Investigation of shale matrix heterogeneity, anisotropy and strain using X-ray and *in-situ* neutron diffraction

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Over the last several years, hydrocarbon exploitation and development in North America has been heavily focused on unconventional plays, particular for shale gas. For the sake of gas production prediction, the strain measurement is critical for shale during the gas depletion. In this study, neutron diffraction as a nondestructive technique is used to measure the phase information and lattice strain in Marcellus shale matrix for both powder and disk samples. X-ray diffraction is used to determine the mineral phases of shale powder. The determined mineral phases are used as the input parameter for structure refinement of neutron diffraction data. The results show that the mineral phase fractions are consistent between X-ray and neutron diffraction data of shale powder. Heterogeneity and anisotropy are detected by neutron diffraction between powder and disk samples, where calcite, clinochlore and dolomite are shown in shale powder rather than shale disk. Pyrite shows in shale disk on radial direction of point 1 and both axial and hoop directions of point 2. During the *in-situ* neutron diffraction measurement, the confined and axial pressures of shale disk are 15 MPa and 20 MPa, respectively. Helium at 4 MPa and 8 MPa and CO_2 at 4 MPa are injected into shale matrix to determine both mechanical compression and sorption-induced lattice strains. The results show that negligible phase average linear elastic strain is found for quartz. Other minerals such as muscovite and albite show variations of strain under helium and CO_2 injections.