STRAIN SCANNING ACROSS A SHOCK-DEFORMED QUARTZITE/DUNITE INTERFACE USING NEUTRON AND SYNCHROTRON RADIATION. T. Kenkmann[1], K. Walther[2], A. Frischbutter[2], C. Scheffzük[2]; F. Eichhorn[3], M. R. Daymond[4], [1]Institut für Mineralogie, Humboldt-Universität zu Berlin, Germany, thomas.kenkmann@rz.hu-berlin.de [2]GeoForschungsZentrum Potsdam, Division 5; Telegrafenberg, Potsdam, Germany, [3]Forschungszentrum Rossendorf, Institut für Ionenstrahlphysik und Materialforschung, Dresden, Germany, [4]Rutherford Appleton Laboratory, Chilton, UK

Introduction: The composite and heterogeneous nature of rocks has a profound effect on the characteristics of shock metamorphism in a rock and leads to differences in strain, stress and temperature compared to that expected for a homogenous system. The present study [1] is devoted to obtain a better understanding of shock related processes across planar interfaces. An experimentally shock deformed compound (16-34 GPa) of a strongly foliated quartzite and untextured dunite has been studied in order to determine the residual strain distribution across the interface. [2]. For this purpose neutron and synchrotron X-ray diffraction techniques have been applied to the experimentally shock deformed rocks.

Experimental procedure: The sample studied consists of two rock types: quartzite and dunite. Half-cylinders of both rock types were fitted together along a smooth polished interface. The quartzite was prepared with its foliation plane parallel to the interface. In order to recover the sample after shock loading, the cylindrical sample (15 mm in diameter and 10 mm in height) was inserted into an iron container. The experiment was performed in such a way that the interface was perpendicular to the shock wave front. To achieve a single loading pulse of 16-34 GPa we used the impedance matching technique at room temperature. This technique and the microstructure of the shocked sample is described in detail in[2].

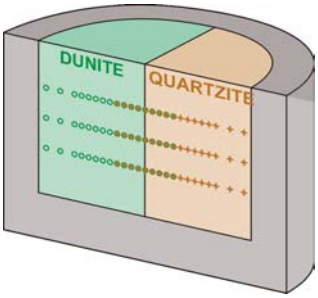

Fig. 1: Sketch of the local measuring grid for the intracrystalline strain measurement using synchrotron radiation (ESRF Grenoble).

Intracrystalline residual strain measurements were carried out using synchrotron-X-ray-radiation at ROBL-beam line (European Synchrotron Radiation Facility in Grenoble, France) and neutron time-of-flight diffraction at ISIS spallation source (Rutherford Appleton Laboratory, Chilton, United Kingdom), respectively. Strain measurement using synchrotron radiation with a wavelength of $\lambda = 1.5418$ Å was used because the method guarantees both good spectral (2ϑ) and spatial resolution (incident beam dimension < 0.2 • 0.22 mm^2). The strain evolution across the interface was determined for three scans perpendicular to the interface; each of the scans consisted of 18 measurement points. A sketch of the measurement grid is shown in Fig. 1. A 2ϑ–scan within the range of $24.5° \leq 2\vartheta \leq 28.5°$ for quartz and $30.3° \leq 2\vartheta \leq 34.3°$.for olivine was measured at each point.

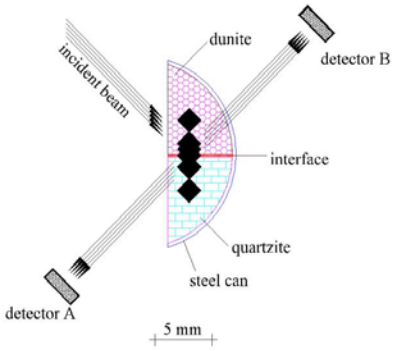

Fig. 2: Experimental layout for the neutron diffraction experiments at the ENGIN-diffractometer. The rhombi indicate the different gauge volumes. Strains are measured in directions within the plane of the drawing; as shown, detector A will measure strains parallel to the interface, while detector B will measure strains perpendicular to the interface.

Neutron radiation is especially useful to study geological materials because their large unit cells require also a large range of lattice planes. The size of the incident neutron beam was reduced using incident slits (1.5•5 mm^2 cross section), and radial collimators to define the scattered beam width to be 1.5 mm. The scattering angle was 2ϑ=90°. Actual d-values were determined for six different positions perpendicular to the interface (Fig. 2). Lattice parameters and strain values for quartz and olivine were calculated using a RIETVELD-code (GSAS, [3]).

Results: Synchrotron radiation experiments showed that the intensity of the diffracted peaks, e.g. the quartz peak $(01\bar{1}1)$ changed as a function of the distance from the interface (Fig. 3). The reduced peak intensity is caused by a decrease in the size of the scattering

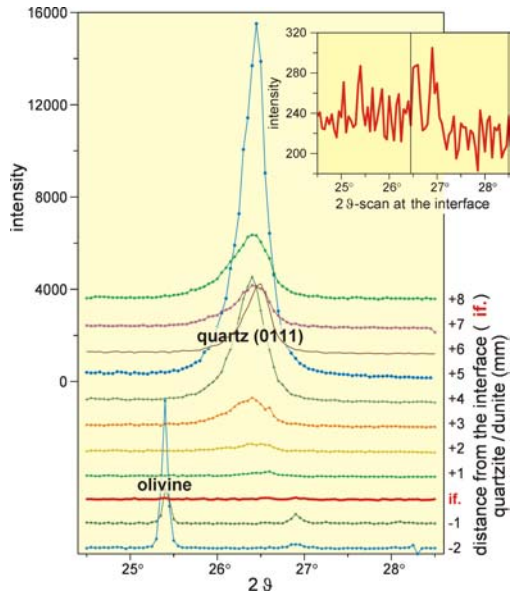

Fig. 3: The intensity of the quartz-(0111)-reflex decreasing towards zero, as the interface is approached. The indicated intensity-range applies to the "if+5"-curve (if = interface).

crystallites close to the interface and sidewalls, down to values smaller than the coherent scattering length. This size of scattering crystallites was calculated by peak shape analysis. Average values for olivine crystallites are less than 100 nm and for quartz less than 20 nm. A preferential reduction of the size of the scattered crystallites could be interpreted in terms of strain concentrations near the interface.

Using synchroton radiation residual strain was calculated from peak positions in the three scans. In general, there are only small changes in residual strain in the dunite part of the sample, but distinct differences occur in the quartzite section. Domains of high magnitudes of residual tension were found for the region near the sample bottom (lower scan). This is caused by a reflection of the rarefaction wave encountering the bottom of the sample. The middle scan is characterised by continuously increasing residual tension towards the interface.

The results of the neutron diffraction experiments are shown in Figure 4. High residual strains of up to $16 \cdot 10^{-3}$ were measured in the region beyond 1 mm of the interface in quartzite. Distinct strain modifications on both sides are restricted to the vicinity of the interface. A striking feature is the high residual strain magnitude in the quartzite section. Whereas in the quartzite section there is a tendency to lower magnitudes of residual strain towards the interface, an increase in residual strain towards the interface is characteristic for the dunite section. The residual strain values, of course, also depend on crystallographic directions due to both the elastic and inelastic anisotropy of the materials. The strong texture in quartzite cause the strain differences in different crystallographic directions.

Discussion: The results obtained from neutron diffraction and synchrotron radiation diffraction measurements are in principle agreement and correleate with the observed microstructures [1]. Considerable differences in residual microstrain between the two rocks were determined. The higher residual strain values in the quartzite section correspond to a lower fracture density in this part with respect to the dunite section. Drastic residual strain changes occur at a distance of only about 1 to 2 mm on both sides of the interface. The two rock types react differently as the interface is approached: Decreasing tensile and orientation-dependent residual strain differences in the quartzite section may be a consequence of increasing fracture density, an effect of anisotropy, and crystal lattice relaxation of quartz due to melt lubrication near the interface. In contrast, the dunite displays a weak and less orientation-dependent increase of tensile residual strain.

References: [1] Walther, K. et al. Tectonophysics (submitted). [2] Kenkmann T., et al. (2000): Meteorit Planet Sci 35, 1275-1290.[3] Von Dreele, R.B. (1997). J. Appl. Cryst, 30, 517-525.

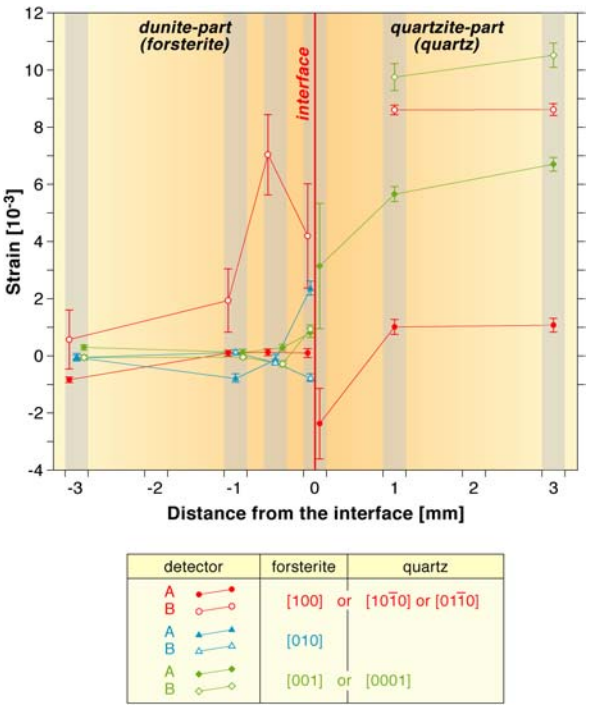

Fig. 4: Results of the strain determinations by neutron diffraction across the shock deformed interface of a quartzite-dunite compound. Detector A shows strains parallel to the interface, while detector B shows strains perpendicular to the interface