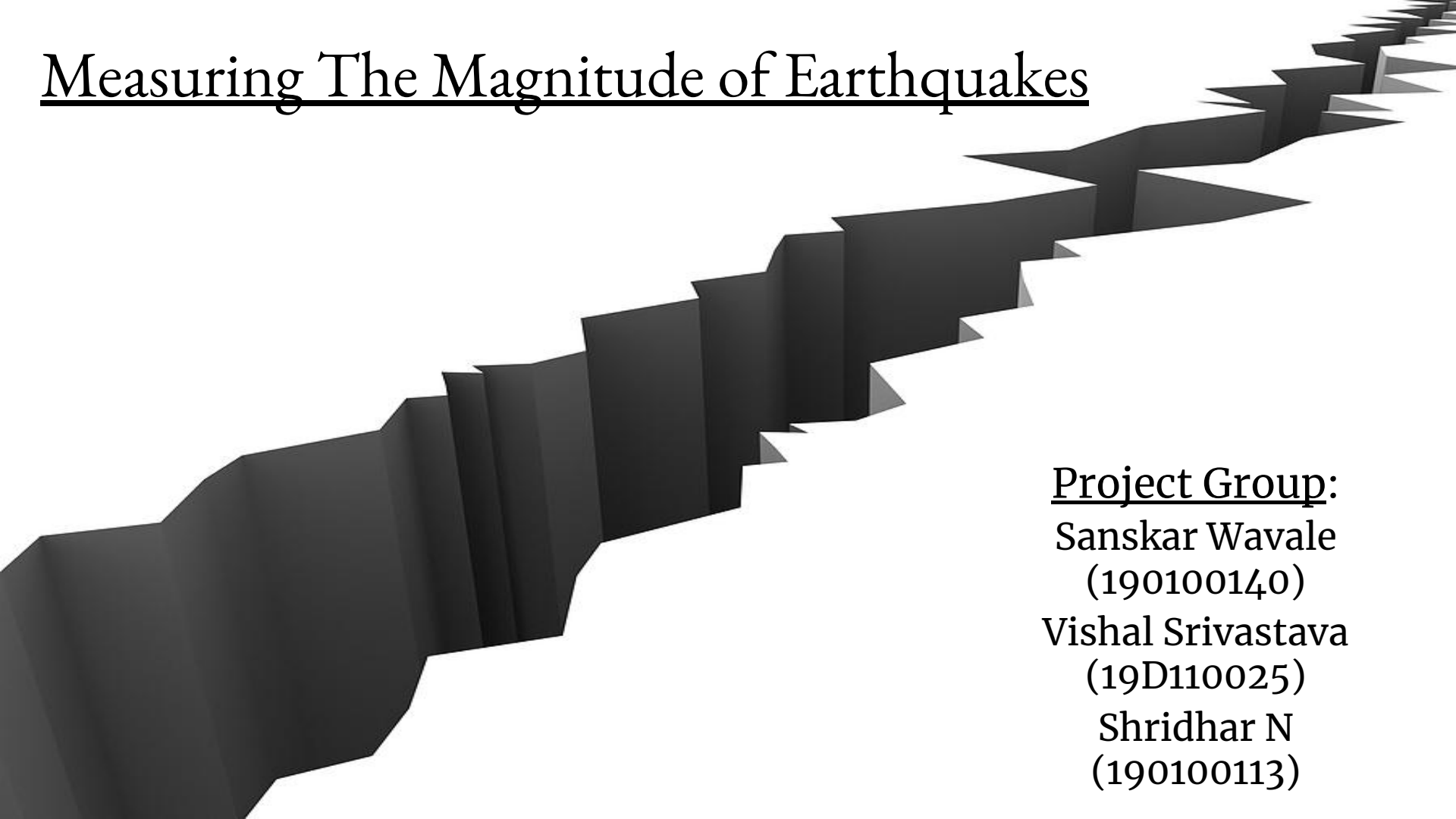
Measuring The Magnitude of Earthquakes



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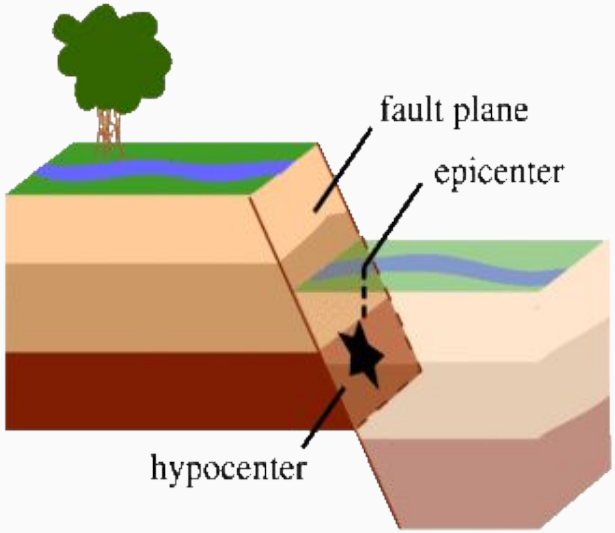
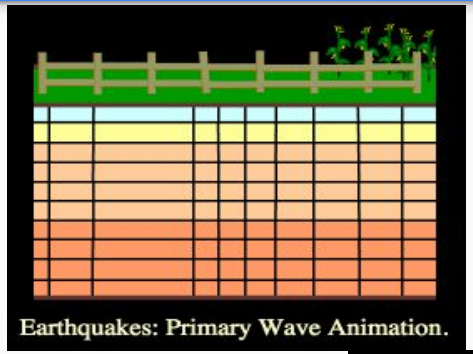
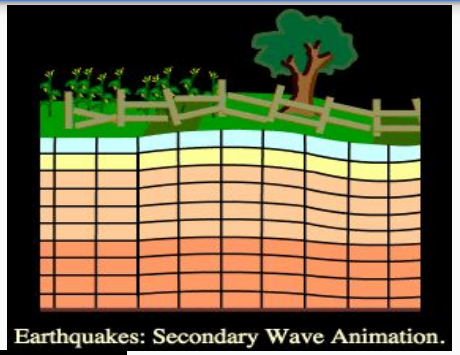
Science of Earthquakes:

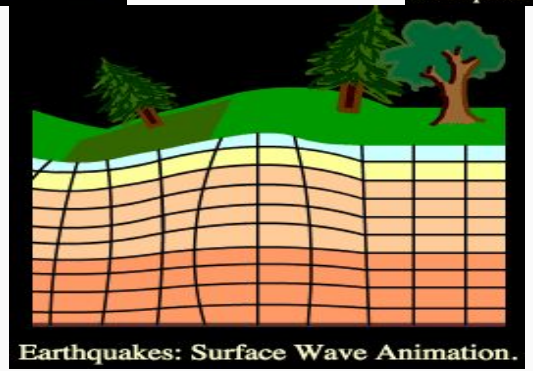
An Earthquake is the result of a sudden release of energy in the earth's crust that creates seismic waves.

Seismic waves are waves of energy that travel through Earth as a result of any natural or artificial phenomenon that causes a sudden release of energy such as earthquakes, nuclear explosion, etc. They are broadly of 2 types: (i) Body waves (P waves & S waves) (ii) Surface waves (Love waves & Rayleigh waves)




Earthquakes: Primary Wave Animation.

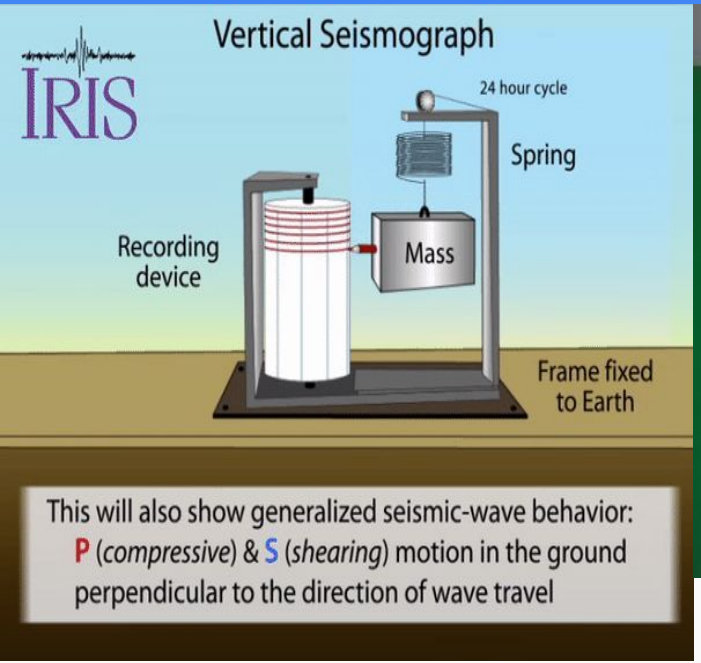

Earthquakes: Secondary Wave Animation.


Earthquakes: Surface Wave Animation.

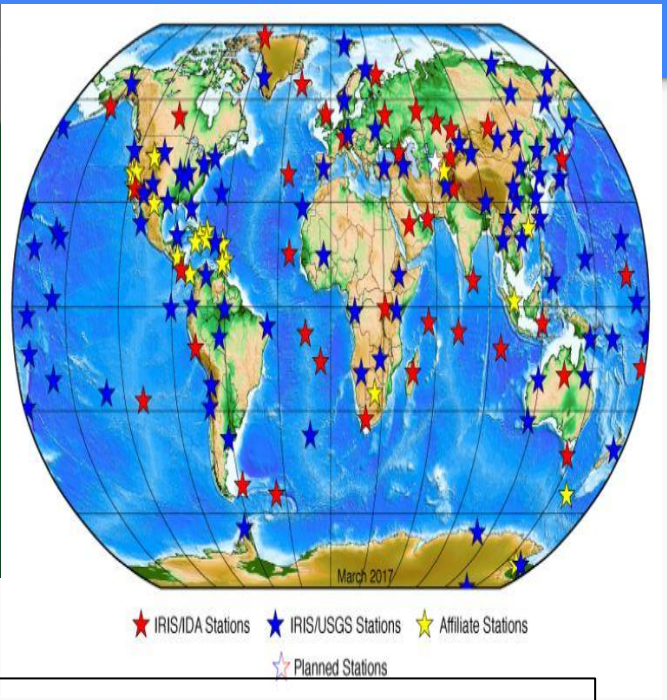
Seismograph:

A Seismograph is a device for measuring the movement of the earth, and consists of a ground-motion detection sensor, called a seismometer, coupled with a recording system.

Gutenberg-Richter magnitude-energy relation:
$\log E = 1.5 \times R + 4.8$



STS-1
An electronic seismograph

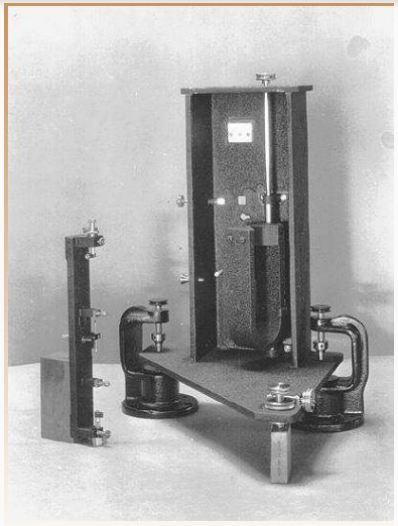


Fun Fact: Seismographs have not only been used on earth but also on Moon to discover **Moonquakes** during the Apollo program in 1970s and on Mars aboard Insight lander to detect **Marsquakes** in 2019.

Richter Scale :

Richter (1935) defined the local magnitude ML of an earthquake observed at a station to be :
ML = log A - log Ao (Δ)

where A is the maximum amplitude in millimetres recorded on the Wood-Anderson Seismograph for an earthquake at epicentral distance of Δ km,
Ao (Δ) is the maximum amplitude at Δ km for a standard earthquake.



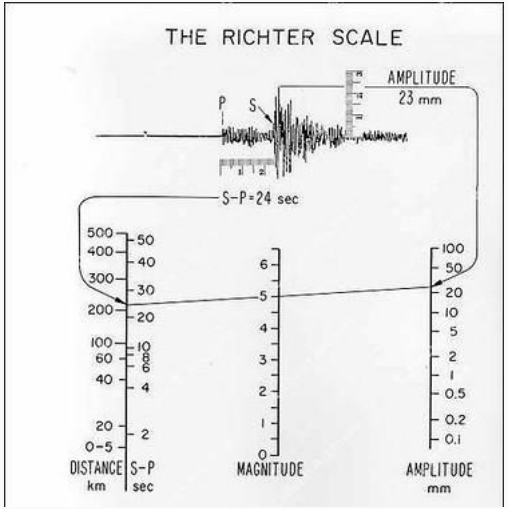
Wood-Anderson Seismograph

TABLE 1

LOGARITHMS OF THE AMPLITUDES B (IN MM.) WITH WHICH THE STANDARD TORSION SEISMOMETER SHOULD REGISTER A SHOCK OF MAGNITUDE ZERO

Δ	−log B	Δ	−log B	Δ	−log B
0	1.4	100	3.0	330–340	4.2
10	1.5	110–120	3.1	350–370	4.3
20	1.7	130–140	3.2	380–390	4.4
25	1.9	150–160	3.3	400–420	4.5
30	2.1	170–180	3.4	430–460	4.6
35	2.3	190–200	3.5	470–500	4.7
40	2.4	210	3.6	510–550	4.8
45	2.5	230–240	3.7	560–590	4.9
50	2.6	250–260	3.8	600	5.1
60–70	2.8	270–280	3.9	700	5.2
75–85	2.9	290–300	4.0	800	5.4
90	3.0	310–320	4.1	900	5.5
				1,000	5.7

-log Ao as a function of epicentral distance in Km



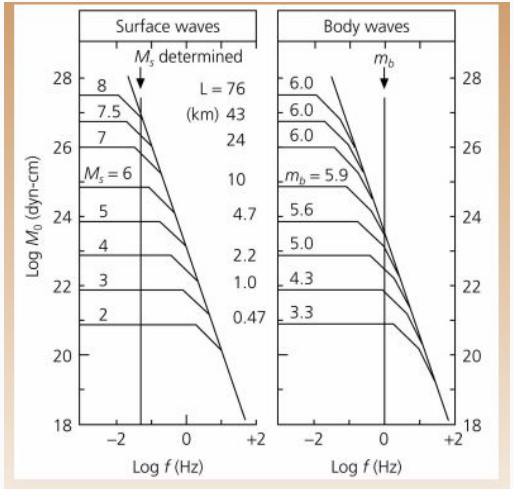
Graphical procedure for estimating the Richter magnitude (ML)

Limitations:

- No direct mechanical basis for the definition of Richter magnitude.
- Amplitudes depend on distance from the source, source depth, frequency and fault dimensions.
- Only applies to Southern California and the Wood-Anderson seismograph.
- For magnitudes greater than 6.5, the values calculated tend to cluster, or “saturate” near one another.

Other Scales :

- Body-wave Magnitude (mb) Scale
- Surface wave magnitude (Ms) Scale
- Moment Magnitude (Mw) Scale
- Duration Magnitude (Md) Scale

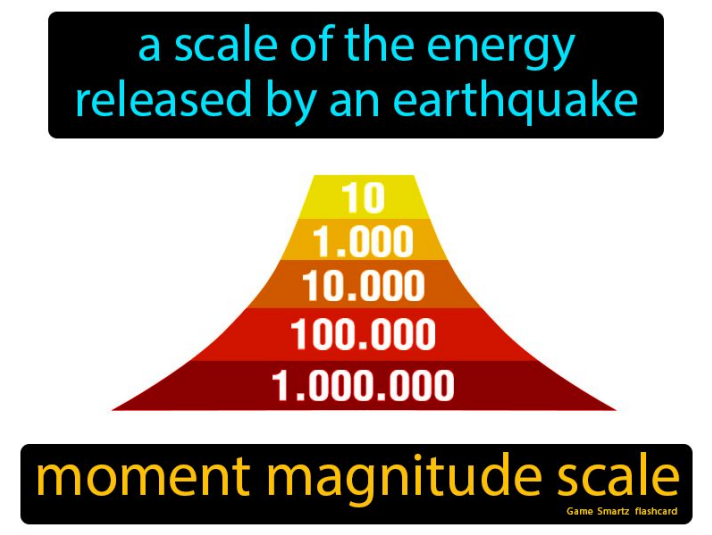


Richter scale of earthquake magnitude

magnitude level	category	effects	earthquakes per year
less than 1.0 to 2.9	micro	generally not felt by people, though recorded on local instruments	more than 100,000
3.0–3.9	minor	felt by many people; no damage	12,000–100,000
4.0–4.9	light	felt by all; minor breakage of objects	2,000–12,000
5.0–5.9	moderate	some damage to weak structures	200–2,000
6.0–6.9	strong	moderate damage in populated areas	20–200
7.0–7.9	major	serious damage over large areas; loss of life	3–20
8.0 and higher	great	severe destruction and loss of life over large areas	fewer than 3

Fun Fact: Because of various shortcomings of the ML scale, Richter Scale is no longer used.
But much of the news media still refers to these as "Richter" magnitudes. All magnitude scales retain the logarithmic character of the original and are scaled to have roughly comparable numeric values.

WHY MMS ?



- Development of Richter scale was based on shallow-moderate sized earthquakes
- At greater depths Richter Scale failed to measure since surface waves are insignificant
- Body wave and Surface wave Magnitude Scale was developed after this but both had an issue of saturation
- This created the need of a more efficient scale

Moment Magnitude Scale

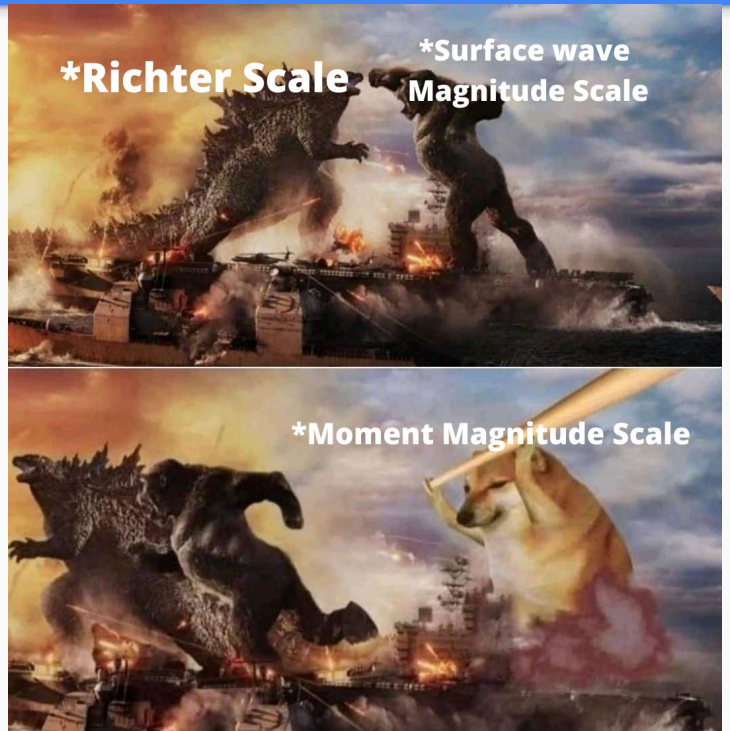
THOMAS C. HANKS and HIROO KANAMORI

- The basis of Seismic Moment (Mo) and its use in Moment Magnitude Scale
- Shifting the basis of Magnitude scale to radiated energy by Hanks and Thatcher in 1972 and its benefits
- Proposal of Moment Magnitude Scale by Hanks and Kanamori in 1979 and the background Maths involved
- Mw = 2/3 log Mo - 10.7 .... (*final equation)*

Features of MMS

- Consistent with previous scales such as M_L: 3-6, M_S: 5-8
- Does not saturate at higher values with sound theoretical basis than other scales
- Based on radiated energy but intrinsically Moment Magnitude Scale as defined by Hiroo Kanamori

SO TO SUM UP !


*Richter Scale
*Surface wave Magnitude Scale
*Moment Magnitude Scale