How burial diagenesis of chalk sediments controls sonic velocity and porosity

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Based on P-wave velocity and density data, a new elastic model for chalk sediments is established. The model allows the construction of a series of isoframe (IF) curves, each representing a constant part of the mineral phase contributing to the solid frame. The IF curves can be related to the progress of burial diagenesis of chalk, which is revised as follows: Newly deposited carbonate ooze and mixed sediments range in porosity from 60 to 80%, depending on the prevalence of hollow microfossils. Despite the high porosity, these sediments are not in suspension, as reflected in IFs of 0.1 or higher. Upon burial, the sediments lose porosity by mechanical compaction, and concurrently, the calcite particles recrystallize into progressively more equant shapes. High compaction rates may keep the particles in relative motion, whereas low compaction rates allow the formation of contact cement, whereby IF increases and chalk forms. Rock mechanical tests show that when compaction requires more than in-situ stress, porosity reduction is arrested. During subsequent burial, crystals and pores grow in size as a consequence of the continuing recrystallization. No lack of porosity loss during this process testifies to the absence of chemical compaction by calcite-calcite pressure dissolution, as well as to the porosity-preserving effect of contact cementation. At sufficient burial stress, the presence of stylolites indicates that pressure dissolution takes place between calcite, and silicates, and depending on pore-water chemistry and temperature, pore-filling cementation may occur over a relatively short depth interval. Limestone and mixed sedimentary rock form, and porosity may be reduced to less than 20%. Isoframe increases to more than 0.6. In hydrocarbon reservoirs in North Sea chalk, relatively high porosity and high IFs are found. The reason may be that recrystallization and porosity-preserving contact cementation progress, whereas pore-filling cementation is small, probably because pressure dissolution along stylolites is arrested. Pressure dissolution may be arrested for two reasons: (1) the introduction of hydrocarbons causes a fall in effective burial stress, and (2) adsorption of polar hydrocarbons on the silicates may shield calcite from the silicates.