STRAIN-RATE DEPENDENT BRITTLE DEFORMATION IN ROCKS. A. S. P. Rae[1*], T. Kenkmann[1], V. Padmanabha[1,2], F. Schäfer[1,2], M. H. Poelchau[1], A. Agarwal[1], M. Dörfler[1], and L. Müller[1]. [1]Institute of Geology, University of Freiburg, Albertstrasse 23b, 79104 Freiburg, Germany, auriol.rae@geologie.uni-freiburg.de, [2]Fraunhofer Ernst-Mach-Institute, Freiburg, Germany.

Introduction: During impact cratering, a significant volume of rock is subjected to extreme deformation conditions. Brittle deformation under these conditions, where strain rates can be in excess of 10^1 to 10^2 s^{-1}, is rate-sensitive. Typically, rocks are stronger when deformed at high strain-rate conditions, e.g. [1], this occurs because fracture propagation has a limited velocity; at high loading rates, the weakest flaws in a material are not able to cause failure before other, increasingly strong flaws are activated. We aim to assess the significance of strain-rate sensitive brittle deformation on the cratering process in various rock types. Numerical impact simulations, so far, do not take strain-rate dependency into account.

To begin our investigation of rate-dependent rock failure in the context of impact cratering, we have focussed on the behaviour of common crustal lithologies: gneiss, basalt, granite, and sandstone. Here, we have obtained mechanical data at strain rates ranging from quasi-static (~10^{-6} s^{-1}) to dynamic (~10^3 s^{-1}). In addition, we have carried out micro-structural analysis on the products of the mechanical experiments.

Methods: Mechanical data and samples for microstructural analysis were obtained using a triaxial loading frame and a Split-Hopkinson Pressure Bar (SHPB). The triaxial loading frame achieves strain rates from 10^{-7} s^{-1} to 10^{-4} s^{-1}, while the SHPB achieves strain rates from 10^0 s^{-1} to 10^3 s^{-1}.

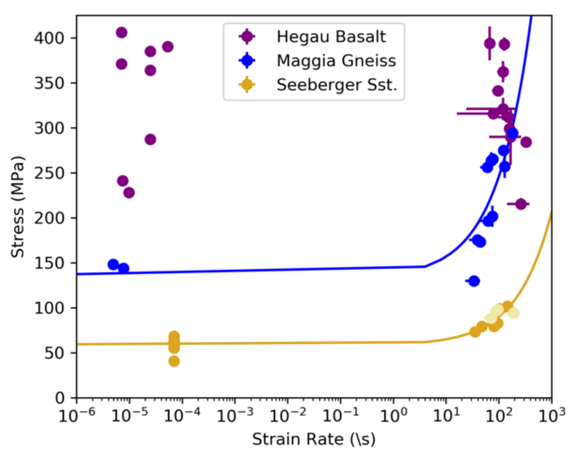

Figure 1: Strain-rate dependent strength of basalt, gneiss, and sandstone (sandstone results of [1] shown in pale yellow). Mechanical data derived from triaxial rock press and Split-Hopkinson Pressure Bar (SHPB). Maggia Gneiss data was acquired with the direction of maximum principal compression parallel to the gneissic foliation.

To carry out our investigation, we have collected samples of gneiss (Maggia, Switzerland), basalt (Hegau, Germany), granite (Marlsburg, Germany), and sandstone (Seeberg, Germany). These samples were prepared for mechanical testing by coring 41 mm diameter cylinders. Cylinders for the triaxial loading frame were 82 mm in length, while samples for the Split-Hopkinson Pressure Bar were typically 41 mm in length, some shorter and longer samples were prepared to facilitate varying of strain-rate.

From the mechanical experiments, the strain-rate dependency of strength was calculated and samples were generated for microstructural analysis. Microanalysis of the deformed samples includes particle size analysis of fragmented material, petrographic characterisation, and white-light interferometry of fracture surfaces.

Results: Preliminary results show dynamic strength increases in Maggia Gneiss and Seeberger Sandstone at threshold strain rates > 12.8 s^{-1} and 24.7 s^{-1}, respectively [2]. Interestingly, no clear dynamic strength increase is observed in Hegau Basalt up to strain rates of 350 s^{-1} (Figure 1).

Microstructural characterization of the resultant rock samples show a progression of increasing fragmentation with increasing strain-rate (Figures 2 and 3). In addition, our results demonstrate that the onset of pulverization is lithology-dependent and is correlated with the characteristic strain rate for the onset of dynamic strengthening.

Discussion: Here, we present parameters that describe dynamic strength during compressive failure in a variety of common rocks. Furthermore, failure under dynamic compression results in progressive fragmentation that can also be parameterized. Our results therefore allow for dynamic strength, and compressive fragmentation models to be implemented in shock physics codes.

In addition to the results described, we aim to characterize rock failure and fragmentation in dynamic tensile conditions, and to expand our compressive results to the highly dynamic regime (~10^6 s^{-1}) using flyer plate tests.

References: [1] Zwiessler R. et al. (2017) *Journal of Structural Geology* 97:225-236. [2] Kimberley J. et al. (2013) *Acta Materialia* 61:3509-3521.

Acknowledgments: This work was funded by DFG project (Ke732/27-1). Herbert Ickler is thanked for technical support during sample preparation.

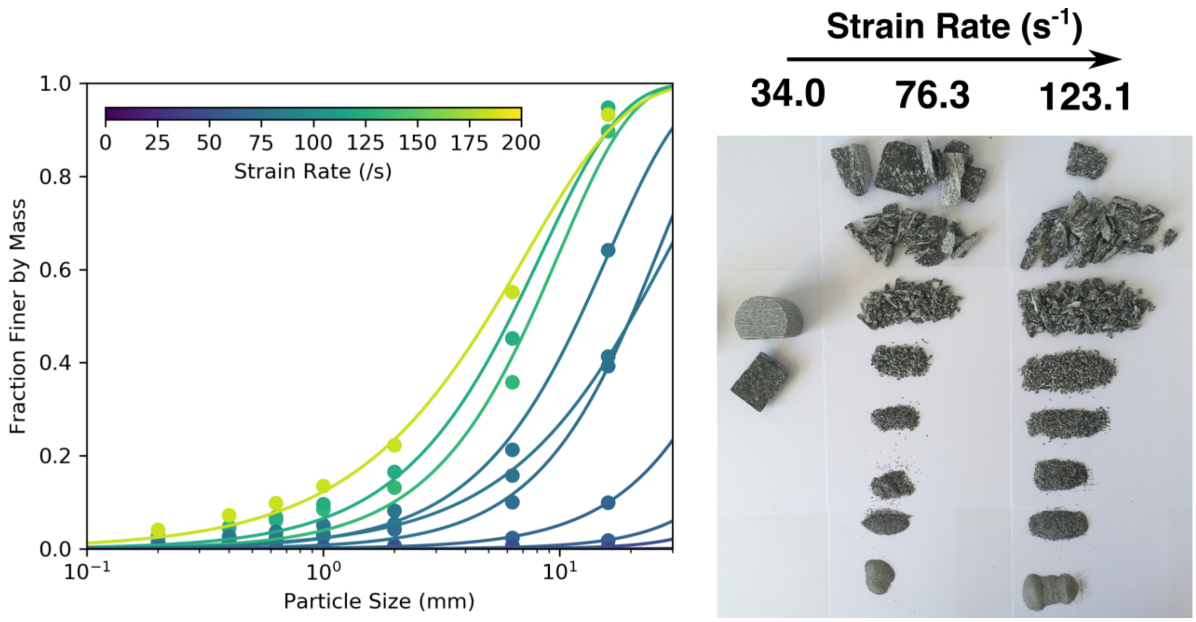

Figure 2: Fragmented Maggia Gneiss and their fragmented size distributions. Points are measured data while lines are fitted Weibull distributions, both are colored by the strain rate at failure (Figure 1).

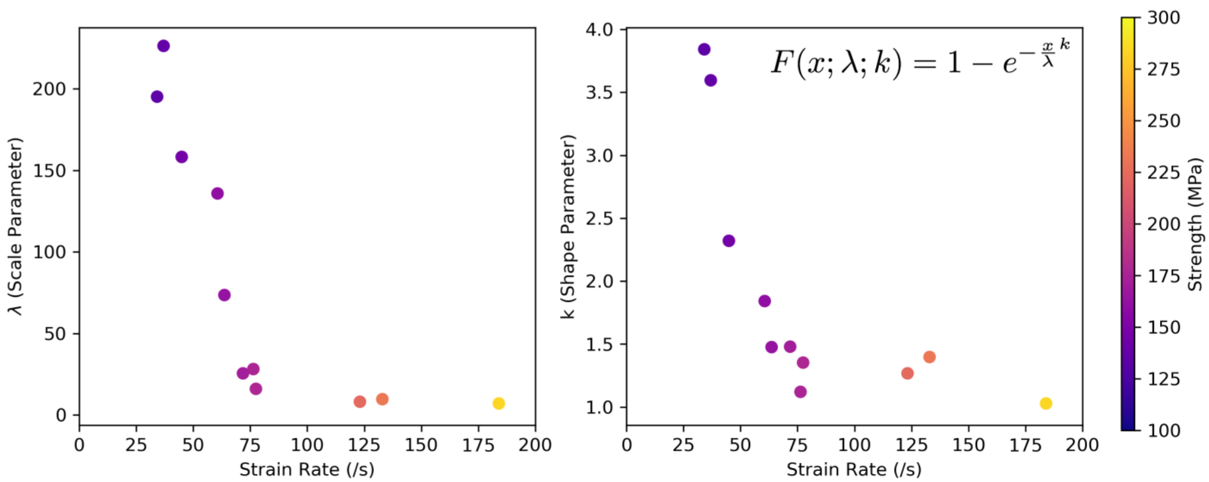

Figure 3: Variation of the parameters of the Weibull distributions of fragmented Maggia Gneiss (Figure 2) with strain rate. The cumulative Weibull distribution function is shown, where λ and k are the scale and shape parameters respectively, and x is the fragment size. Points are colored by the stress at failure (strength).