IS MARS SEISMICALLY ACTIVE?

OBJECTIVE OF FUTURE MARS MISSIONS

Emplacing Seismic Network

Determine Internal Structure (Crust, Mantle, Core?)

SHOULD BE MORE SEISMICALLY ACTIVE THAN MOON/LESS THAN EARTH

Geologically more active than Moon/Less than Earth

Moon 28 high-frequency teleseisms in 5 years

(equivalent to tectonic earthquakes/not tidally triggered)

Young fault scarps, recent volcanic activity,

uncompensated loads - Tharsis

Viking Results

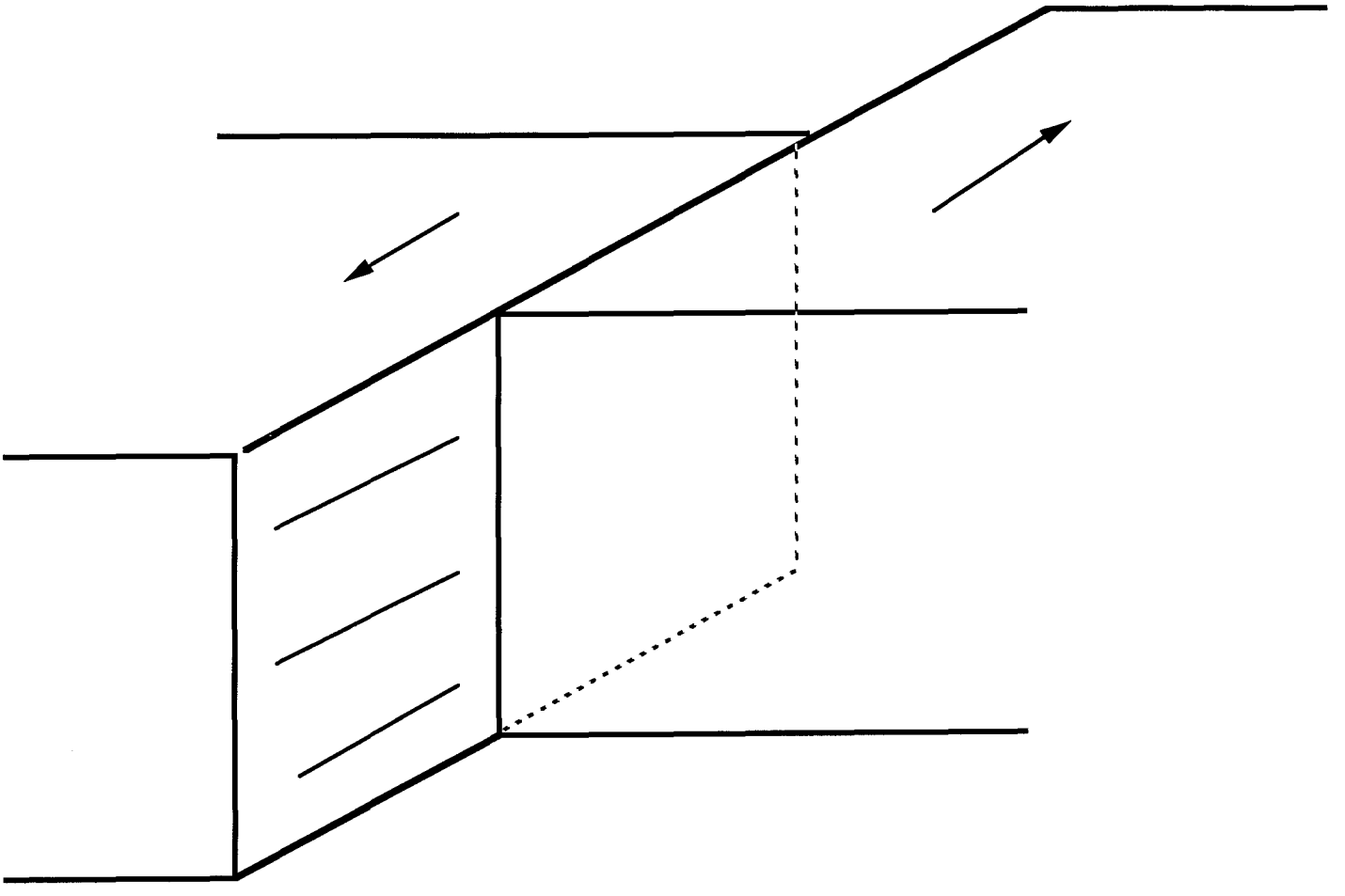
2 Seismometers; only VL 2 uncaged (Utopia Planitia)

no marsquakes (19 months, listened ~3 months)

Could have detected about magnitude 6 teleseism (mag 5 < 1000 km)

Note that VL 2 is ~5,000 km from Tharsis

Mars Could be Seismically Active - How Active?



Seismic Moment

$$Mo = \mu sA$$

μ = rigidity

s = slip on fault

A = Area of fault

On Mars - know enough about fault area, displacement and history to estimate seismicity through time

ASSUMPTIONS/CALCULATIONS

USED DIGITIZED DATA SETS

SIMPLE GRABENS (l/2 during each period)

6841 Grabens; total length 354,556 km (Watters and Maxwell, 1983)

WRINKLE RIDGES (LN/EH)

1845 WR; total length 32,117 km (Watters and Maxwell, 1983)

MEASURED

VALLES MARINERIS (1/2 during each period)

40 km deep; 4-8 km slip (from surface topography)

MA/UA 20 faults each 50 km long; 100 m slip Lucchitta

TEMPE TERRA RIFTS

1470 km long; 10 km deep; 0.5 km slip (from surface topography)

THAUMASIA GRABEN/RIFT

1200 km long; 40 km deep; 1.5 km slip (from surface topography)

ALBA GRABENS

5-10 km deep; 0.2-0.5 km slip (from surface topography)

ALL MIDDLE/UPPER AMAZONIAN GRABENS

Caldera Fault Lengths (Olympus, Ascreaus, Arsia, Pavonis Mons)

Depths (10 km) from Zuber & Mouginis-Mark (1990) and Thomas et al. (1990)

Slips from Mouginis-Mark (1990) and Pike (1978) from surface topography

Fernandina Caldera Collapse, Galapagos 1968 occurred by equivalent seismic process (Filson et al., 1973)

MOMENT RELEASE TODAY

LATE AMAZONIAN

Most Likely Estimate is 1.3×10^{22} dyne-cm/yr
for past 250 m.y. (assuming Hartmann et al., crater-age correlation)

EXPONENTIAL DECAY IMPLIES MARS IS AS SEISMICALLY ACTIVE TODAY

THIS ESTIMATE SIMILAR TO THEORETICAL LITHOSPHERIC COOLING (Phillips and Grim, 1991)

3.6×10^{23} dyne-cm/yr
when adjusted for
- 4 times thicker seismogenic lithosphere
- 7 times greater μ
- whole planet versus western hemisphere only

Expect Surface Faulting Estimate to be Smaller
only includes faults that break the surface

SEISMICITY TODAY

ON EARTH SUBSTANTIALLY MORE EARTHQUAKES OCCUR WITHOUT SURFACE BREAKS

IF ABOUT 100 TIMES MORE

THEN About	**#/yr**	
	2	**(5>m>4)**
	15	**(4>m>3)**
	115	**(3>m>2)**

TO CALIBRATE

PERFORMED SIMILAR CALCULATION FOR THE MOON

17,000 km Grabens formed 3.8-3.6 Ga

26,000 km Mare Ridges formed 3.6-3.0 Ga

Predict Moment 1000 Times Less Than Measured

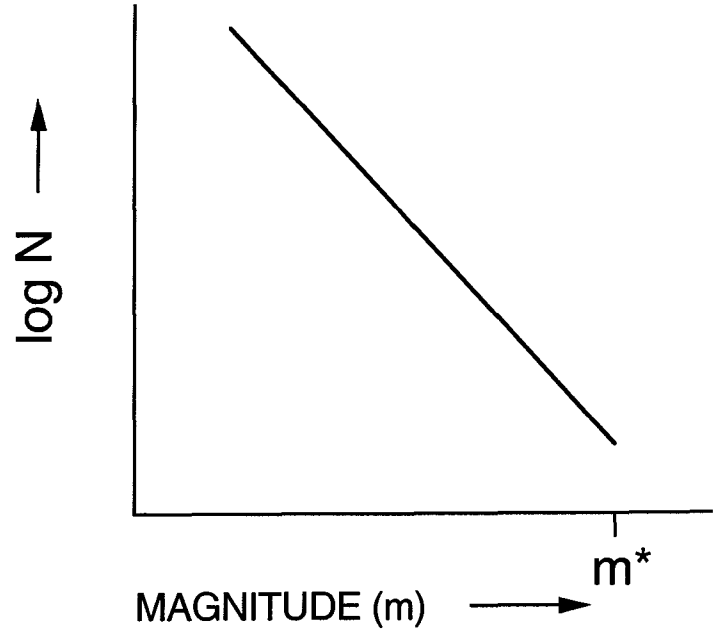
(Extrapolation of Moment from Tectonic Features)

IF ESTIMATES FOR MARS SIMILARLY LOW

Of Order 100 Marsquakes > m=3 per year

About 2 > m=5/yr

DISTRIBUTION OF EARTHQUAKES



log N = a-bm b = slope

log Mo = A+Bm

log N (m<N<m*) = log[Mo(B/b-1)]+(m*-m)b-(Bm*+A)

where m* is largest earthquake

For Intraplate Oceanic Earthquakes

b = 0.9
A = 11.71
B = 2.35 for body-wave m

(Bergman, 1986;
Bergman and Solomon, 1980)

SEISMICITY TODAY

ASSUME LARGEST MARSQUAKE EQUIVALENT TO m=6 EARTHQUAKE

BASED ON

Largest Moonquake (Oberst, 1987; Nakamura, 1980)

Largest Intraplate Oceanic earthquake (Bergman, 1986)

Smallest Teleseismic Marsquake Detectable by VL 2
(Anderson et al., 1977; Goins and Lazarewicz, 1979)

RECURRENCE INTERVALS

m =	6-5	5-4	4-3	3-2
	435 yr	55 yr	7 yr	1 yr

LIKELY MINIMA

ALSO

Equivalent Magnitude 4 Earthquake on Mars similar to a Magnitude 5 Earthquake

Likely Teleseismic Event on Mars

AND ...

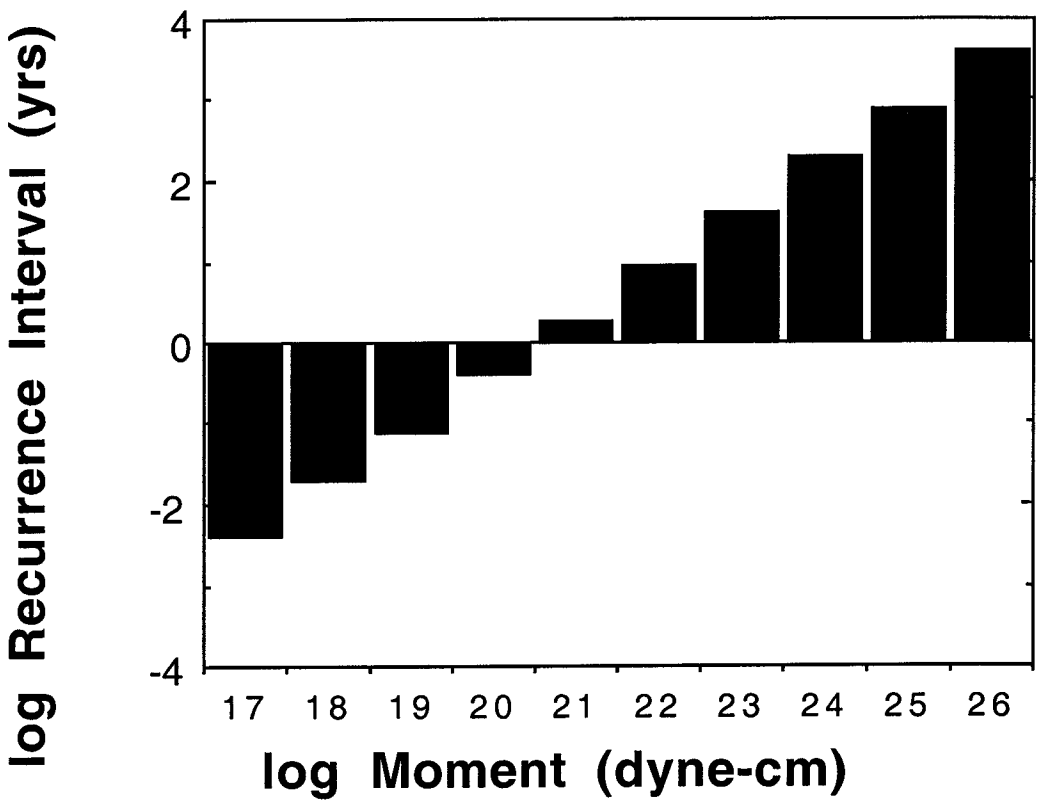
MOMENT FREQUENCY

$$N(M_o) = aM_o^{-b}$$

$$\Sigma M_o = [ab/(1-b)]\ (M_o^{max})^{1-b}$$

assume b = 0.67 (Bergman)
$M_o^{max} = 10^{26}$ dyne-cm
solve a for measured ΣM_o

$$N(M_o, M_o+\Delta M_o) = a[M_o^{-b} - (M_o+\Delta M_o)^{-b}]$$



log Moment	Terrestrial magnitude	Recurrence interval from surface faulting	Recurrence interval for entire lithosphere
26.5	6.7	35,587 yr	356 yr
25	5.8	4,484 yr	4.5 yr
23.5	4.9	565 yr	6.8 mo
22	4	71 yr	0.9 mo
20.5	3.1	9 yr	3.3 dy
19	2.2	1 yr	9.8 hr
17.5	1.3	52 dy	1.2 hr