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The effect of grain size and porosity on compaction localisation in high-porosity sandstones

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As sandstone reservoirs are depleted, the pore pressure reduction can sometimes result in pore collapse and the formation of compaction bands. These are localised features which can significantly reduce the bulk permeability of the reservoir and are therefore problematic in the oil, water, geothermal, and CO_2 sequestration industries. However, the influence that grain size, grain shape and sorting have on compaction band formation in sandstone is still poorly understood, due to the fact that finding natural sandstones with specific properties is challenging. Consequently, a method of forming synthetic sandstones has been developed, in order to produce a suite of sandstone specimens with controlled grain size and porosity characteristics. During production of the synthetic sandstones, amorphous quartz cement and sodium chloride are precipitated between sand grains as a product of the reaction between sodium silicate and hydrochloric acid. The salt can then be dissolved, resulting in synthetic sandstones that have very comparable physical properties to their natural counterparts. In this study, triaxial experiments were performed on synthetic sandstone cores with four different grain size ranges of 250-300, 425-500, 600-710 and 850-1000 microns, at three different starting porosities of 27%, 32% and 37%. The samples were each axially loaded from a point along their hydrostat corresponding to 85% of their hydrostatic yield point, P*, values. These conditions mean that failure will occur within the shear-enhanced compaction regime so as to try and produce localised compaction structures. All samples were taken to 5% axial strain. The microstructural results indicate that localisation of deformation within the samples did occur and was favoured in the low starting porosity, small grain size samples. Localisation of deformation was most easily recognised by grain size reduction through grain crushing. This was weakly correlated to a change in porosity but recognition of the localisation of deformation was difficult to make using variations in porosity alone. Porosity reduction was not necessarily associated with a reduction in grain size. With increasing grain size and starting porosity, the deformation becomes more distributed in the samples with the highest starting porosity samples (37%) exhibiting more widely distributed grain crushing which was less intense overall. The results indicate a significant grain size and starting porosity influence on localisation, but also that compaction can occur by two mechanisms; one involving mostly grain rearrangement and the other primarily by grain fracturing. Consequently, the localisation of deformation is most evident in grain size reduction and is only weakly shown by porosity

reduction.