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Sequential Vertical Gas Migration Through Multilayered Sequences Controlled by Central Conduits: Observations and Modeling

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ABSTRACT

Stacked amplitude anomalies (AAs) are described from a 3D seismic survey acquired in Block A of the Dutch North Sea. The AAs have opposite polarity with respect to the seabed and produce a substantial push down at their centres. The AAs have a sub-circular planform geometry when observed on map view and they are stacked vertically in that they have a high degree of spatial overlap in the vertical succession. The AAs are grouped into 4 main sets and are interpreted as vertical anomaly clusters (VACs) composed of 5-7 major AAs each. The VACs crudely resemble a pyramidal geometry where the larger AAs are always located toward the base of the VACs. Seismic interpretation of the VACs and quantitative analysis of the reservoir intervals reveal that the VACs are due to gas-bearing silt-rich reservoirs hosted in the upper section of the Upper North Sea Group, a mixed clastic succession of Pliocene to Pleistocene age. Novel analysis based on the geometry of the individual AAs reveals that these are likely to be the result of a vertical gas injection and similar in geometry to what observed in laboratory experiments, such as in Hele-Shaw cells. The formation of VACs is demonstrably controlled by sequential upward gas charge into reservoir units and that the flow across the seals separating the reservoirs is controlled by central regions of focussed fluid flow. These regions, where the injection take place, function as seal-by pass systems and are most likely formed by hydraulic fracturing. A finite volume modelling approach has been developed to support the proposed mechanism behind the formation of VACs. The model utilises a novel approach where the reservoir intervals, separated by membrane seals, are in pressure communication. The seals are also subject to leakage when overpressure overcomes the capillary entry pressure of the seal units. The results of the model show a good match with the observations on the seismic data. Importantly the model shows that the geometry of the VACs is mainly function of the gas-induced flow of water and the distribution of the gas in place. The work has strong implication for cross-stratal migration of gas in general and also for the formation and charging history of multilayered reservoirs.