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NUMERICAL MODELING OF THE STRUCTURAL HETEROGENEITIES AND BRITTLE BEHAVIOR OF THE ABA PANU (L3) METEORITE

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Why Study Meteorite?

- **Near earth objects (NEOs) such as asteroids represent potential hazard to human civilization**
- **The breakup of NEOs in Earth's atmosphere depends not only on hypersonic aerodynamics but also on the strength and physical properties**

Asteroid Meteoroid Meteors Meteorites

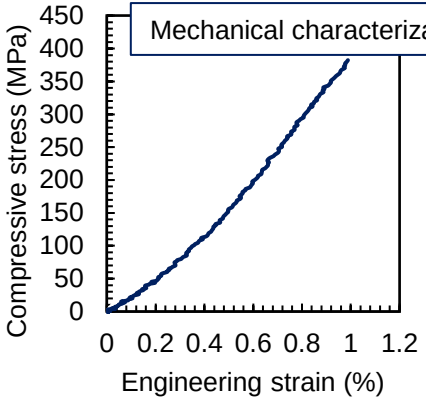
Image credit: NASA

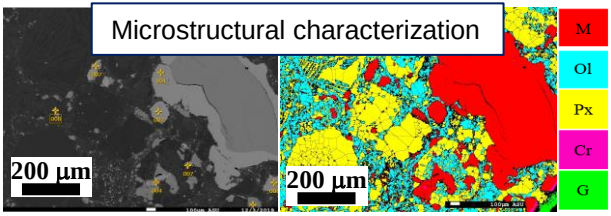
Why Study Meteorite?

- **Meteorites provide important clues to understanding the formation and properties of their asteroidal parent bodies.**
- **Although abundant studies have been conducted on the chemical and physical properties of meteorites, our understanding of their fundamental mechanical properties and failure is limited♦**
- **Hence modeling the mechanical response and failure along with experimental investigation of structural heterogeneity allow us to predict the behavior of meteorite subjected to compressive loading**

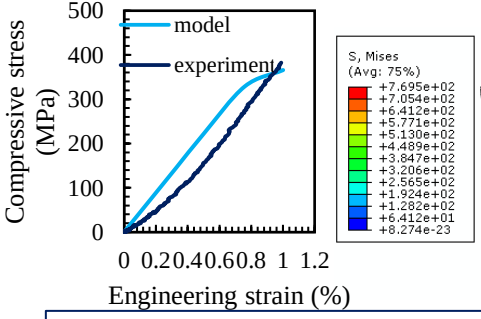
(*Cotto-Figueroa, 2016, ♦Ostrowski, 2019, ♦Pohl, 2020)

Previous Study of Aba Panu (L3)

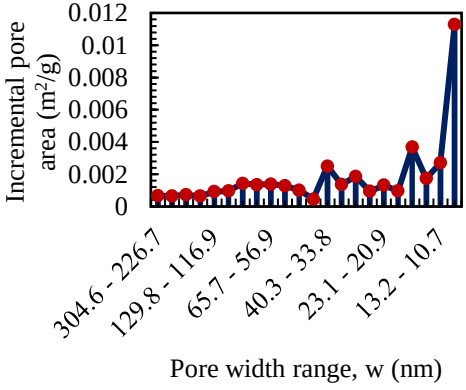




(M= Fe-Ni and FeS metal grain, Ol= olivine, Px= Pyroxene, Cr= Chromite, and G= glass



Numerical modeling of Aba Panu (L3)



Pore size distribution of Aba Panu (L3)

Rabbi et al., 2021

Modeling the brittle failure

- **Effective medium theory presents total strain as a function of matrix strain and extra strain induced by the microcracks.**

$$\varepsilon_{ij} = \varepsilon^{o}_{ij} + \Delta\varepsilon_{ij} = (S^{o}_{ijkl} + \Delta S_{ijkl})\sigma_{kl}$$

- **For one dimensional analysis, non-linear elastic response of meteorite can be modeled assuming cracks (preexisting microcracks) axial strain as a function of axial stress**

$$\varepsilon_1 = \frac{\sigma_1}{E} + V_m[1 - \exp(-\frac{\sigma_1}{n})]$$ ♦

where, model parameter, Vm represents maximum closure strains of microcracks and n is a model parameter with stress unit

♦ Peng et al., 2015

Modeling the brittle failure

- **Damage due to initiation of new cracks under compression and its growth can be written as**

$$\sigma = E\varepsilon(1-D)$$

- **Assuming strength of microcrack elements obeys Weibull distribution, micro element damage rate can be written as**

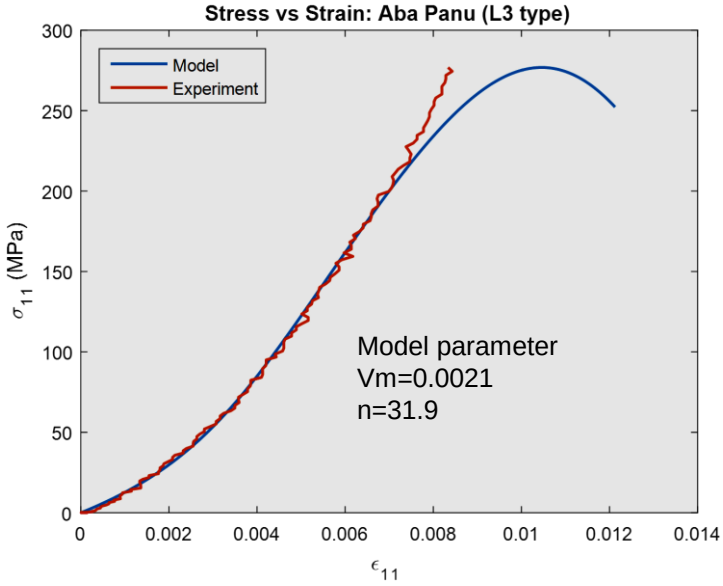
$$\frac{dD}{d\varepsilon} = \frac{m}{a}\varepsilon^{m-1}\exp(-\frac{\varepsilon^m}{a}) \quad ♦$$

Weibull shape parameter, m and scale parameter, a can be calculated based on peak stress, σ_c and peak strain, ε_c using following equations

$$m = \frac{1}{\ln(E\varepsilon_c / \sigma_c)}, and \;\; a = m\varepsilon_c$$

♦ Yang et al., 2005, Li et al., 2021

Modeling the brittle failure



- **Developed model agrees well with experimental results**
- **Model parameter n determines how crack closure behaves as n increases and crack-closure effects start to minimize.**

Rabbi et al. 2021 (in preparation)

Conclusion

- A model combining a phenomenological model of crack closure and a damage constitutive relationship is developed for the brittle behavior of Aba Panu (L3) meteorite

- The model predicts the initial crack closure due to the compression loading, which closely follows the damage progression

- In future the variability in strength and elastic response and an appropriate damage mechanism will be developed to capture the heterogenous brittle response of Aba Panu

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