Unconventionals Acoustic Velocities: Model Development from Acoustic Microscope Measurements

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Abstract

An important aspect of exploration in shale reservoirs is understanding the controls on the acoustic properties of these rocks. We use integrated micro-CT, thin section, XRF, SEM, and acoustic microscopy to quantify the controls on the acoustic properties of source rock reservoirs. A scanning acoustic microscope is used to measure velocities of individual laminae. We infer that for unconventional reservoirs, in which typical particle and pore sizes are substantially smaller than 20 microns (i.e. resolution of a 20MHz probe), the difference in travel time between the first arrivals from the top and bottom surfaces of the sample provides an accurate measure of the velocity. The large acoustic microscope wavelength eliminates the need for ray tracing. One inch diameter core plugs are first micro-CT scanned and their acoustic properties are measured as received. After CT scanning, end trim and axial thin section and SEM mounts are prepared. The entire end trim, or 1" axial slice, is ion milled in preparation for SEM and acoustic microscopy. Large area image mosaics are produced using low voltage SE imaging for characterizing porosity, and BSE imaging for characterization of organic content and mineralogy. Scanning CL imaging and image analysis are utilized to differentiate between detrital and authigenic phases. Energy dispersive x-ray mapping is also used for the identification of major mineral phases. The resulting suite of mosaic images are analyzed using UH-developed image analysis software. Segmented volumes of porosity, TOC, and mineral phases are determined for each layer type in the sample. After the SEM imaging is complete, the velocity of each layer type is measured on the same sample volume using scanning acoustic microscopy. A Backus average of the measured velocities of each layer type agrees well with laboratory measurements made at the core plug

scale. We illustrate the relationship between segmented porosity, TOC, and mineralogy on the acoustic properties of each layer type. Mineral phases included in the modeling are: clay minerals, pyrite, carbonate, and quartz. We include, where possible, the differentiation of authigenic quartz and carbonate phases. Velocities for each layer type are mapped to the microCT data for the core plug. We illustrate the technique applied in several highly heterogeneous formations including the Niobrara, Haynesville, Barnett, Woodford, and Eagle Ford. By observing changes in acoustic velocity signals and relating them to bulk mineralogy, TOC and maturity, a model can be applied to determine the presence and distribution of organic material. As maturity increases, the location of organic material will shift from predominantly bedding plane parallel oriented laminae, to interparticle pores, as kerogen is thermally altered to bitumen. This results in distinct changes in the vertical acoustic velocity signal and in the observed anisotropy.

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