Ultrasonic velocities of North Sea chalk samples: influence of porosity, fluid content and texture

We have studied 56 unfractured chalk samples of the Upper Cretaceous Tor Formation of the Dan, South Arne and Gorm Fields, Danish North Sea. The samples have porosities of between 14% and 45% and calcite content of over 95%. The ultrasonic compressional- and shear-wave velocities (V-P and V-S) for dry and water-saturated samples were measured at up to 75 bar confining hydrostatic pressure corresponding to effective stress in the reservoir. The porosity is the main control of the ultrasonic velocities and therefore of the elastic moduli. The elastic moduli are slightly higher for samples from the South Arne Field than from the Dan Field for identical porosities. This difference may be due to textural differences between the chalk at the two locations because we observe that large grains (i.e. filled microfossils and fossil fragments) that occur more frequently in samples from the Dan Field have a porosity-reducing effect and that samples rich in large grains have a relatively low porosity for a given P-wave modulus. The clay content in the samples is low and is mainly represented by either kaolinite or smectite; samples with smectite have a lower P-wave modulus than samples with kaolinite at equal porosity. We find that ultrasonic V-P and V-S of dry chalk samples can be satisfactorily estimated with Gassmann's relationships from data for water-saturated samples. A pronounced difference between the V-P/V-S ratios for dry and water-saturated chalk samples indicates promising results for seismic amplitude-versus-offset analyses.