PRACTICAL EXPERIENCES OF SHOCK BAROMETRY. A. S. P. Rae†. †Institute of Geology, University of Freiburg, Albertstrasse 23b, 79104 Freiburg, Germany, aurio1rae@geologie.uni-freiburg.de.

Introduction: Shock barometry is the process by which the thermodynamic conditions at which shock metamorphism occurred can be determined in naturally shocked rocks. It relies upon a combination of careful petrographic observation and the results of experimental shock studies.

Shock barometry can be carried out in a number of ways. The most common of which utilizes the mineral, quartz. Quartz is often used in shock barometry for three reasons: firstly, quartz is extremely common in crustal rocks; secondly, quartz is a robust mineral, and thirdly, quartz shows a large variety of solid-state shock metamorphic effects. In particular, quartz develops planar deformation features (PDFs; Figure 1) at a variety of crystallographic orientations dependent of pressure in the range between 5 and 35 GPa [1, 2]. Obtaining the orientations of PDFs in quartz in a sample (using a Universal-stage and following a specific method, e.g., [3]) and, using an experimentally determined calibration scheme, can be used to calculate an average shock pressure for the sample, e.g. [4].

In this talk, I will provide a number of examples of the value, uses, and limitations of shock barometry in impact cratering studies.

Clearwater Lake Impact Structures: Located in Northern Quebec, Canada, Clearwater Lake is the result of two impact events. Here, samples of shock-metamorphosed quartz-bearing lithologies at the West and East Clearwater Lake impact structures are used to estimate the maximum recorded shock pressures in three dimensions across the crater. These measurements demonstrate that the currently observed distribution of shock metamorphism is strongly controlled by the formation of the structural uplift. The distribution of peak shock pressures, together with apparent crater morphology and geological observations, is compared with numerical impact simulations to constrain parameters used to describe transient weakening during crater collapse [5].

Siljan Impact Structure: Located in central Sweden, Siljan is Europe’s largest impact structure. The structure has been heavily eroded since the time of impact, 380 Ma ago. Here, the results of a shock barometry study of quartz-bearing surface and drill core samples combined with numerical modelling. An observationally constrained model is used to estimate the original crater size, morphology, and the thickness of the sedimentary cover, as well as the amount of erosion experienced since [6].

Discussion: Shock barometry is a valuable tool in impact cratering research, nevertheless it is not without a certain number of limitations:

1) Observed volumes of shocked rocks in impact structures are inconsistent with expected shock volumes from equations of state and numerical impact models.
2) How can precise shock pressure estimates be made using observations of more than one specific mineral?
3) Are laboratory-based single crystal shock experiments directly applicable to shock barometry in natural rocks?
4) What should one do in the absence of quartz? And, are shock schemes of other minerals overly reliant upon the accuracy of the quartz calibration scheme?

Summary: Shock barometry is a fundamental approach used in impact cratering research. Here, several examples of the use of shock barometry in impact cratering studies will be shown and discussed. Despite its long-time importance in impact cratering studies, unresolved questions remain, and the development of shock barometric techniques is far from complete.


Acknowledgments: I wish to thank all of those who introduced me to shock barometry and collaborated with me over the last few years, notably: L. Ferrière, M. Poelchau, R. A. F. Grieve, and S. Holm-Alwmark.
Figure 1: Microphotographs of Planar Deformation Features (PDFs) (planar fracture (PFs) and feather features (FFs) can also be seen in (c)) in quartz grains from the Siljan impact structure [6].

Figure 2: Comparison between numerical impact models and shock barometry results from the West Clearwater Lake impact structure. a) Final simulation colored by peak shock pressure, b) simulated peak shock pressures in drill cores from West Clearwater Lake compared to c) number of Planar Deformation Features per grain (N*/n), a proxy for shock pressure, within drill cores. d) simulated radial peak shock pressure compared to e) N*/n within acquired field samples by radial distance from the crater center [5].

Figure 3: Comparison between the results of shock barometry at Siljan and numerical simulations of the Siljan structure at varying levels of erosion [6].