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Effects of Pore Collapse and Grain Crushing on Ultrasonic Velocities and Vp/Vs

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Compressionnal, shear wave velocities and their ratio, Vp/Vs, were measured along with porosity variations during wet and dry hydrostatic compaction of Bleurswiller sandstone, a 25 % porosity Vosgian sandstone. At first, increase in hydrostatic pressure was accompanied by a simultaneous increase of both Vp and Vs as expected. At a critical effective confining pressure P*, a large mechanical decrease of porosity was observed, due to pore collapse and grain crushing, which was readily confirmed by SEM microstructural analysis. Theoretically, two different processes are affecting the elastic wave velocities in counteracting ways during inelastic compaction: cracking and porosity decrease. Our experimental results shows that cracking is the dominant effect, so that grain crushing and porosity reduction was accompanied by a large decrease in velocities. However and beyond P*, both velocities started re-increasing as new cracks were progressively closed. The ratio Vp/Vs was also observed to change during our experiments: in the wet specimen, Vp/Vs value increased from 1.72 to 1.84, while in the dry specimen, it increased from 1.59 below P* to 1.67 beyond P* respectively. To quantitatively interpret these results, an isotropic effective medium model (EM) was used, considering the sandstone as a mixture of spheroidal pores and penny-shaped cracks. In particular the increase in Vp/Vs, in the wet case, is well reproduced and shows the important role played by the mechanical coupling of fluid with low aspect ratio cracks (<0.01). In the dry case however, our experimental results are the first ones showing an apparent increase of Vp/Vs ratio during inelastic compaction, in apparent contradiction with the predictions of the EM model. Indeed, increases in Vp/Vs ratio, hence in Poisson's ratio, are in general attributed to fluid saturation. A closer look to the microstructure may provide a possible interpretation: beyond P*, grains are no more cemented. Using Digby's granular model as an alternative model,

we were able to reach a quantitative agreement with the experimental results. The possible implication is that, both in dry and wet conditions, inelastic compaction due to grain crushing induces an increase in Vp/Vs ratio.