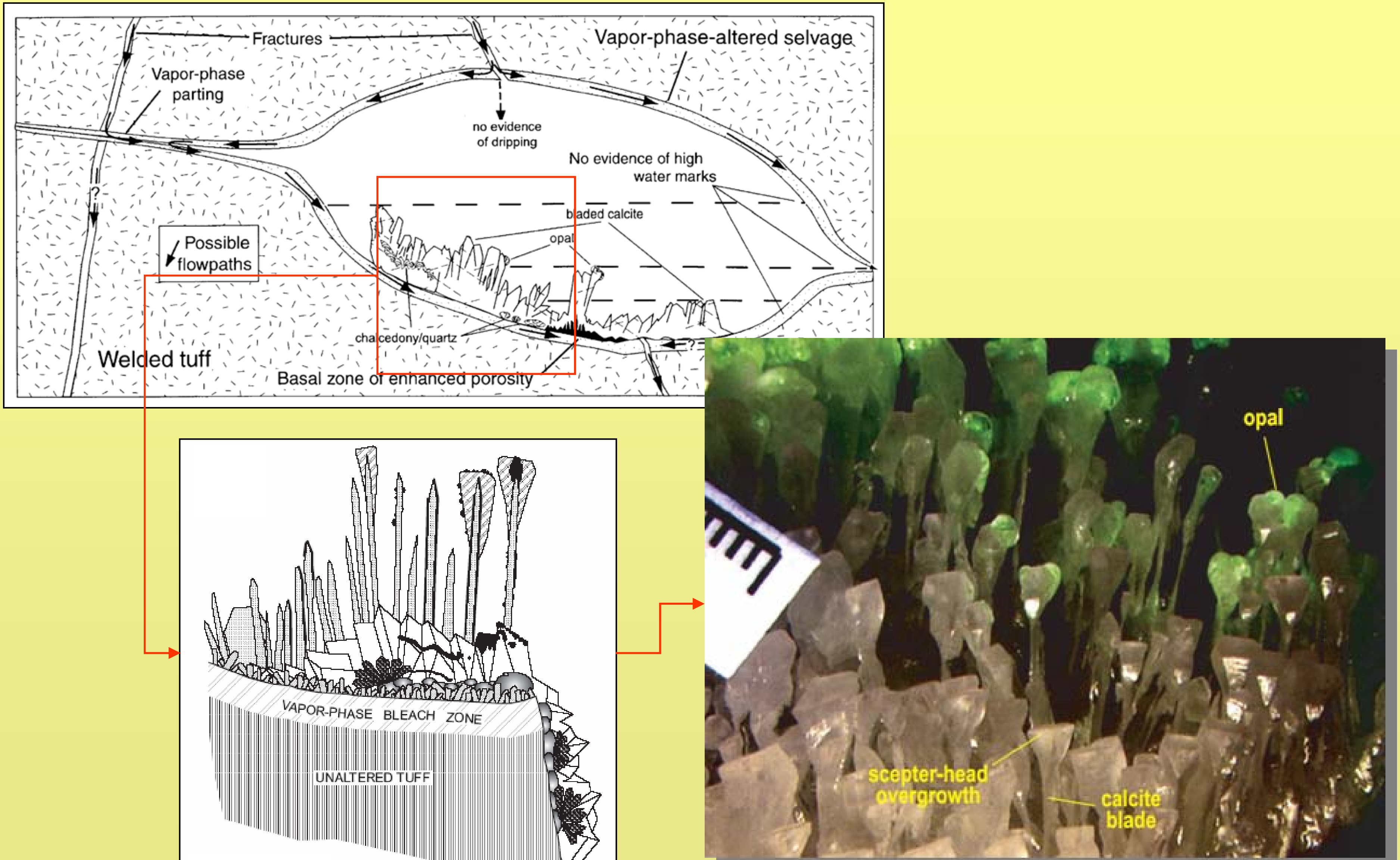
Evaluating Fragile Blades and Filaments in the Lithophysae for Constraints on Long Return Period Earthquake Ground Motions at Yucca Mountain Nevada

August 2004 *Workshop on Extreme Ground Motions at Yucca Mountain*
USGS, Menlo Park Ca

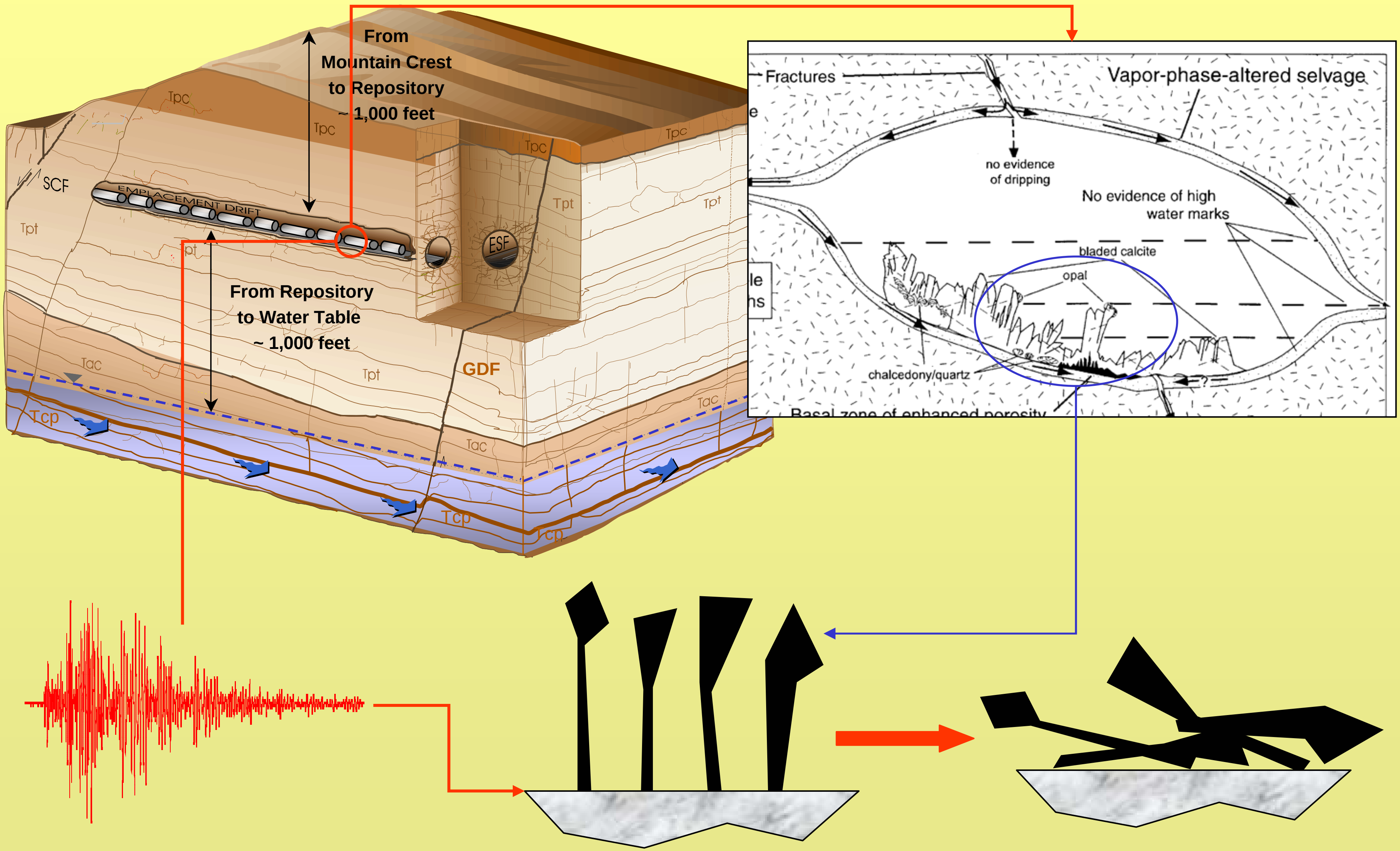
D. McCallen
Yucca Mountain and Repository Science Program
Lawrence Livermore National Laboratory
Livermore, California

J. Whelan
Environmental Science Team
Yucca Mountain Project Branch
United States Geological Survey
Denver, Colorado

The lithophysal voids contain delicate geologic structures of potential interest for constraining historical motions

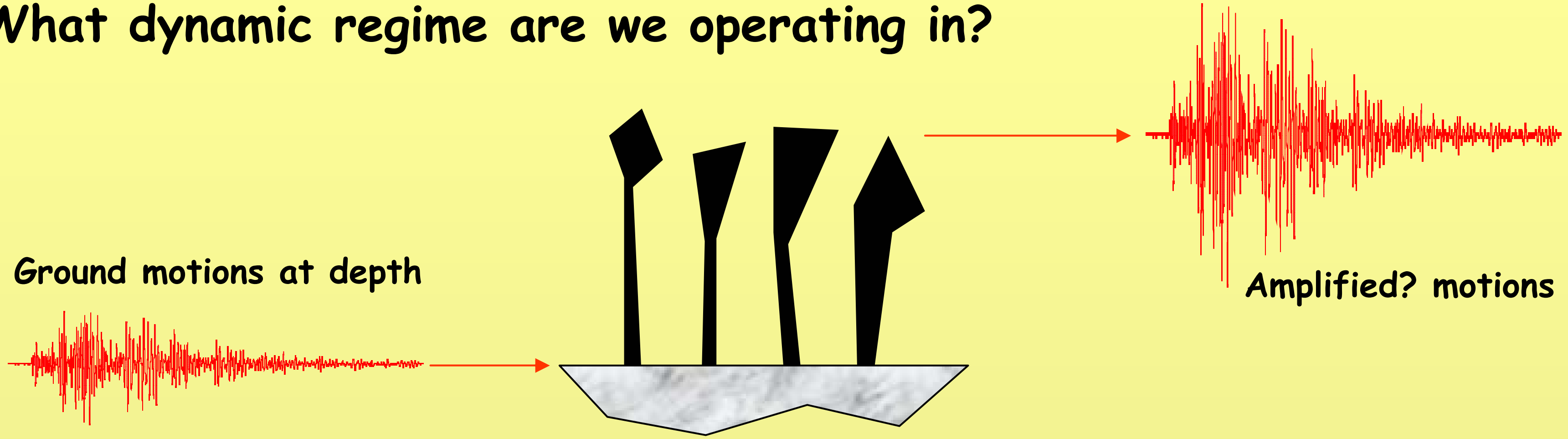


Would such delicate mineral structures be subject to damage under large earthquake motions?

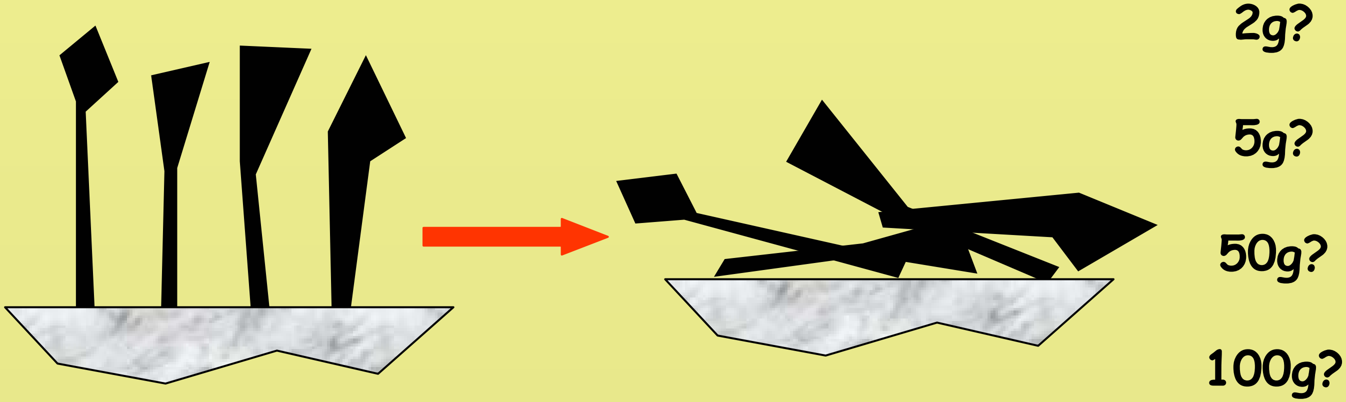


If so, does the existence of fine geologic structure allow us to constrain historical ground motion levels?

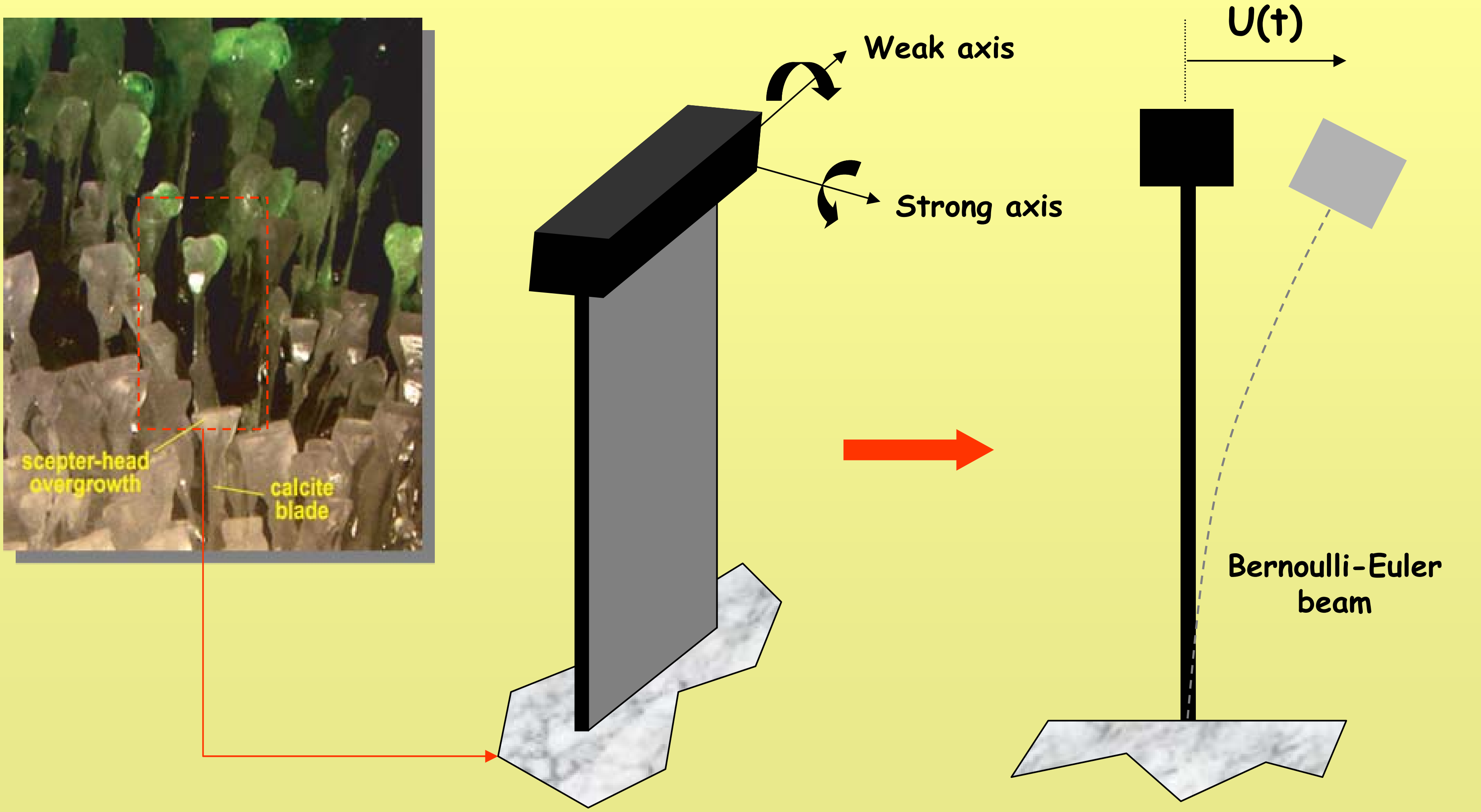
- What dynamic regime are we operating in?



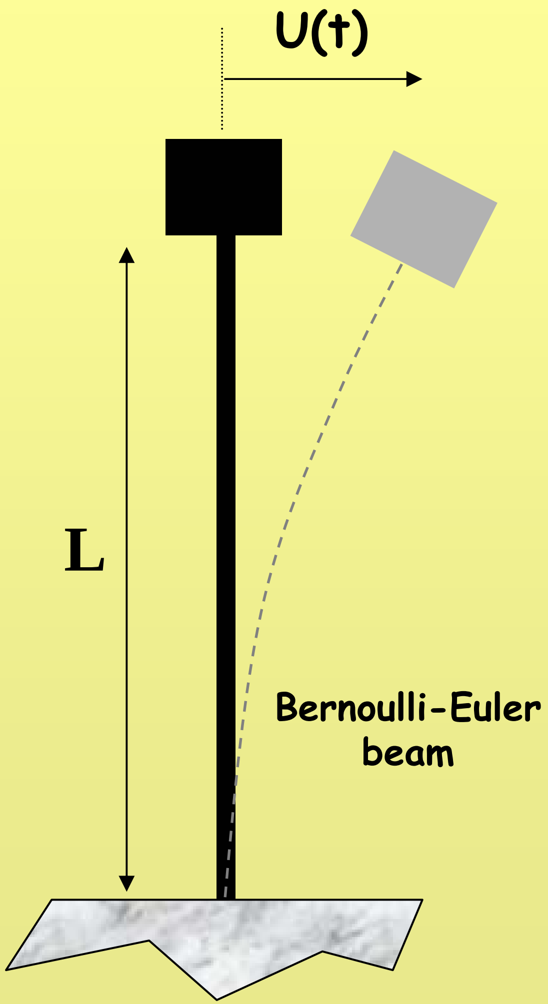
- Is the fragility of the fine geologic structures low enough to constrain the ground motions?



A simple beam model can be invoked to shed light on the dynamics of the blade structures



This idealization can essentially reduce the blade to a single degree of freedom oscillator



System stiffness

$$K = \frac{3EI}{L^3}$$

E = modulus of elasticity
I = moment of inertia
L = length of blade

System mass

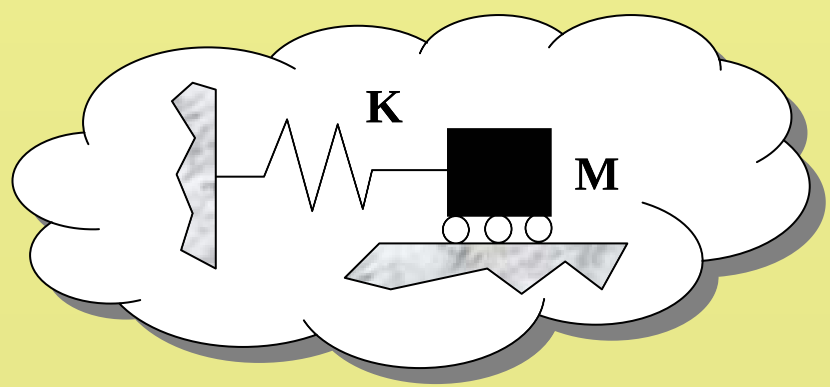
$$M = M_{head} + \frac{M_{beam}}{2}$$

M_{head} = mass of head
M_{beam} = mass of beam

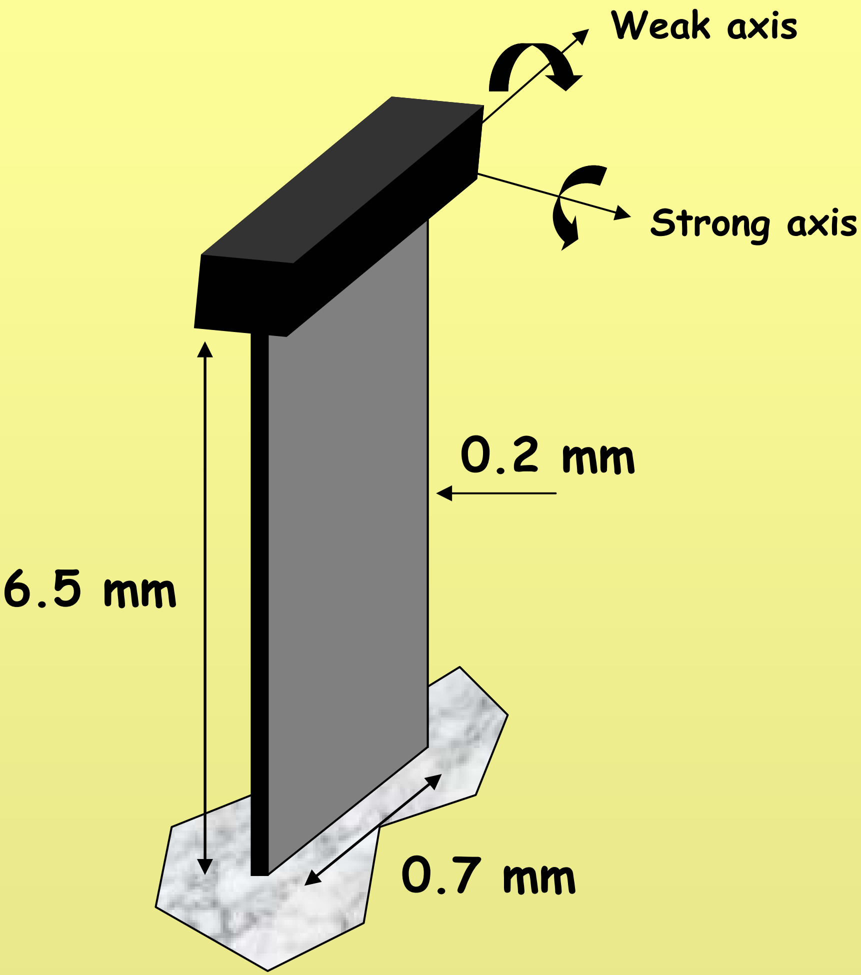
System natural frequency

$$f = \frac{1}{2\pi}\sqrt{\frac{K}{M}}$$

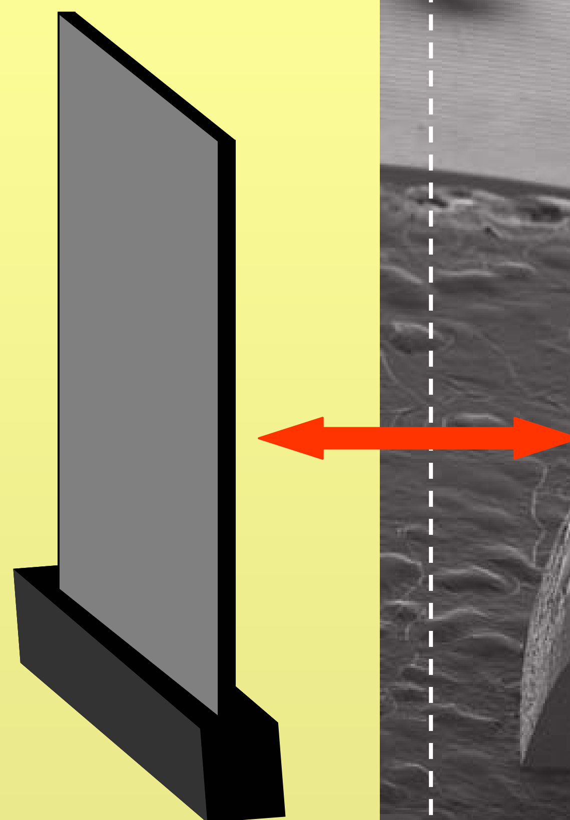
Mathematically analogous to…

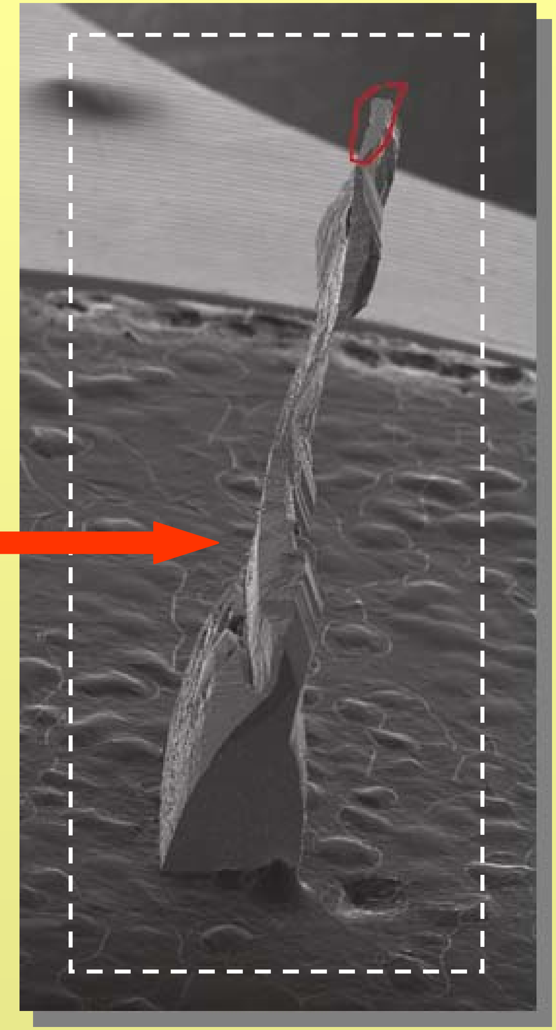


The blade structures are small and delicate, but the mass is also small



Representative dimensions for one blade (per Whalen)



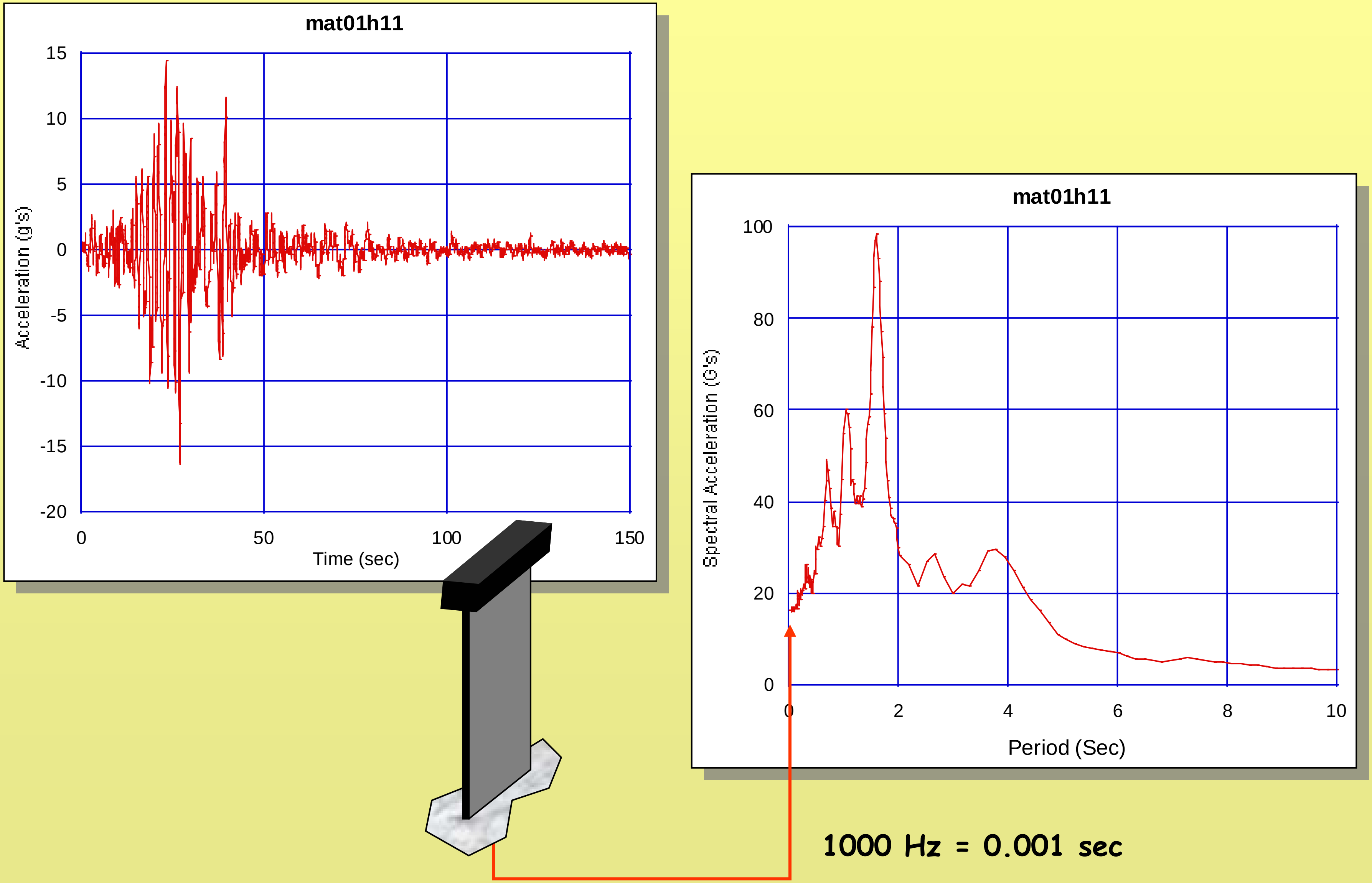


Scanning electron microscope image of a broken blade

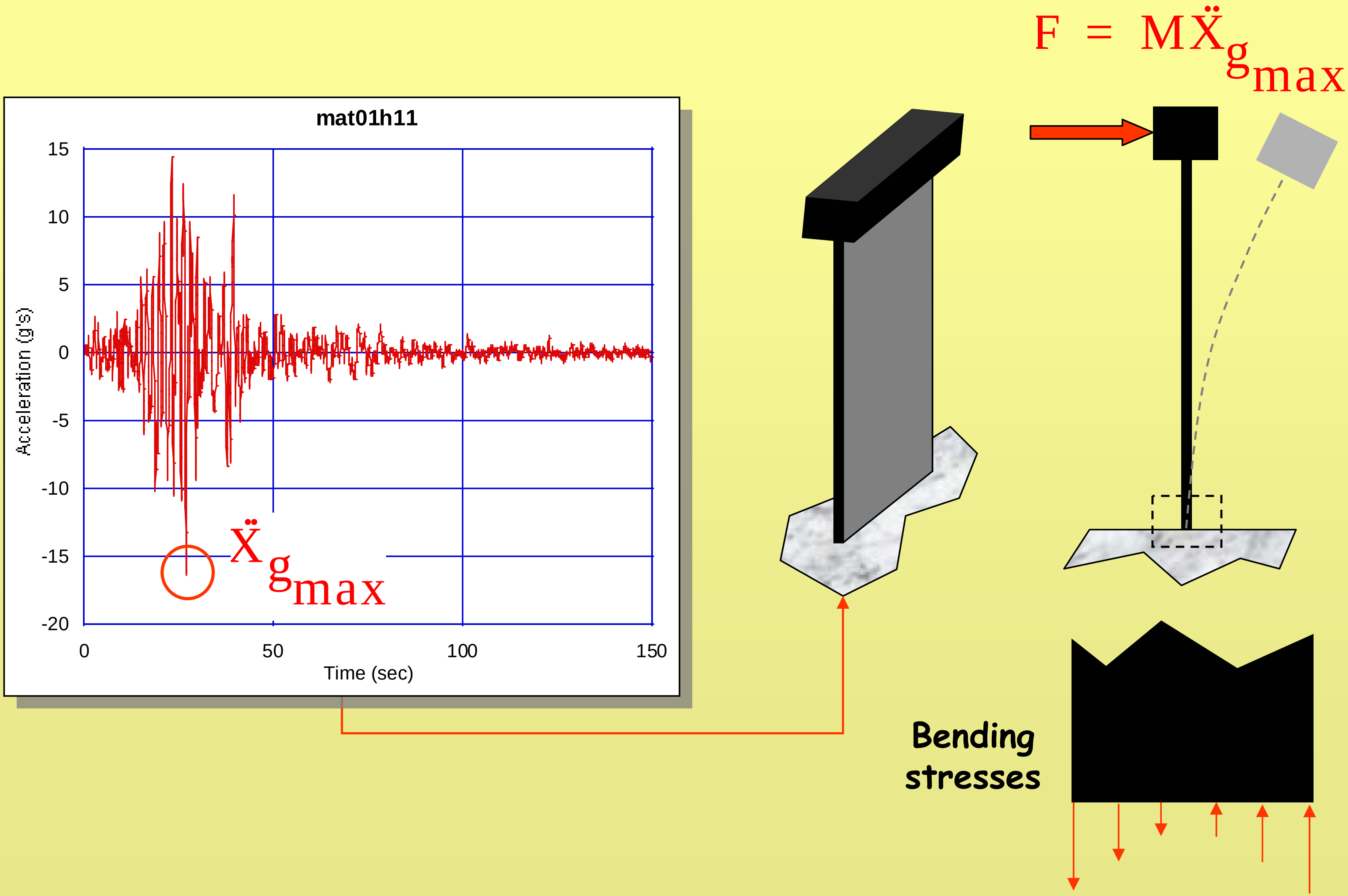
The frequency of the current blade identified in the USGS inventory is quite high

Stiffness Value (K)	428 (N/m)	$E = 8.4 \times 10^{10}$ N/m^2 $I = 4.667 \times 10^{-16}$ m^4 $L = 6.5 \times 10^{-3}$ m
Mass Value (M)	1.042×10^{-5} (Kg)	½ Beam mass = 1.229×10^{-6} Kg Opal head mass = 9.196×10^{-6} Kg
Frequency (Hz)	~1000 (Hz)	Mother Nature is not cooperating!

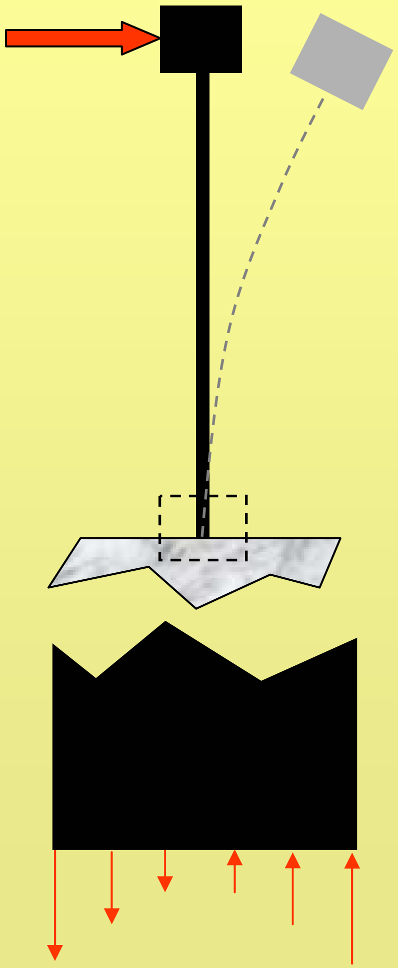
The frequency of the blade is quite high compared to the dominant frequencies of the YMP motions



Due to the high frequency of the blade, it will respond essentially as a rigid body to the earthquake motions



The stress level in the blade can be computed with a static equation of equilibrium using peak ground acceleration



$$F = M\ddot{X}_{g_{max}}$$

$$\sigma_{tensile} = \frac{TY}{I}$$

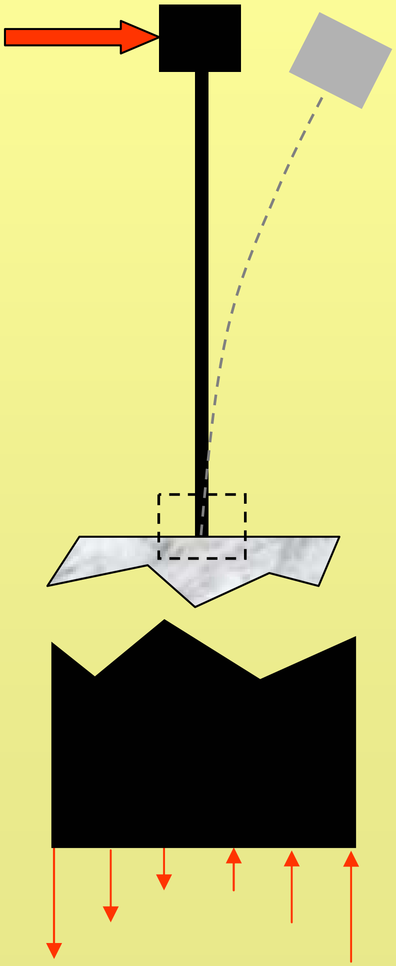
T = Moment applied at root (F x L)
Y = Extreme fiber distance from centroidal axis (thickness/2)
I = Moment of inertia of beam

$$\sigma_{tensile} = \frac{\left(M\ddot{X}_{g_{max}} L\right)Y}{I}$$

or $$\ddot{X}_{g_{max}} = \frac{\left(\sigma_{tensile_{max}}\right)I}{MLY}$$

Given the tensile strength of calcite, we can estimate the peak ground acceleration causing fracture of the blade

$$F = M\ddot{X}_{g_{max}}$$



$$\sigma_{tensile}$$

$$\ddot{X}_{g_{max}} = \frac{\left(\sigma_{tensile_{max}}\right) I}{MLY}$$

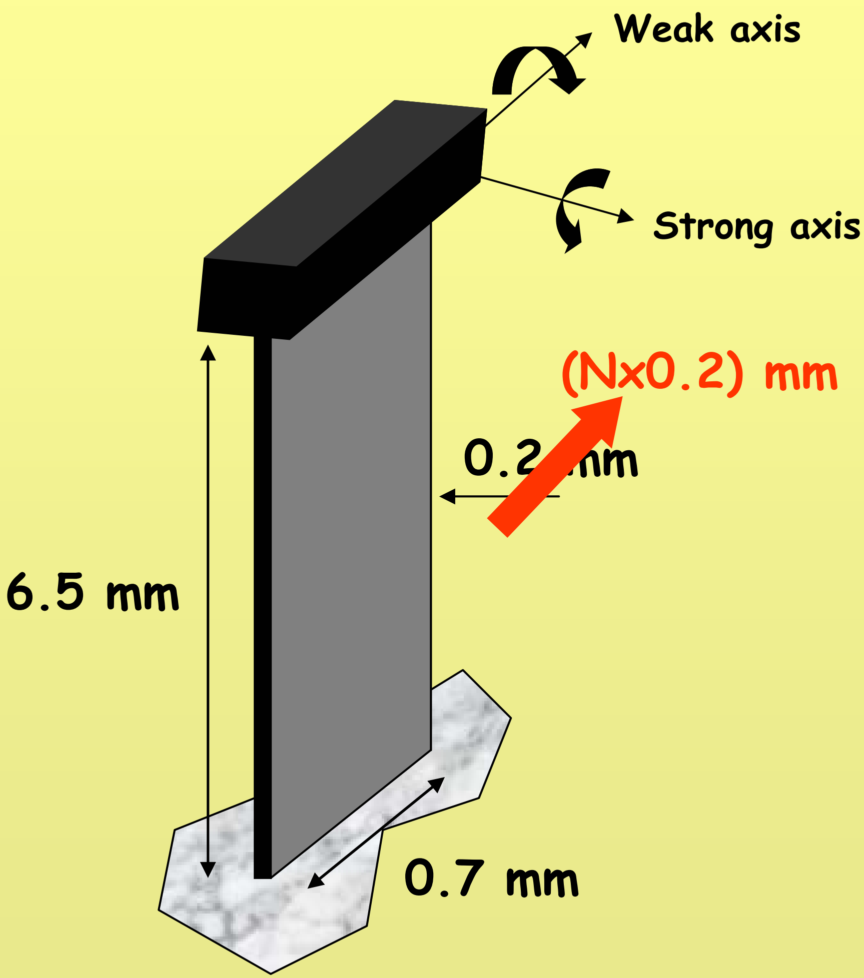
$$\sigma_{tensile_{max}} \approx 10 \times 10^6 \frac{N}{m^2}$$ (Calcite)

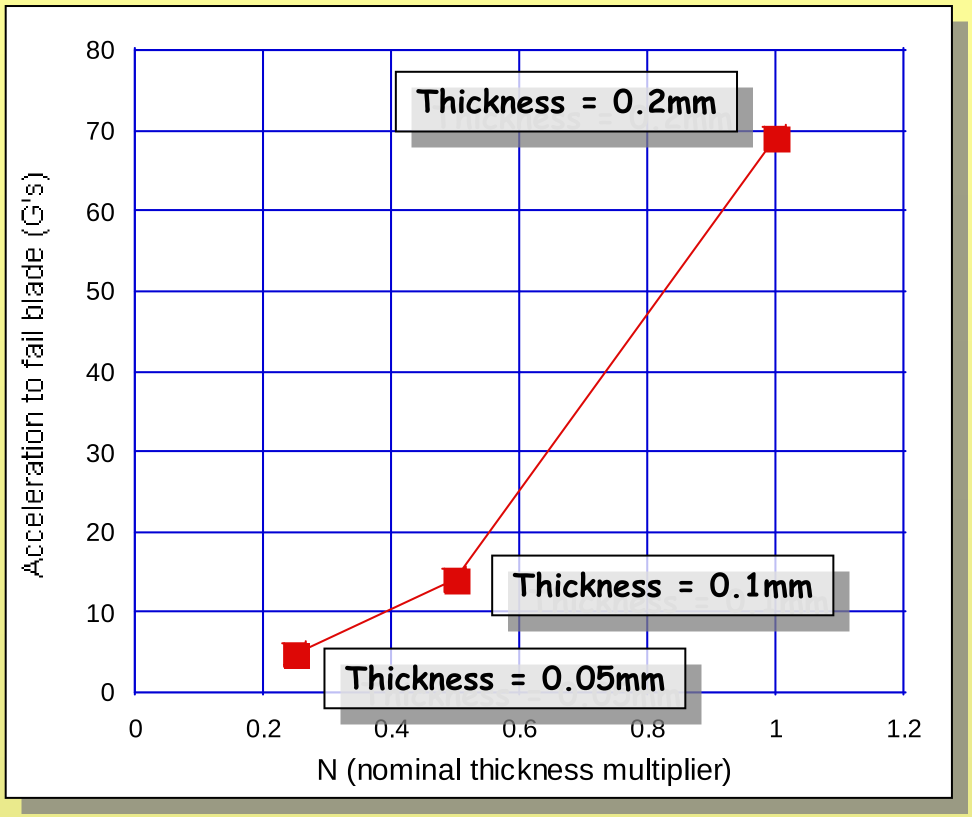
(literature ranges from 4-20 MPa)

$$\ddot{X}_{g_{max}} \cong 680 \frac{M}{s^2}$$

(~25-130 *g*'s!)

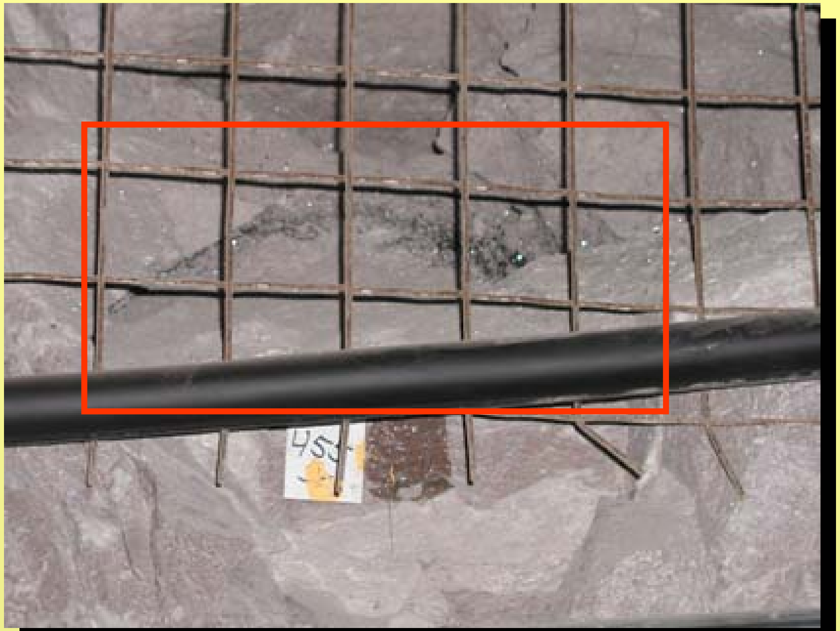
Question - what size of a blade would we have to find to actually constrain the motions?



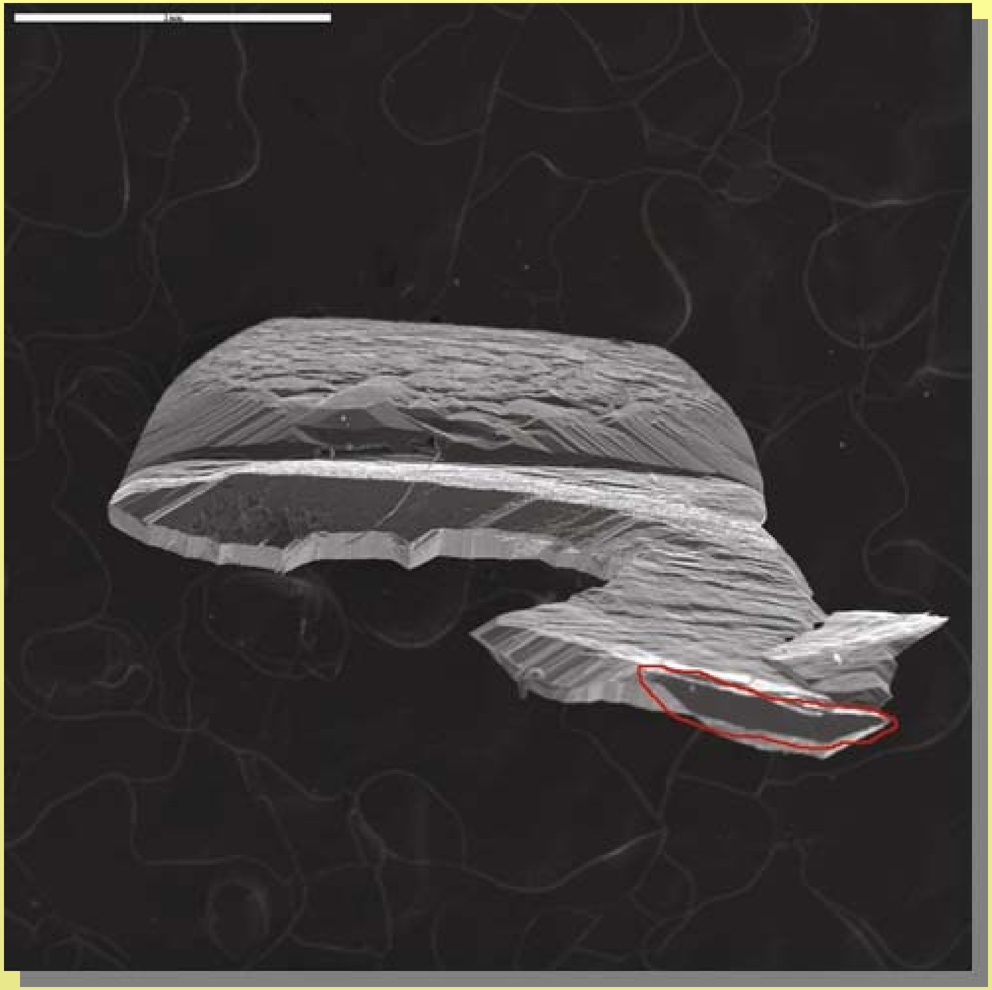


Tends towards tickness^2 dependence as Thickness diminishes

There are a very large number of lithophysal voids evident in the exploratory drifts – many potential blades



What could be done?



- Thorough search for more delicate blades
- Determine if blades of interest could actually survive tunnel boring and excavation
- Construct a better model (numerical finite element model) of critical blades
- Establish material tensile strengths and validate model with destructive testing of a few selected blades
- Compute fragility of constraining blades and validate with destructive test