From cradle to grave – The rock-physics “life story” of a clastic sediment

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Introduction

Present-day rock-physics properties and associated seismic signatures are strongly affected by the geological “life cycle” of sedimentary rocks. By honoring the geological processes, the rock physics modelling will be more predictive in an explorational setting. We have investigated porosity-velocity trends of sandstones associated with geological processes starting from deposition to mechanical compaction and chemical compaction. We have combined compaction models with rock physics contact theory and shown how different geological factors, including sorting, grain size and clay coating, will affect the observed trends.

Combined compaction/diagenesis and rock physics modelling

In this study the focus is on improved understanding of the geological trends and pathways in velocity-porosity crossplots. First, we perform modelling of mechanical compaction and diagenesis of sands and shales as a function of burial history. Mechanical compaction is handled via empirical relationships between porosity and burial depth (Avseth and Lehocki, 2016). The velocities are modelled using Hertz-Mindlin contact theory (see Avseth et al., 2000). The cementation process is modelled using the Walderhaug model (Walderhaug, 1996), when temperatures are higher than 70 ^{o}C, a threshold usually associated with initial cement precipitation (Avseth and Lehocki, 2016). We model the elastic effect of cement with the Dvorkin-Nur model, but instead of starting from a critical porosity, we start the cementation from the reduced porosity caused by mechanical compaction at the depth corresponding to 70 ^{o}C. We also take into account the effective pressure and closing of cracks due to mechanical compaction before we start the cementation. Sorting can be varied at the depositional porosity before the mechanical compaction, which is consistent with geology.

Results and discussion

Figure 1 shows the combined burial and rock physics modelling of P-wave velocity versus porosity where we couple the mechanical compaction (packing) with the chemical compaction (cementation). We do the joint diagenesis-rock physics modelling for different degrees of clay coating (subplot 2), average grain size (subplot 3), and depositional porosity/sorting (subplot 4). Both clay coating and grain size will affect the degree of cementation, in addition to temperature and time, in accordance with the Walderhaug model. This shows that at a given reservoir depth, the cement volume can vary and also that the velocities can change along a diagenetic trend if there are significant variations in grain size and clay coating. If we assume grain size to be constant (d=1mm) and no clay coating, and only vary the sorting, we obtain 3 different paths in the porosity-velocity crossplot. The end-points of these 3 paths (red dots) show a trend that is very similar to the constant cement model. This confirms the validity of the constant cement model (Avseth et al., 2000) provided that constant grain size and no clay coating are assumed.

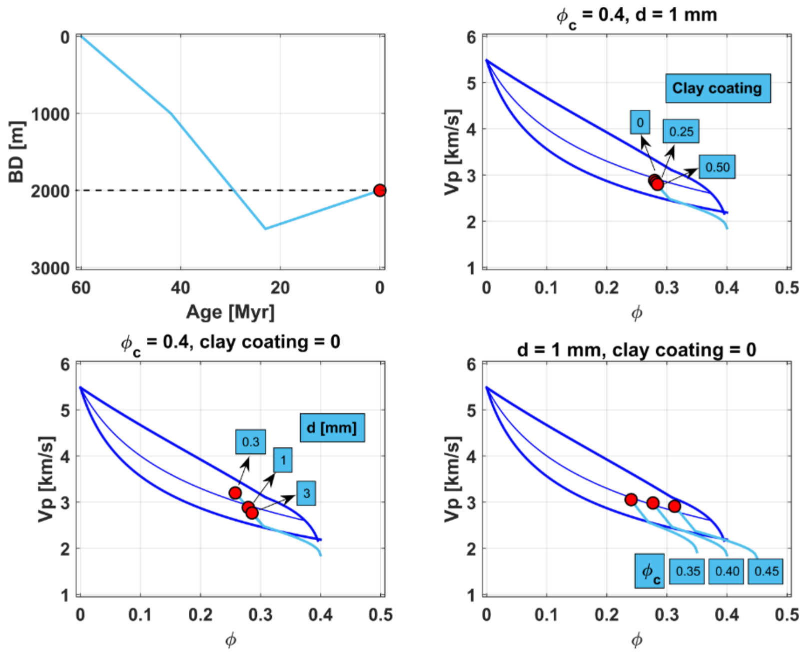

Figure 1: Combined burial (mechanical and chemical compaction) and rock physics modelling using contact theory. The end-points in red represent the present day properties, whereas the light blue curves show the rock physics properties as a function of geological time. Note the good match between the end-points in the 4th subplot and the constant cement model (2% cement), showing the validity of the lower bound Hashin-Shtrikman for modelling of sorting.

Conclusions

We have investigated porosity-velocity trends of sandstones associated with geological processes starting from deposition to mechanical and chemical compactions. We have combined compaction models with rock physics contact theory and shown how different geological factors, including sorting, grain size and clay coating, will affect the observed trends. The modelling confirms that the constant cement model is valid, but porosities will normally be reduced due to mechanical compaction before cementation starts, and this should be taken into account in rock physics modelling of cemented sandstones.

References

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