Status of AE experiments at GSECARS

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Acoustic emission: a widely occurring phenomenon

“Two striking features of acoustic emission are its intermittent character and its occurrence in a surprisingly large variety of systems, ranging from geological scales to laboratory scales. A good example from the geological scale is the acoustic emission (AE) during volcanic activity. Varied laboratory scale examples such as AE from crack nucleation and propagation in fracture of solids, thermal cycling of martensites, peeling of an adhesive tape, and collective dislocation motion can be cited.”

Current ongoing experiments

- Eclogitization of granulite: Deep crustal EQs (Tibet) – Feng Shi
- Blueschist – eclogite facets transition (upper Wadati-Benioff plane seismicity) – Sarah Incel
- Dehydration in serpentinite-olivine complex (lower Wadati-Benioff plane seismicity) – Thomas Ferrand
- Degassing of carbonates (volcanic eruption and energy release) – Tahar Hammouda
Current facility status

• All experiments at 13-BM-D, up to 65 keV
• 6 mm TEL (up to ~5 GPa, ~ 55 tons)
• PZT transducers (2-3 MHz, bandwidth 0.1-0.2 MHz)
• InSite Lab™ hardware and software

“Ringing” in PZT records
Progress in DDIA-30 for AE

• Anvil diameter: 75 mm (D-DIA: 23 mm)
• Load capacities: >500 tons (D-DIA: 100 tons)
• Mechanically more robust – less distortion from designed symmetry
• Easy to switch assembly size (MA-6-6 cells)
• But long signal path length (Could mount transducers under second-stage anvils)
Pressure generation tests

Non slotted WC anvils, 6/9 cell

Load, Tons

Pressure, GPa

Versimax SD anvils

D1444

D1446

D1645

Slotted WC anvils, 6/9 cell

Load, T

Pressure, GPa

Fired pyrophyllite

Will test tougher carbide

AE Workshop, Jan, 2016
More on-going tests

- So far only been to 80 tons
- Will optimize geometry
- Optimal (tougher) WC grade

Compound anvils
New SD materials?

- Experiments show that strength of SD depends on sp³ bonding
- Versimax has no sp³ bonding
- Sumitomo WD700/800 has highest sp³ bonding.
- WD800 (with metals leached out) may be a good choice for transparent anvils
Can we conduct micro-/nano-seismology in the lab?

- More accurate event locations
- Record both P and S waves – compound transducers
- Waveforms that accurately reflect rupture processes in the sample – broadband transducers
- Faster sampling rates
- Better detection sensitivity
- Knowledge on “station” response function
- Etc.
Improving spatial resolution for AE location

Before applying the DD cross-correlation algorithm

After applying the DD cross-correlation algorithm

Waldhauser & Ellsworth, BSSA, 2000
A test using hypoDD:
D1279 - 593 events

Simple “10^-6 scaling rule”: km → mm, s → μs

Analysis performed by L. Zhu

Group 1: 121 events

Group 2: 99 events

Omega

Omega
Spatial distribution
Event location

Event time sequence

Green, 1994

Cross-correlation increases detection sensitivity

Waveforms in the black box multiplied by 10
Optimizing transducer bandwidth

<table>
<thead>
<tr>
<th>$f_c$, MHz</th>
<th>$\lambda$, mm</th>
<th>$\tau$, $\mu$s</th>
<th>$L_R$, mm</th>
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<td>0.4</td>
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</table>

$f_c$ - transducer center frequency  
$\lambda$, $\tau$ – wavelength and period for $V_p$  
$L_R$ - detectable rupture length ($\approx \tau \times 2.5$ km/s).  
Assuming rupture speed $= 0.5 \times V_S$ and $V_S \approx 5$ km/s and $V_p \approx 8$ km/s for Mg$_2$GeO$_4$ olivine.

Mechanically damped transducers, NDTT, LLC
Spring-load mounting design for reuse
How to characterize transducer response function in the D-DIA?

• InSite pulsing function? Arbitrary waveform generator (Tektronix)?
• What’s the best waveform?
• Calibration over a (least lossy) WC cube?
Short-term tasks

• Higher P-T capabilities
• Test new transducers, develop P/S-wave transducers
• Minimize system asymmetry for better cross-correlation analysis – use 6 identical anvils
• Better cell designs – higher TC survival rate, lower P-T gradients, etc.
• Easier beamline controls
Long-term goals/challenges

- Expand AE detection technology (detecting both P and S waves; optical versus piezo?)
- Increase spatial resolution to sub-microns
- Increase time resolution (MBA upgrade)
- “Nanoseismology” – full waveform analysis/focal mechanism modeling, in collaboration with seismologists
  - Source characterization and focal mechanism (L. Zhu, SLU)
  - Simulations of wave propagation in solid media in DDIA (Y. Shen, URI)
- Seeking connections among various scales: sub-micron (individual AE) – mm (lab sample faults) – km (geological settings)
AEs in pre-cut Wesley granite

Ghaffari & Young, Sci Rep, 2013
AE rate versus failure in steel

Isochorically tempered Fe-3.5Ni-0.21C steel
Model based on dislocation band propagation

Can we resolve stress drops during AE occurrence?

Wadley et al., Mat. Sci., 1981
Kumar et al., PRB, 2015

AE Workshop, Jan, 2016
Are scaling laws on strength of solids related to mechanics or to geometry?

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One of the largest controversial issues of the materials science community is the interpretation of scaling laws on material strength. In spite of the prevailing view, which considers mechanics as the real cause of such effects, here, we propose a different argument, purely based on geometry. Thus, as happened for relativity, geometry could again hold an unexpected and fundamental role.

Nature, 2005

Tsai et al., PRL, 2016
Your inputs are important!