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Title: Configurational affects on the compaction response of CeO2 powders

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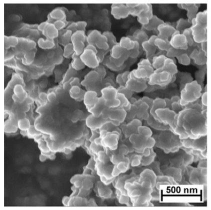
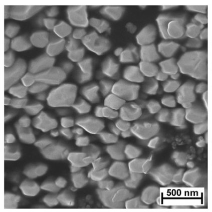
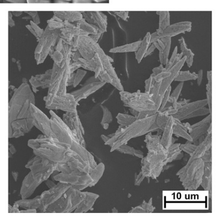
Configurational affects on the compaction response of CeO_2 powders



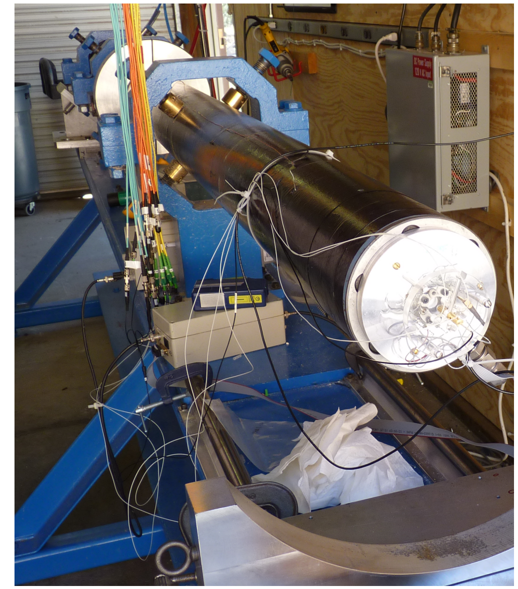
300 nm



equiax



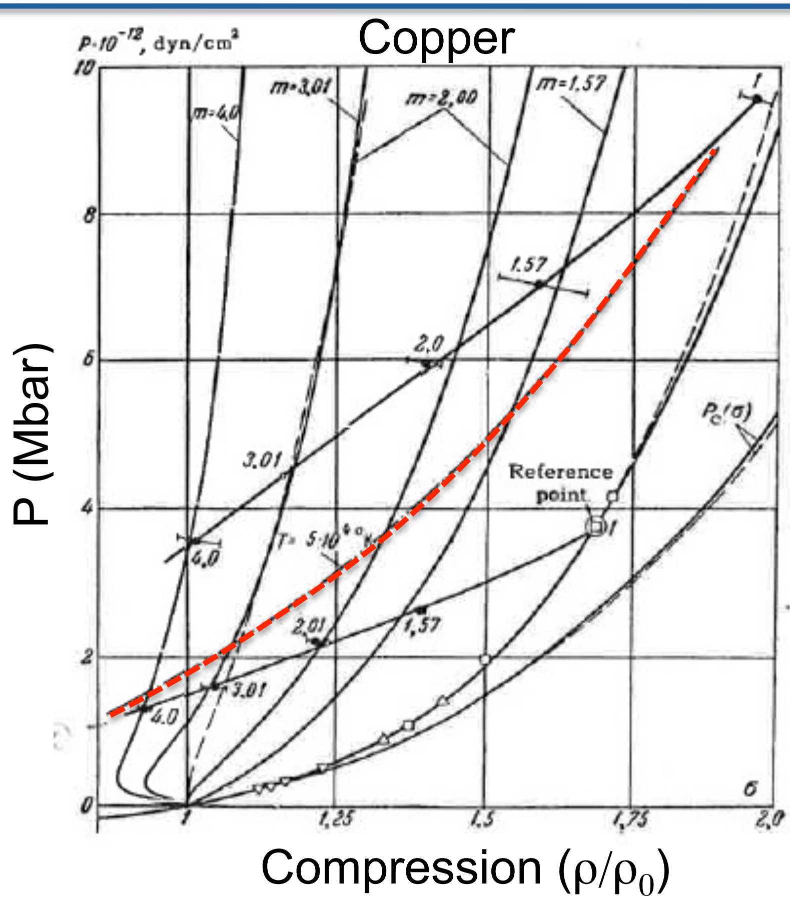
rods



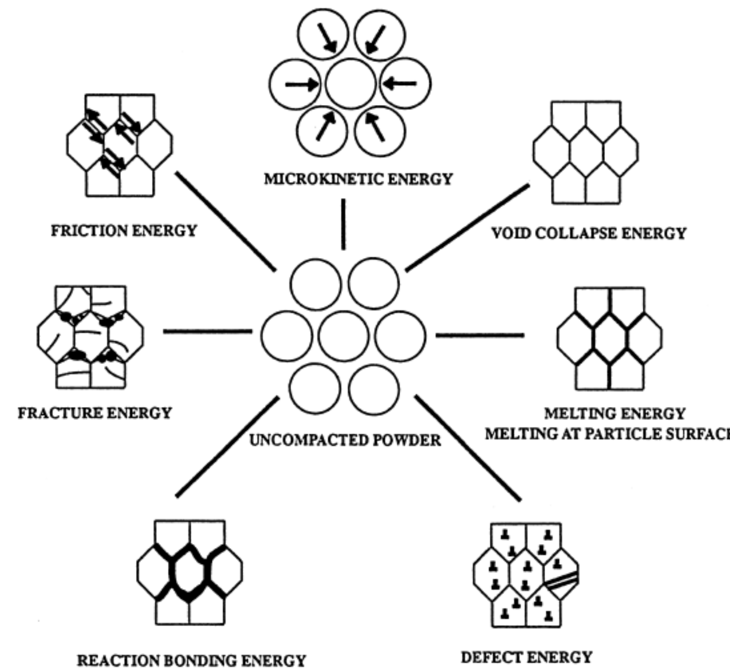
Anthony Fredenburg
WX-9: Shock and Detonation Physics
Los Alamos National Laboratory

Collaborators: P.A. Rigg, D. D.-Koller, R.J. Scharff, D.M. Dattelbaum (WX:-9); E.D. Chisolm (T-1); B.P. Nolen, D.J. Alexander (MST-6)

Shock response of powders more complex than solids



Excess energy for porous materials leads to a “family” of Hugoniots for a given material



Kormer, Funtikov, Urlin, Kolesnikova (1962);
Meyers, Benson, Olevsky (1999)

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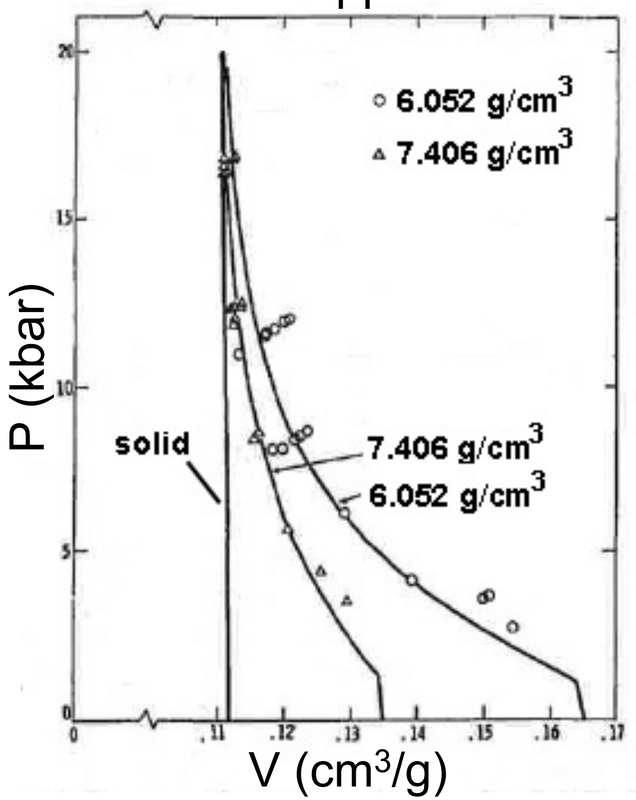
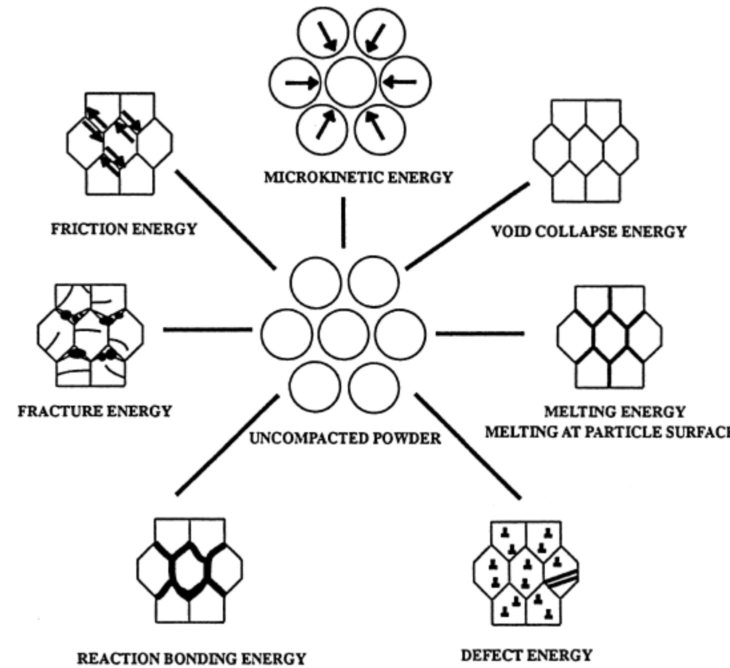
EST. 1943

Shock response of powders more complex than solids



Excess energy for porous materials leads to a "family" of Hugoniots for a given material

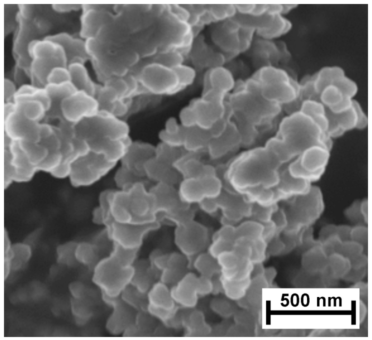


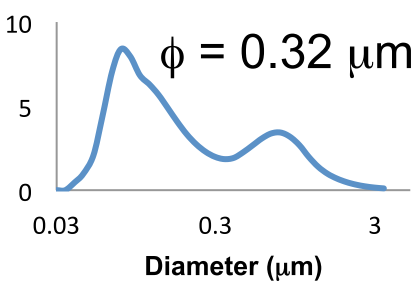
How can we improve predictive capabilities through physically based theory and experiments?

Boade (1968)
Meyers, Benson, Olevsky (1999)

CeO_2: a metal-oxide system

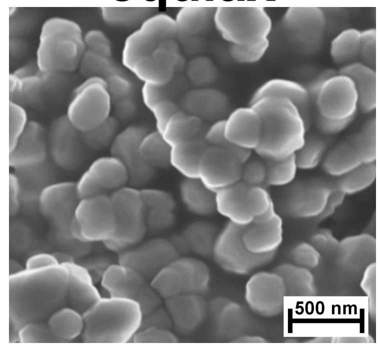
300 nm

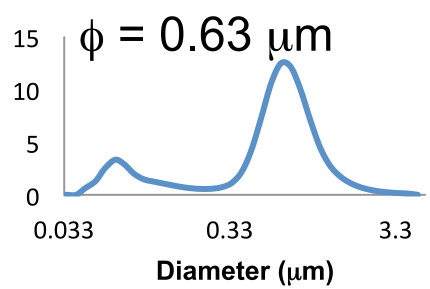




Surface Area (m^2/g)
10.72
Bulk Density (g/cm^3)
1.00
Tap Density (g/cm^3)
1.41

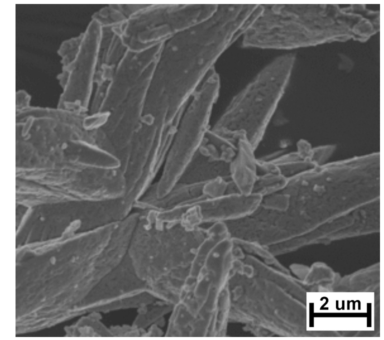
equiax

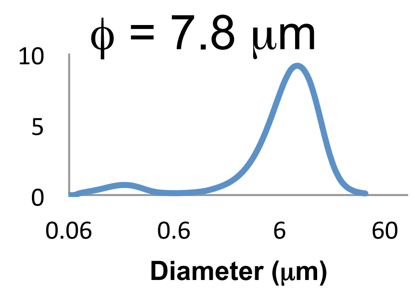




Surface Area (m^2/g)
3.34
Bulk Density (g/cm^3)
1.27
Tap Density (g/cm^3)
2.13

rods





Surface Area (m^2/g)
6.28
Bulk Density (g/cm^3)
1.01
Tap Density (g/cm^3)
1.62

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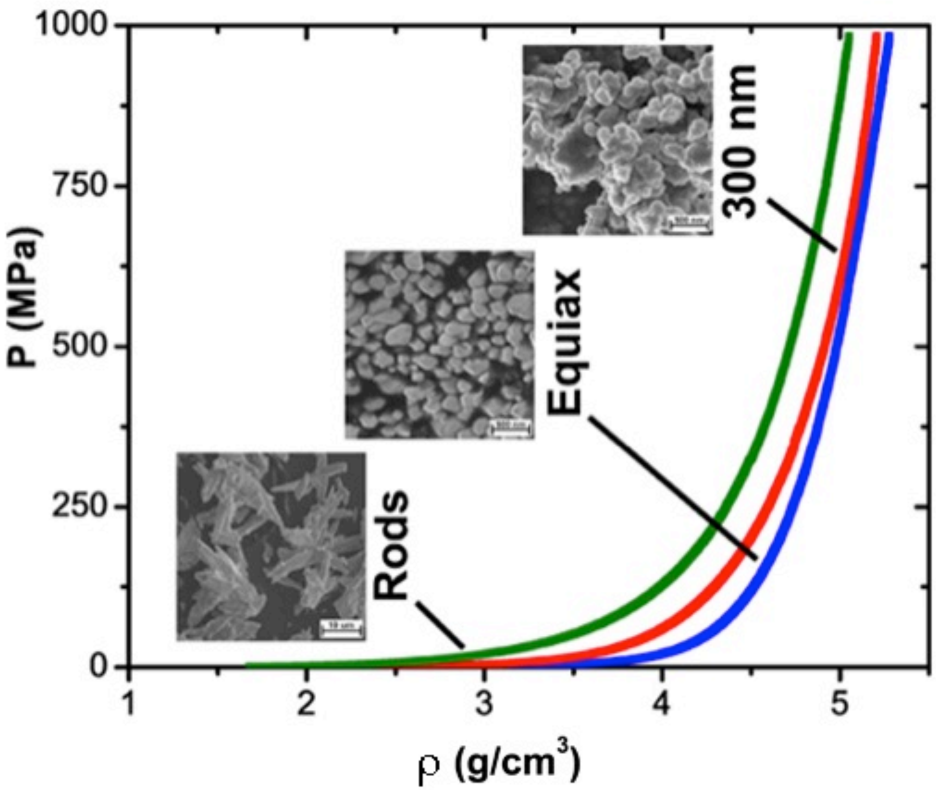
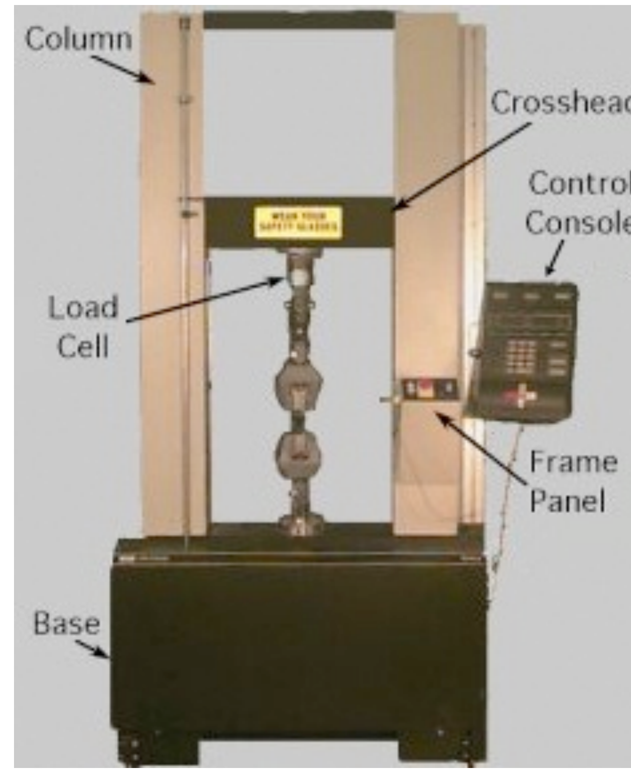
Uniaxial compression tests reveal morphology-dependent compaction response

ϕ = 12.7 mm I.D., Max Load = 125,000 N, Max P = 980 MPa,





Early stages of compaction strongly influenced by particle shape, equiax morphology most easily compressed

mtil.illinois.edu/eq-load.htm

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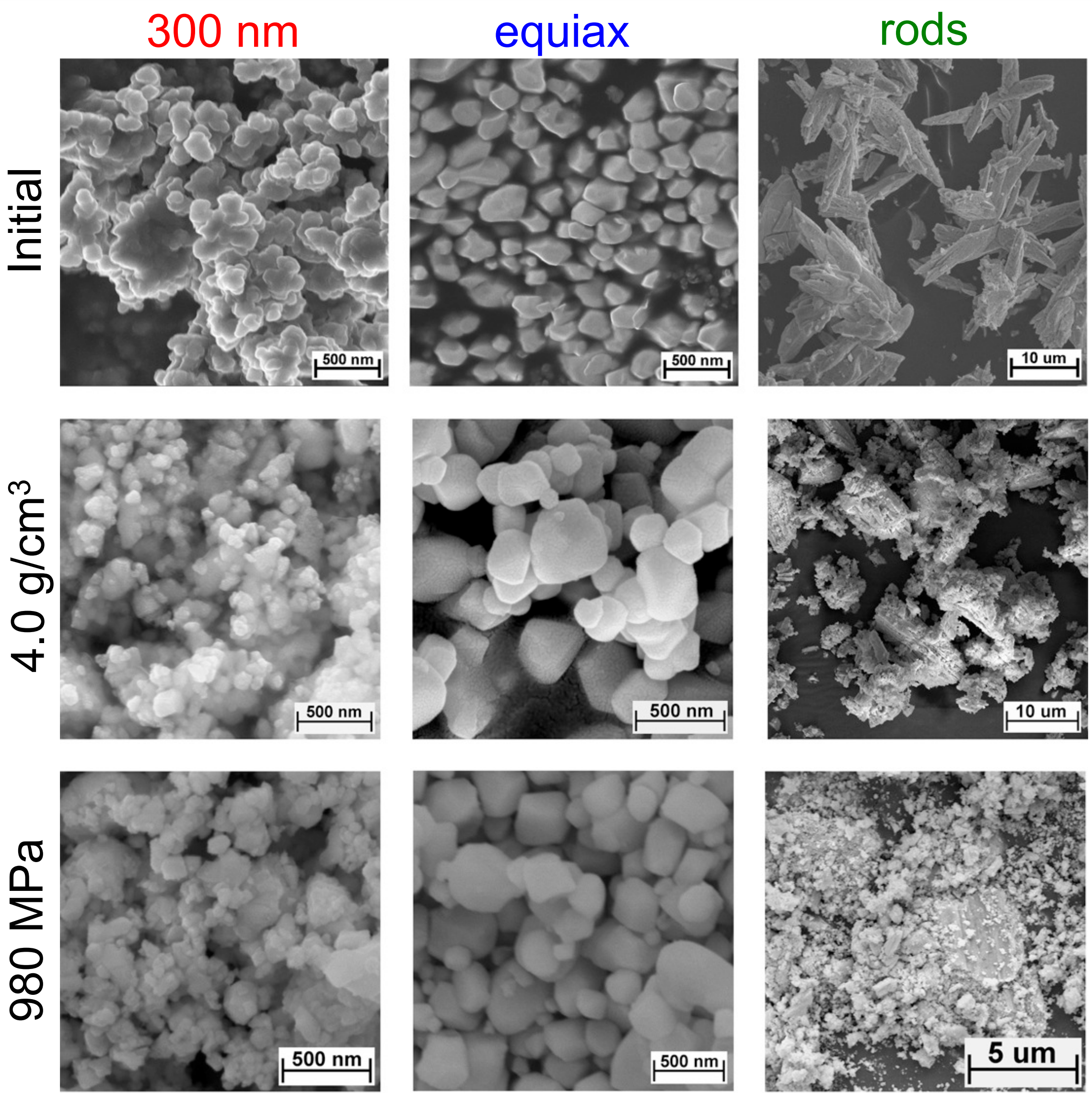
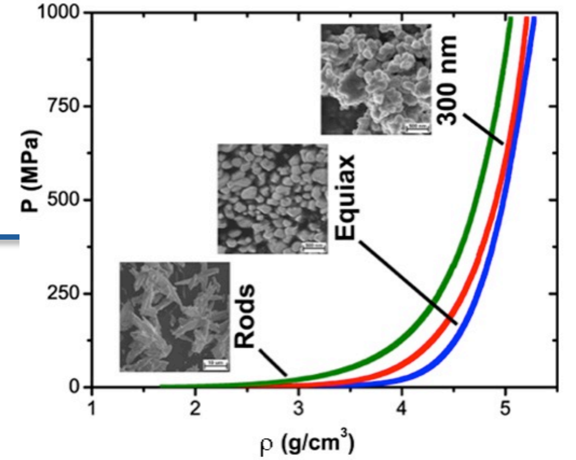
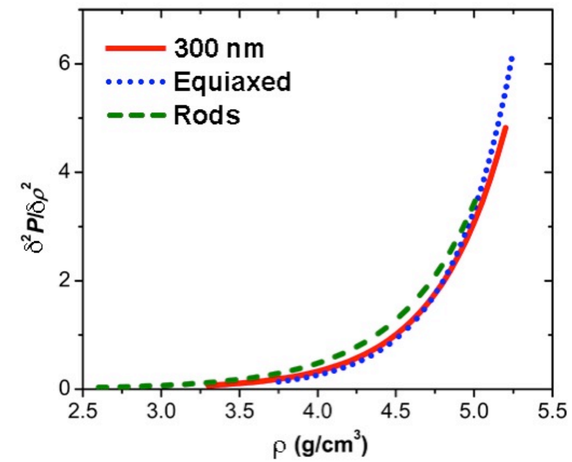
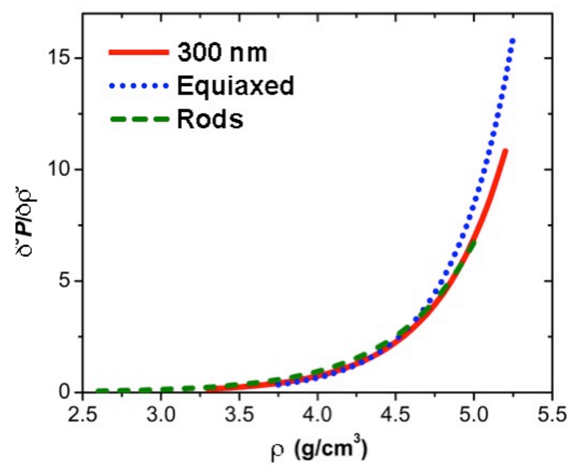
Fractionation occurs for rods, 300 nm & equiax retain microstructure









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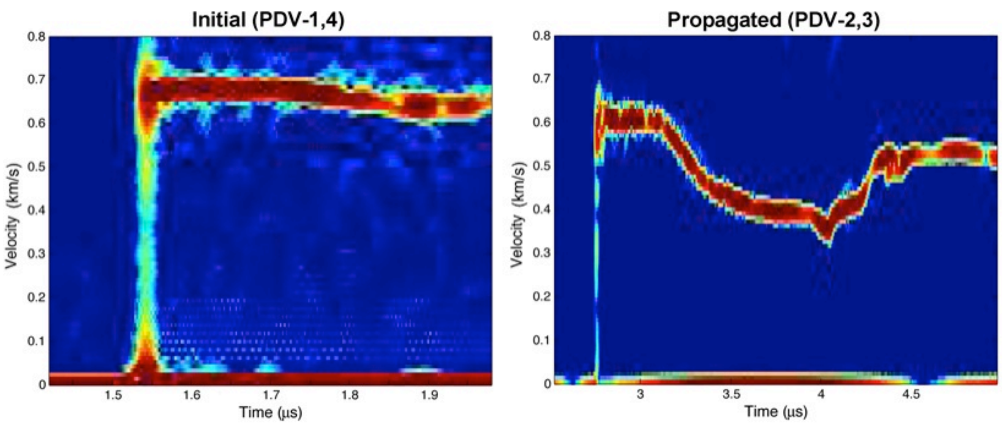
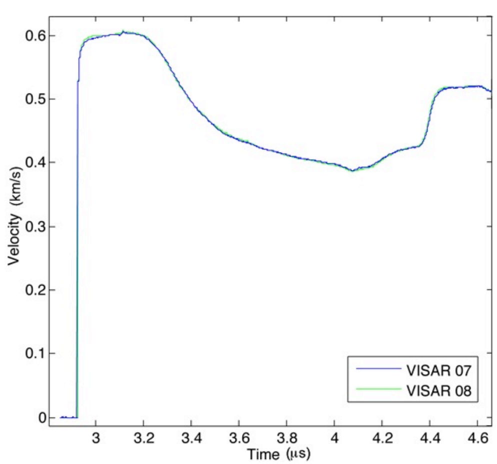
Dynamic experiments performed over velocity range 0.15 – 5.6 km/s

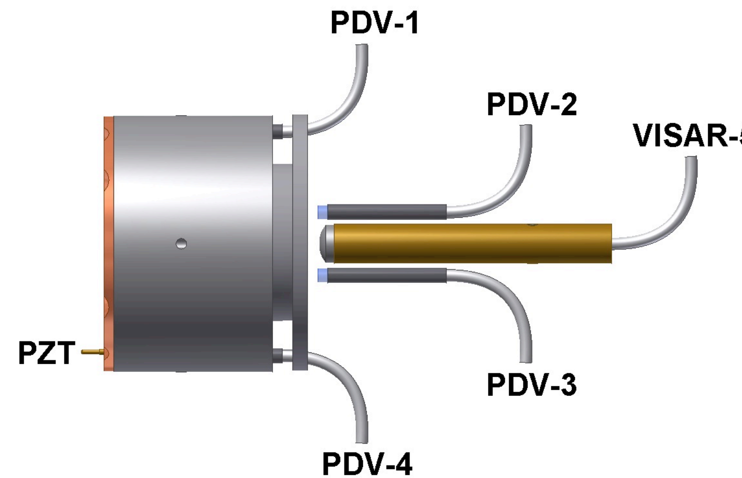
Powders pressed into target fixture to 4.0 g/cm^3

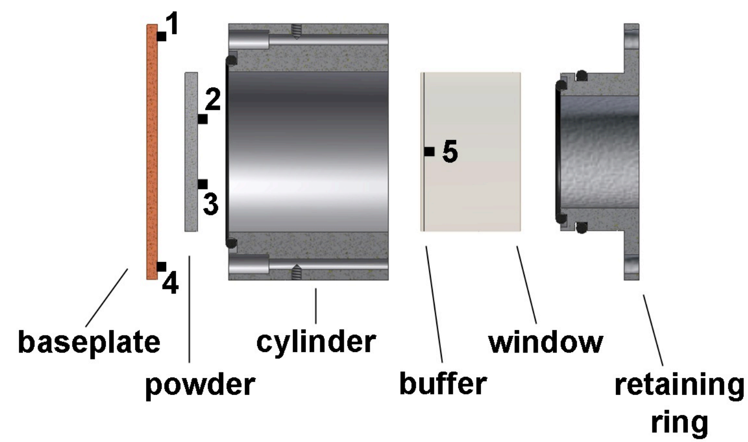
Heterodyne velocimetry (PDV) used to measure shock transit time, U_S, through powder





Transmitted waves recorded with VISAR





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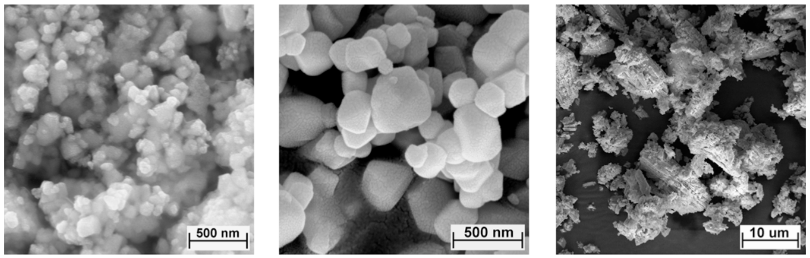
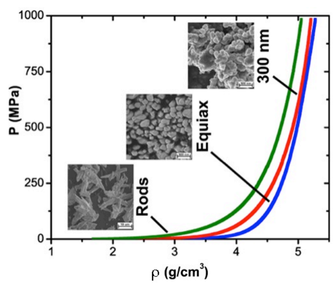
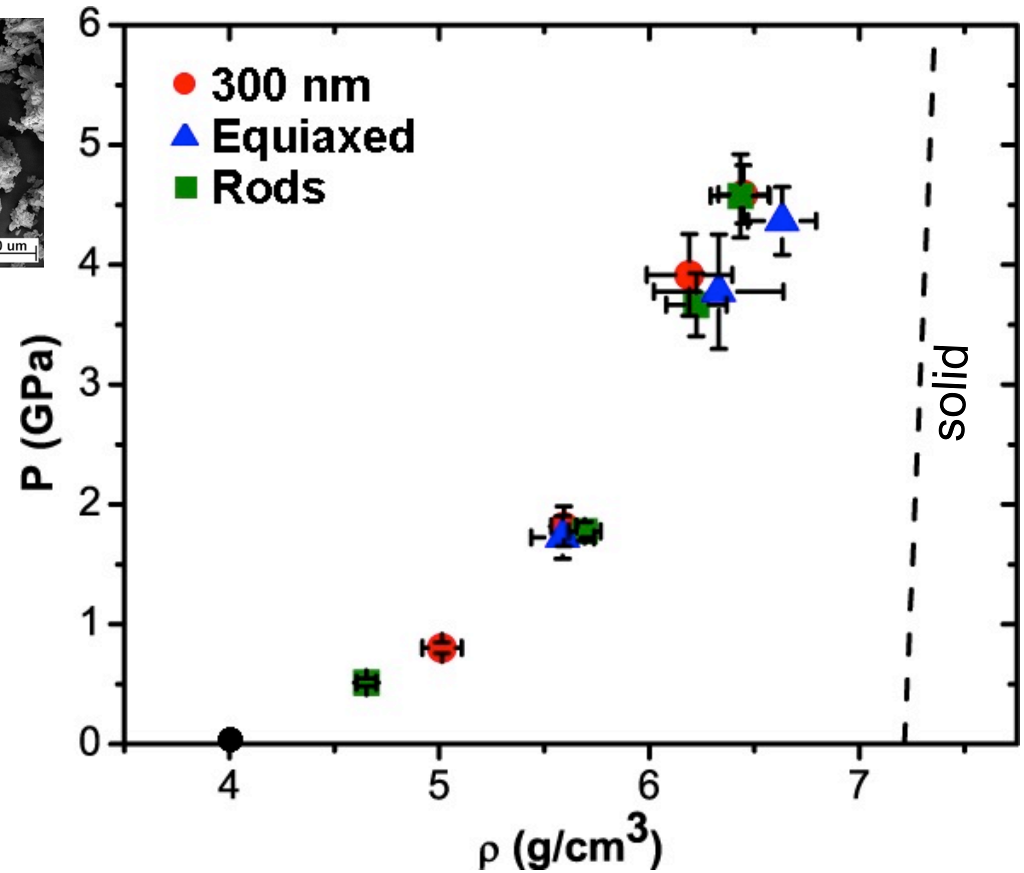
Dynamic response not morphology-dependent at low stresses

300 nm **equiax** **rods**



At 4.0 g/cm^3 semi-continuous particle network likely exists





Incomplete compaction regime for the three powders could be represented well by a single model (P-α, P-λ)

Chisolm, LA-UR-12-21066 (2012)

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Complex response at high stresses

Rods:

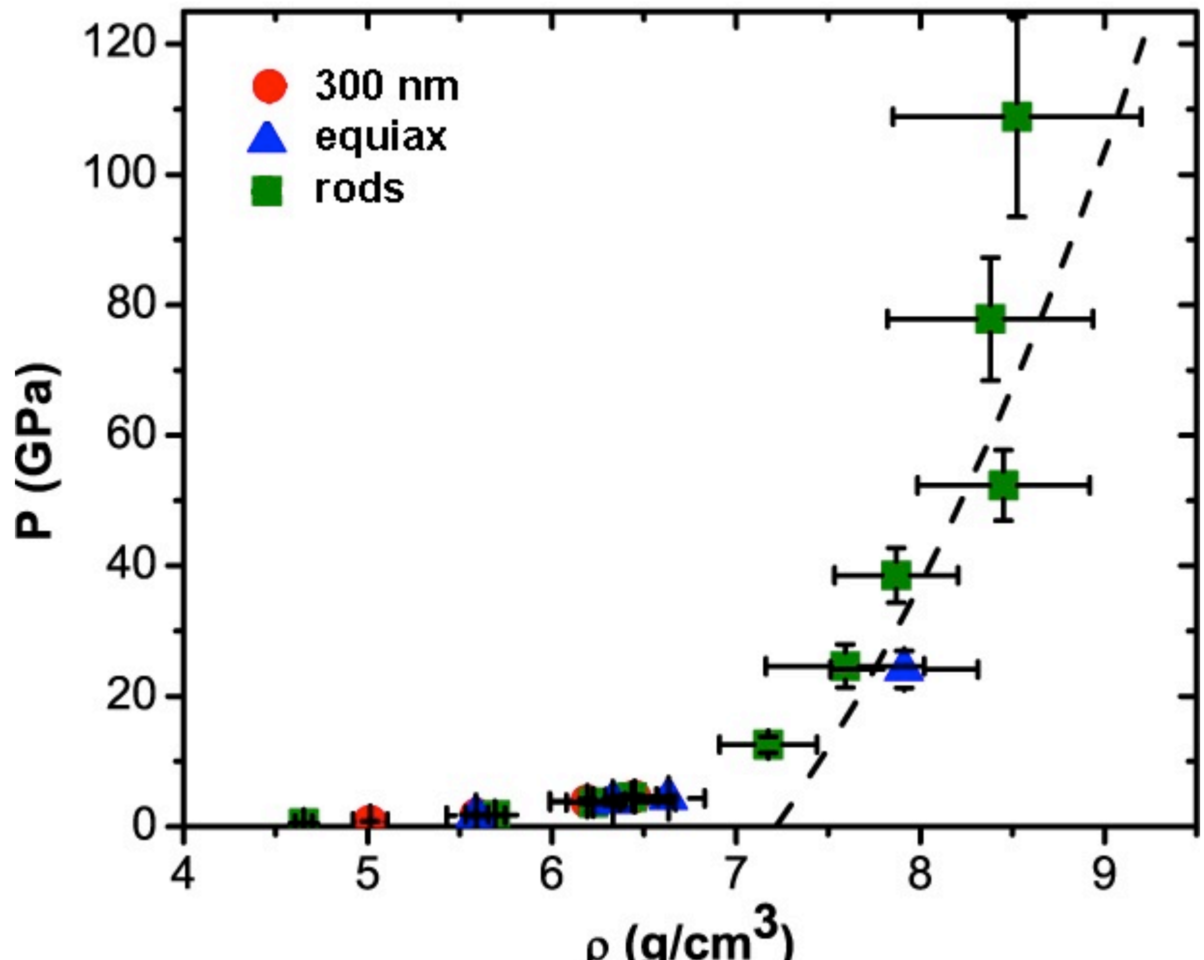
Normal compaction up to 40-50 GPa

Solid density reached at 13-14 GPa

Vertical P-ρ response above 50 GPa

Rods and Equiax:

Densify past calculated solid Hugoniot



What causes anomalous behavior?

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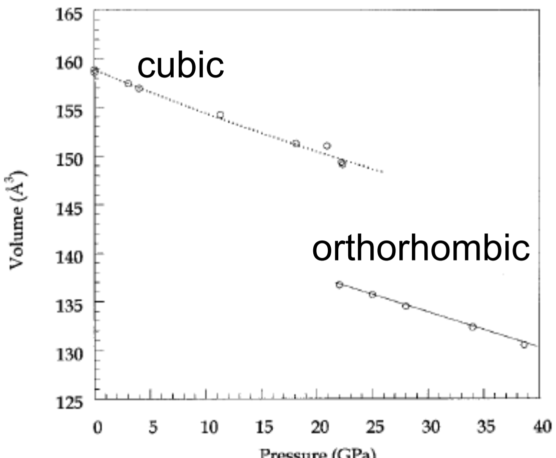
Potential mechanisms to describe response include

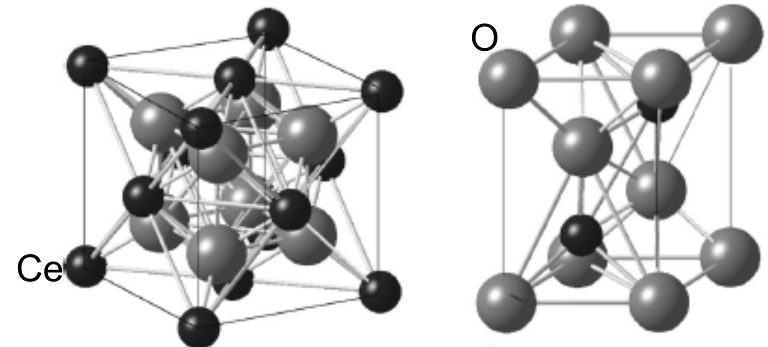
P-V Diagram



7.5% volume decrease

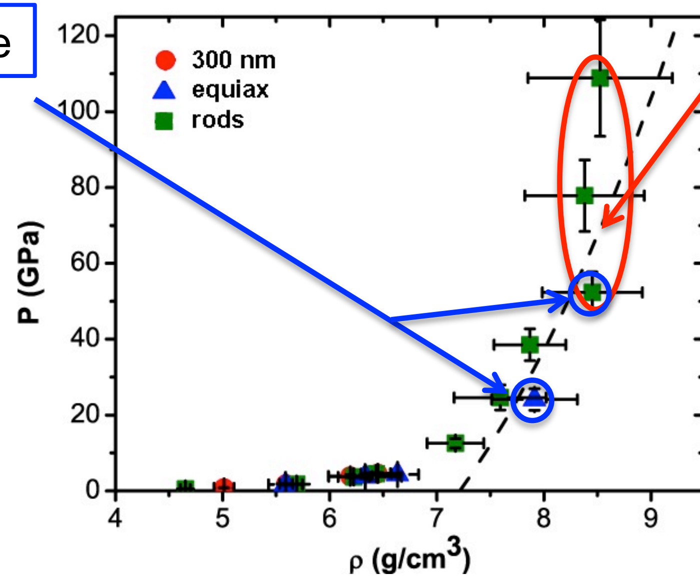
Phase change
cubic → orthorhombic

CeO_2 Ce_2O_3



cubic fluorite → hexagonal

16% volume increase



Stoichiometry change
CeO_2 → Ce_2O_3

Wang, Saxena, Pischedda, Liermann, Zha (2001)
Skorodumova, Ahuja, Simak, Abrikosov, Johansson, Lundqvist (2001)

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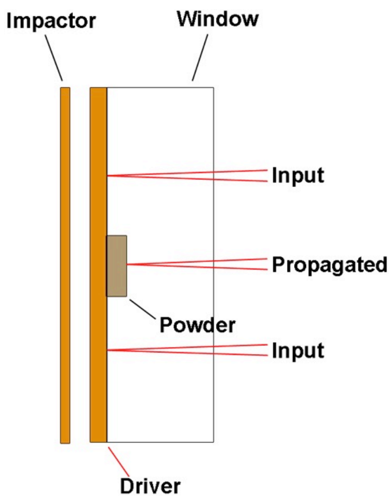
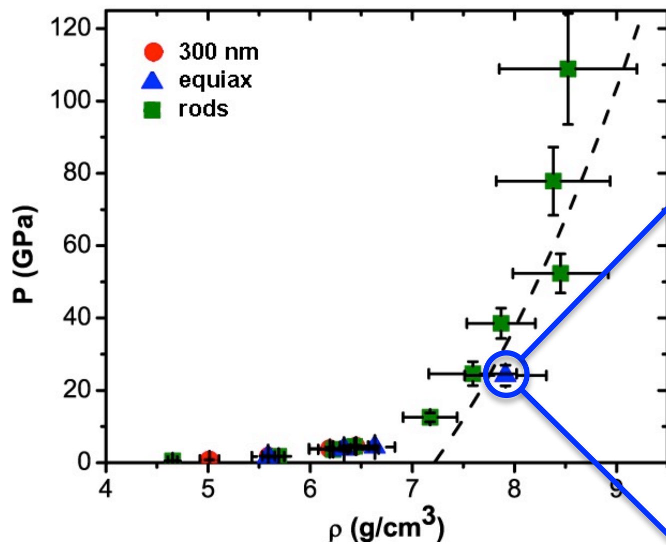
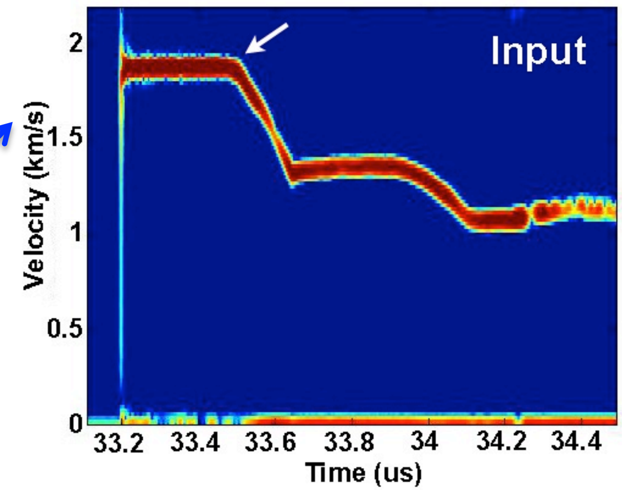
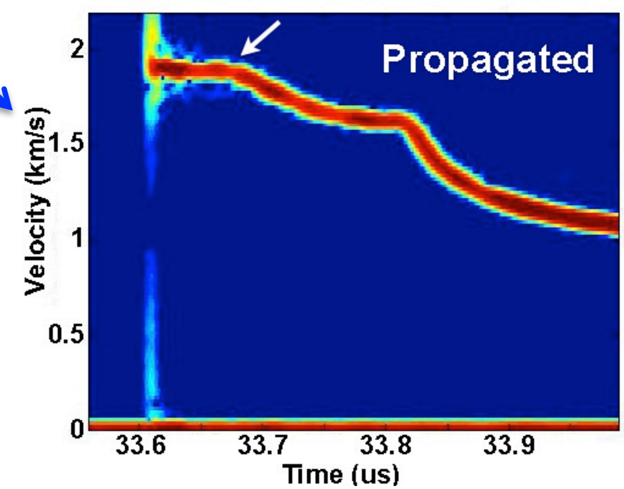
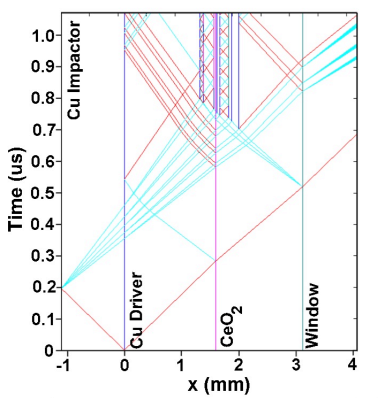
Sound speed at pressure may also help identify transition











Equiax (@ P = 24.11 GPa)
C_L ~6.8 km/s
C ~3.5 km/s

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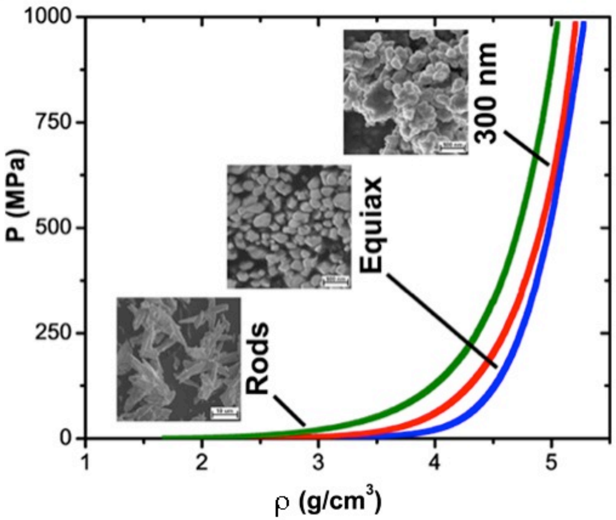
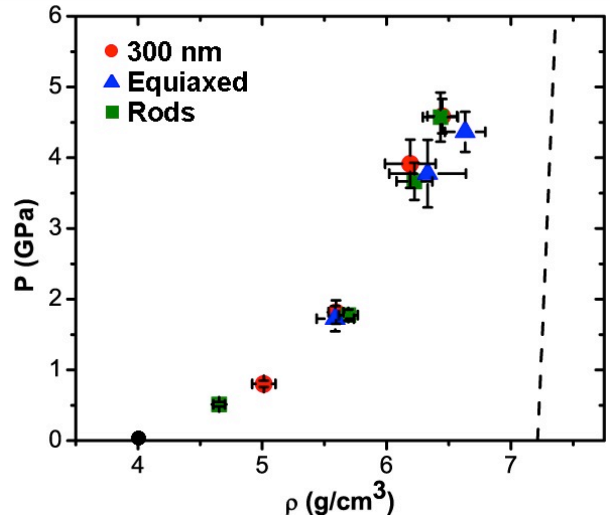
Influence of configuration varies with strain-rate and stress



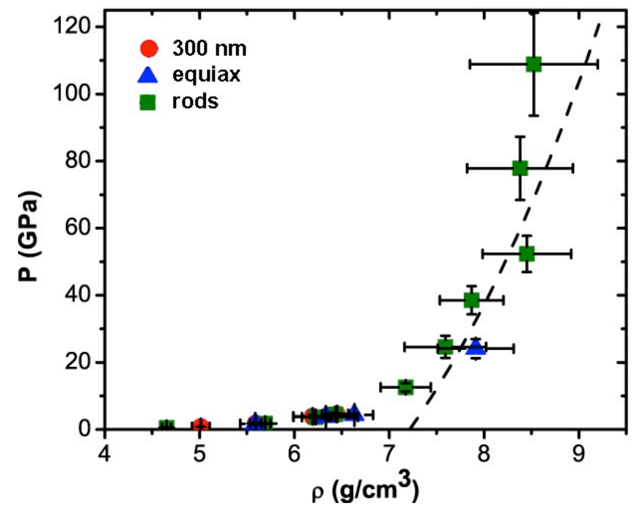
Low Stress
Low-Strain-Rate

Strongly influenced, especially during initial rearrangement



Moderate Stress
High-Strain-Rate

Minimal influence, possible deviation of exuiax as *P* increases



High Stress
High-Strain-Rate

Possible influence, crosses solid Hugoniot at lower stresses

Work underway to populate high stress region with additional EOS and sound speed at pressure measurements to further elucidate role of particle configuration

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