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Anomalous sonic velocities in the formation containing multi-phase fluids

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It is well known that the velocity of sonic waves that propagate gas-bearing formation is reduced due to low bulk modulus of gas. However, Vp/Vs ratio sometimes increases in some sediment which may contain gas phase as reported by Mikada et al. (2008). When sonic waves propagate a fluid containing gas bubbles, bubbles oscillate radially maintaining their spherical shape following fluid pressure change in some condition. In the case, if the frequency of the sonic wave is close to the natural frequencies of bubbles, the wave is highly dispersed and the phase velocity of the sonic wave may become higher than that of the fluid without the bubbles. Commander and Prosperetti (2008) developed a theory of frequency dependence of wave velocities of fluid containing air bubbles. We applied their theory and considered the frequency dependence of the sonic waves propagate the formation fluid containing gas bubbles. And we showed that the sonic phase velocities in the formation containing gas bubbles, in case sonic logging frequencies, i.e., 8kHz and assuming the radii of bubbles to be about 1mm, may increase than sonic phase velocity of formation which contains same amount of gas, predicted by using rock physics theory (Banno et al., 2009). Consequently, a high Vp/Vs value could be obtained if we ignore any interaction of the bubbles. Since the bubbles might interact with each other, we need to consider the effects of bubble interactions in terms of the change in resonance frequencies. Takahira et al.(1992) have developed a theory which describes the natural frequencies of bubble cloud using eigenvalue analysis. Based on the theory, we focus on the interactions of bubbles with the other bubbles and soil particles to estimate the change of the natural frequencies and the sonic phase velocities that might depend on the distance between the bubbles and number of bubbles. As a result, the natural frequencies of a cloud of plural bubbles are found to become lower than that without considering the interference of gas bubbles in formation fluids. These results indicate that the smaller gas bubbles than predicted bubbles without considering the interference of gas bubbles may increase sonic phase velocity in the pore water of the sediment in case sonic logging frequencies. More and closer condition to in-situ condition will be applied in future work.

Keywords: bubble, sonic phase velocity, multi-phase fluids, dispersion