimes with complete collapse; reinforced masonry seriously damaged. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluvial areas, sand and mud ejected, earthquake fountains, sand craters
X.	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. Railway 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 air.

Table 3. Modified Mercalli Scale of Felt Intensity

There is essential difference between intensity scales and magnitude scales. Magnitude corresponds to the energy released at the source of the earthquake. The magnitudes are determined numerically so that they do not depend on where the measurement is made.. Intensity scales, like the Modified Mercalli Scale and the Rossi-Forel scale, measure the strength of shaking produced by the earthquake at a particular location. So the intensity of an earthquake will depend on where it was measured. Intensity is determined from effects on people, human structures, technical facilities, and the natural environment. Intensity does not have strong mathematical basis, but is based on observed effects. Since the destruction caused by earthquakes depends upon building practices, soil conditions, and population density near the epicenter, as well as the total amount of energy released by the earthquake, intensity measurements are not generally used in the study of the earthquake process itself. Nevertheless sometimes earthquakes are referred to by the maximum intensity they produce.

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Biographical Sketch

Dr. Sergei Yunga is one of the leading Russian seismologists who has worked extensively on various aspects of earthquakes, including focal mechanisms, seismic moment release, maximum magnitude evaluations, and earthquake prediction. He was involved for 20 years in seismological research in Tadjikistan and Kazakstan, in Central Asia. He is currently the principal scientist of the United Institute of physics of the Earth, one of foremost Russian research centers for earth sciences, and a corresponding member of the Russian Academy of Natural Sciences.

Sergei Yunga graduated from Moscow Physical-Technical Institute in 1973, in the department of applied mathematics and space investigations, specializing in the theory of elasticity, theory of plasticity, and fracture mechanics. He received his formal training in geology and seismology as a post-graduate student. He holds both candidate (equivalent of Ph.D.) (1977) and doctorate degrees (1989) from the Institute of physics of the Earth, USSR Academy of sciences. His works have been published in international, Russian and American seismological and geophysical journals. Dr.Yunga is the author of one monograph of his own and several monographs with co-authors. His scientific results have been discussed at international meetings, conferences and seminars in the U.S.A., Great Britain, France, Egypt, Germany, Bulgaria, China.