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Interval velocities of a Triassic claystone:
Key to burial history and velocity modelling

Introduction

Compressional wave velocities, as recorded by sonic logs in boreholes, may reveal information on the burial history of clastic sediments. This is important in view of the question of source rock maturity in a hydrocarbon province. Furthermore, a proper comprehension of compressional wave velocity of sediments is a prerequisite in adopting an adequate velocity model for traveltime-to-depth conversion of seismic horizons. Key to the use of seismic velocity of clastic sediments is its dependence on the weight of the (previous) overburden. An increasing overburden, or increasing depth of burial, effectuates an increase in seismic velocity. If this velocity increase appears to be mostly irreversible during a later phase of uplift and erosion, then seismic velocity contains information on the previous maximum depth of burial and on the apparent uplift. Apparent uplift is the actual, net result of all phases of uplift, erosion, subsidence and sediment deposition since maximum burial.

This presentation deals with the average compressional wave velocities (interval velocities) of the Main Claystone Member in the Dutch on- and offshore. This Claystone was deposited quite uniformly over most of the Dutch area. Moreover, it predates several major phases of uplift and erosion.

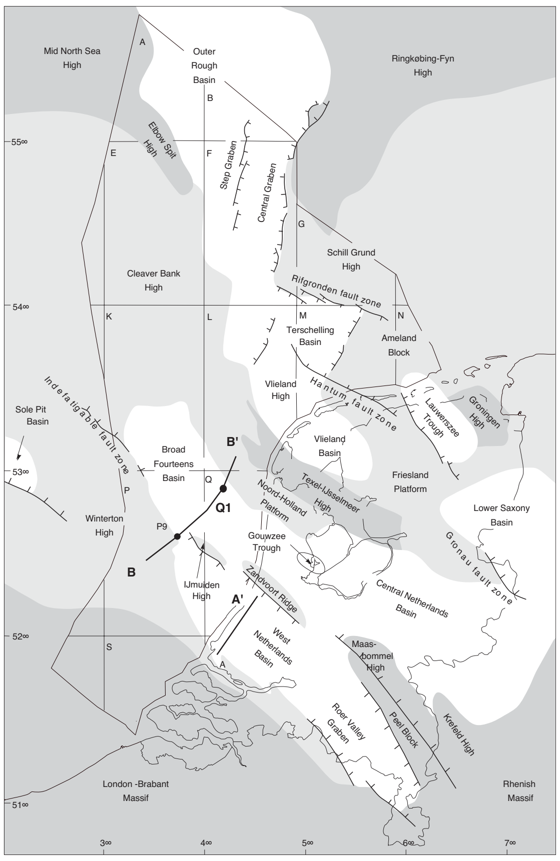

Figure 1. Dutch on- and offshore with delineation of Mesozoic structural elements.

Interval velocities of the Main Claystone Member

An inventory was made of digitally scanned sonic logs in the database of the Netherlands Institute of Applied Geoscience. For some 460 boreholes, logs were available from which a reliable interval velocity could be evaluated for the Main Claystone Member of the Lower Buntsandstein Formation of the Lower Germanic Trias Group in the Dutch area. Apart from a number of areas in the southern part of the Netherlands, where no sediments of the Trias Groups were deposited, sediments of these groups are present over large areas of the Dutch on- and offshore. On a number of highs (Figure 1) they are absent as a result of erosion related to, amongst others, the Late Kimmerian uplift (Van Adrichem Boogaert and Kouwe, 1993). The Main Claystone Member consists mainly of a succession of claystones. Their gamma-ray logs reveal small-scale fining-upward cycles, which can be correlated over large distances in the Permo-Triassic Basin. Where the Main Claystone Member has not been affected by erosion, its thickness is about 200 m.

The interval velocity map (Figure 2) shows a pattern of highs and lows, which is to be related with tectonic elements. Particularly conspicuous is the coincidence of the Broad Fourteens Basin with an area of high interval velocities. Here, graben formation took place since the Early Triassic. Due to burial, graben sediments were compacted resulting in a burial-dependent increase of the seismic velocity of the sediments. Subsidence in this basin was followed by inversion during the Late Cretaceous, when the Main Claystone Member in the basin underwent a considerable uplift. It appears from the map that the uplifted Claystone in the Broad Fourteens Basin has, at least partially, preserved its relatively high interval velocities incurred as a result of burial.

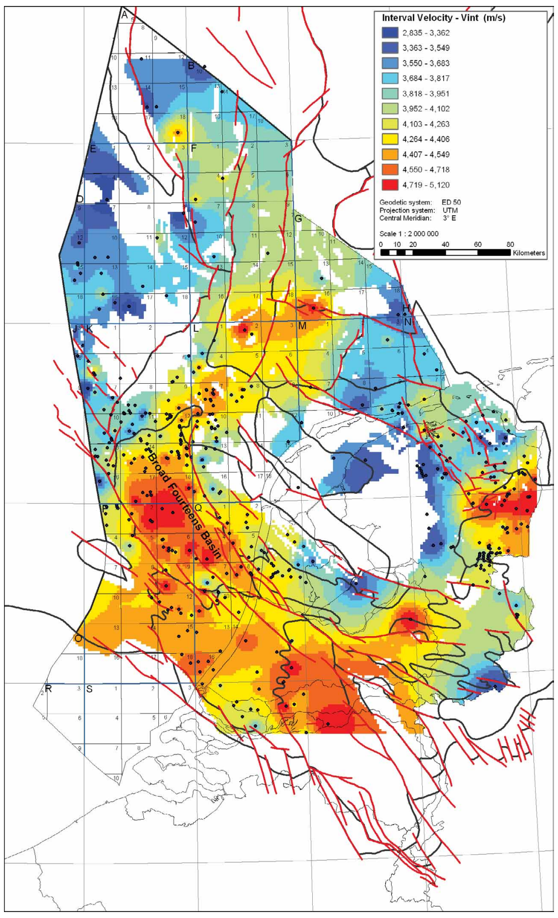

Figure 2. Interval velocity of the Main Claystone Member.

Compaction of the Main Claystone Member

We adopt a simplified model for compressional wave velocity of the sediments of the Main Claystone Member. It assumes that velocity only changes when sediment is being buried at depths not attained before. Velocity does not change during uplift and subsequent subsidence, unless burial depth exceeds the previous maximum burial depth. Thus v(z), the velocity at depth z, does not necessarily depend on the actual depth z of the sediment, but on its (previous) maximum depth of burial z_{max}. This implies that v(z) is not single-valued. In case of $z = z_{max}$, the velocity of the Main Claystone Member is approximated by the equation $v(z) = v_0 + k \times z$. In this formula, v_0 is the compressional wave velocity of clay at the surface, and k is the average increase of the compressional wave velocity of the clay per unit of burial depth. We assessed values for v_0 and k by inspection of the Main Claystone Member interval velocities, plotted against their mid-depths z_{mid} (Figure 3).

The straight purple line in Figure 3 is assumed to represent the compressional velocity of compacting clay at monotonous burial.

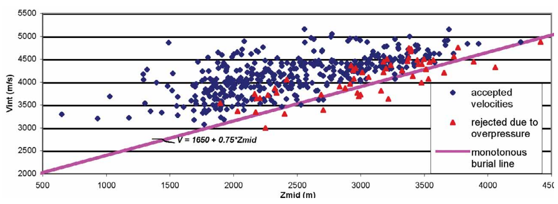

Figure 3. Interval velocities of the Main Claystone Member and model of its compressional velocity at monotonous burial.

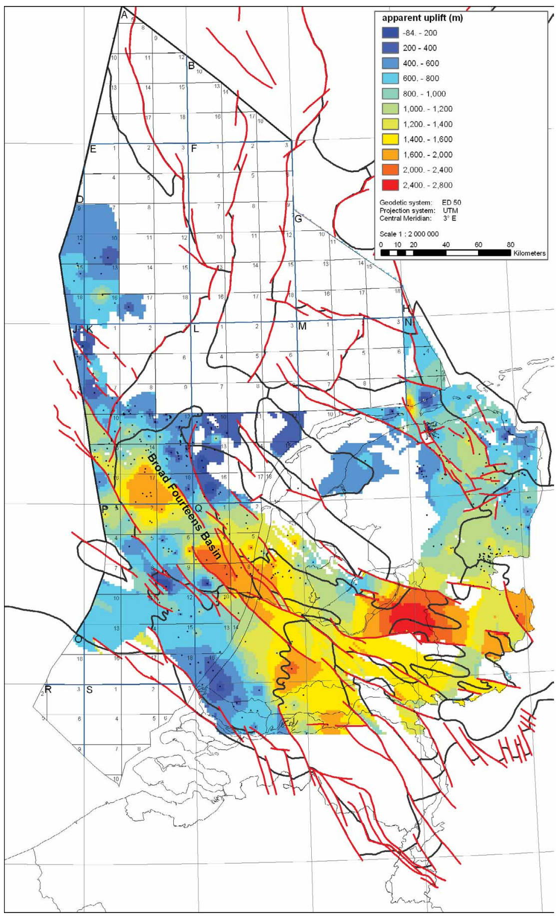

Figure 4. Apparent uplift of the Main Claystone Member.

The values of the model-parameters are: $v_0 = 1650$ m/s and $k = 0.75\ s^{-1}$. In deriving this line, interval velocities of the Main Claystone Member in known overpressured areas (Simmelink et al, 2005) were rejected.

Maximum burial depth and apparent uplift of the Main Claystone Member

On the basis of the above velocity model, maximum burial depth of the Main Claystone Member and its apparent uplift can be estimated directly. Figure 4 is a map of the apparent uplift of the Main Claystone Member in the areas that are not overpressured. Apparent uplift in the Broad Fourteens Basin appears to be in the range 1600-2400 m, and in accordance with geohistory modelling results of Verweij (2003).

Conclusions

1. Interval velocities of a claystone formation may serve to obtain information about its past maximum burial depth and apparent uplift.
2. In assessing a velocity model for seismic time-to-depth conversion, burial history of sediments must be taken into account.

References

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