Using image analysis to quantify textural changes due to post-depositional remobilization of fine-grained sands

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Summary
An image analysis method is used to describe textural changes caused by remobilization of very fine to medium grained sands. Image analysis on non-cemented injected sands shows that sands with high primary porosities (25-40%) get packed to give porosities below 20% due to remobilization. Calcite cementation in some reservoir-scale sandstone dykes causes them to loose any remaining porosity. Cementation is most pervasive in loosely packed parts of the sandstone dykes thus in the end leaving more porosity in tighter packed parts of sandstone dykes. Furthermore, it is demonstrated, that compaction of sandstone dykes is preferentially strongest in the horizontal direction perpendicular to the dykes margins. The methodology explained here can be used to quickly asses textural changes in both cemented and non-cemented remobilized sands in samples from both onshore and off-shore localities.

Introduction
The recognition of large-scale sandstone remobilization in North-Sea basin hydrocarbon plays has only been appreciated in the last five to ten years. They are especially common in the deepwater play within the latest Paleocene and early Eocene of the North Sea basins, but might also have their influence on older plays. Some of the most impressive sand-remobilizations are found in the Alba, Balder and Gryphon fields (e.g. Jenssen et al., 1993; Dixon et al., 1995; Duranti et al., 2000). One of the key-questions with respect to remobilized sands is what textural changes are caused by remobilization and injection of sand, with the prime focus towards assessing changes in porosity and permeability. Remobilization may result in tighter or looser packing of grains and in the precipitation or dissolution of material from fluids flowing through the injections. To investigate both the influences of re-packing and cementation, outcrops of remobilized sands in the Kimmeridgian of NE-Scotland where investigated (fig. 1). Two distinct different types of sand-remobilization and injection where recognised (Jonk et al., 2001):

1. Remobilization and injection of sands shortly after deposition associated with normal faulting in response to gravitational sliding (locality A in figure 1). These injected sands have no cements associated with them. In this case, the difference in packing between the depositional sands and the sands injected from the depositional units can be assessed. Injections have width’s up to a few centimeters and lengths up to a few meter.
2. Sandstone dykes associated with strike-slip movements along the Helmsdale and Great Glen Faults (locality B in figure 1). These sandstone dykes are well cemented with calcite and penetrate at least 50 to 100 meters of surrounding stratigraphy. The source-beds of these dykes are not exposed. Dykes typically have width’s up to 1 meter and lenghts up to several hundreds of meters. The influence of calcite cementation was assessed in the samples.

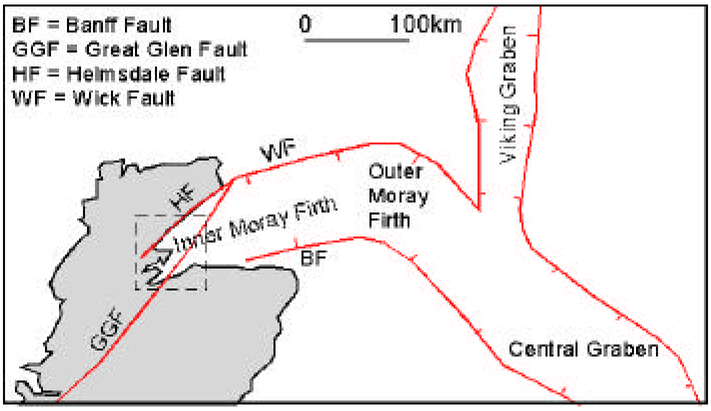
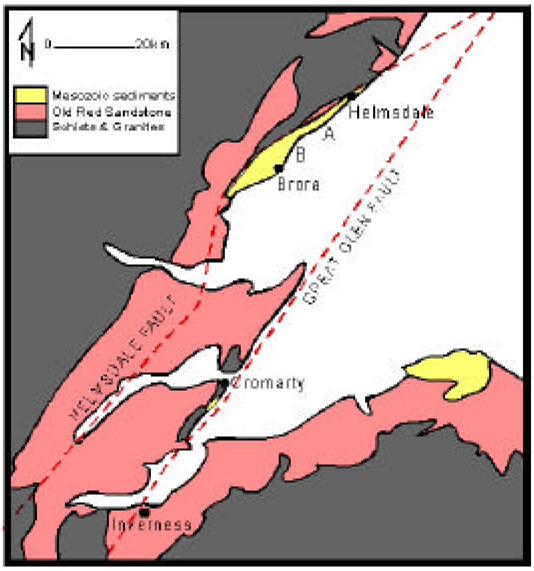


Figure 1: The sample locations A and B within the Upper Jurassic outcrops of NE Scotland, located on the western margin of the Inner Moray Firth basin



Methods

Rock samples from both localities where cut for thin-sections. Samples from locality A, containing no cements, where stained with blue dye, giving the porosity in the sample a blue colour. In this case, under plain polarized light, grains are white, porosity is blue and small amounts of carbonaceous fossil material are brown. Samples from locality B, containing carbonate cements, where impregnated with KCl, giving the carbonate cements a red colour. In this case, under plain polarized light, grains are white, porosity is black and carbonate cement is red. Using the SigmaScan Pro5 image analysis program, photographs of the thin-sections could easily be converted into reliably grey-scale thresholds, with the different grey-scales reflecting the different components by using there colour-contrast.

Results

Sample A (figure 2):

The depositional sands (fig. 2 left) contain very fine to fine grains, that are subangular. The sands are moderately sorted. Using the image-analysis, it can be shown that porosity of these sands is typically between 25 and 40%. The presence of small amounts of carbonaceous material (less than 5% can also be demonstrated).

The injected sands (fig. 2 right) obviously contain subangular very fine to fine grains as well and are also moderately sorted. The most striking difference is the tighter packing of the injected sands (less than 20% porosity) and the large amount of carbonaceous material present (between 10 and 20%). This is caused by the fact that the injected sands penetrate strata rich in carbonaceous material, incorporating some of it during the injection. Typically, these elongated pieces of carbonaceous material are aligned vertically, which is caused by the dominant vertical flow-direction within the injection.

Sample B (figure 3):

Unfortunately, the source sands of the calcite cemented sandstone dykes are not exposed. The sands consist of very fine to medium grained grains, that are subrounded

Figure 3 shows two thin-sections taken horizontally along the dike (left) and vertically and perpendicular to the dyke-margin. The section perpendicular to the dyke-margin nicely shows the preferred vertical alignment of grains, probably caused by the dominant vertical direction of flow during injection. The dyke has negligible porosity left (less than 1%) and contains for 40 to 60% of calcite cements, overgrowing and corroding the grains. Obviously, this cementation caused the complete disappearance of any porosity that might have been present in the sands. Although the source-sands are not exposed and therefore an estimation of the porosity reduction seems impossible, the effect of calcite cementation can still be demonstrated.

Granulation seams (figure 4) developed within the dykes prior to large-scale calcite cementation. They have orientations parallel to the dyke-margin and developed in response to differential compaction that was strongest in the direction perpendicular to the dykes margins.

Calcite cements hardly penetrate the granulated parts of the dyke, probably because of the tighter packing within the granulation seams. Instead, calcite cements traverses granulation seams by clear fractures (figure 4). The highest present-day porosity is within the granulation seams (about 2-5%) since these where not cemented by calcite. The fact that calcite-cementation is less in tighter packed areas is also demonstrated by the much smaller amounts of calcite cements in sections perpendicular to the dykes margins (fig. 3), since (as we already stated) compaction seems to have been strongest in the horizontal direction perpendicular to the dykes margins.

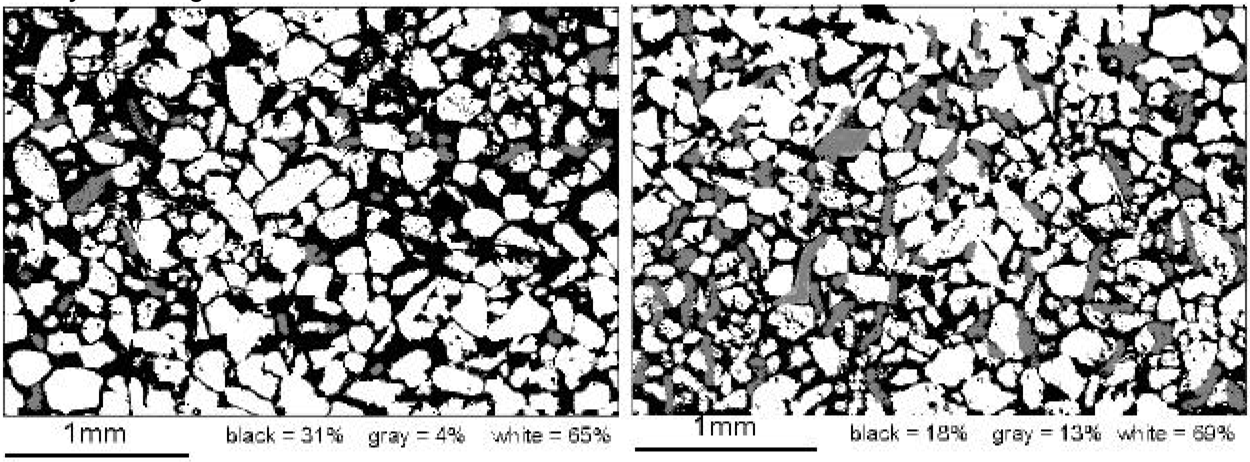


Figure 2: Threshold of thin-sections from a depositional sand (left) and an injected sand (right) black is porosity, white is grains and grey is carbonaceous fossil material.

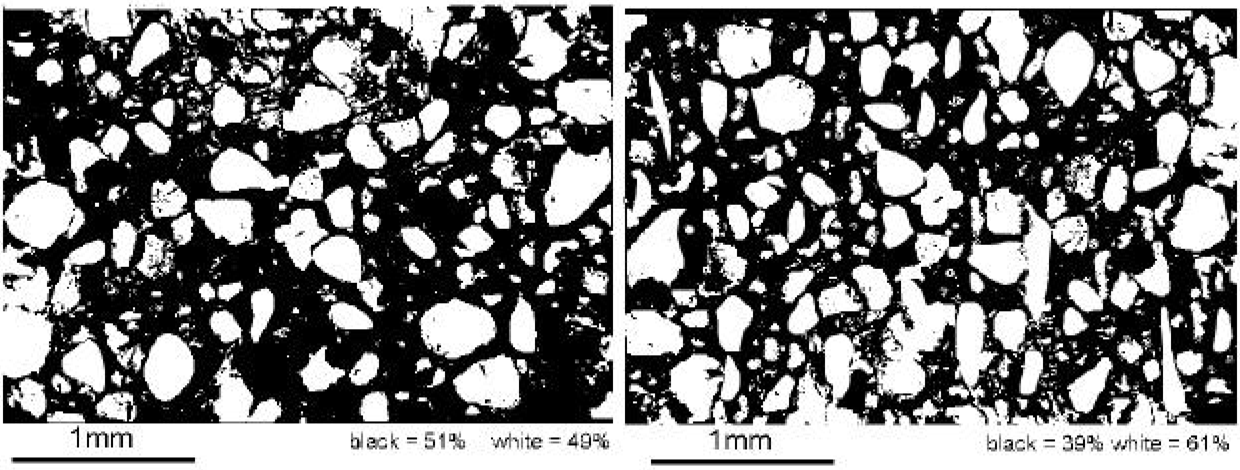


Figure 3: Threshold images of thin-sections from a calcite cemented sandstone dike. Left is a section taken horizontally through the dyke, right is a section taken vertically and perpendicular to the dyke-margin. Black is calcite cement, white are grains.

Conclusions

In the investigated area, post-depositional remobilization of sands greatly diminishes porosity of sands, either by tighter packing or by the precipitation of cements from fluids flowing through the injection structures. Furthermore, it is demonstrated that during compaction of sandstone dykes, porosity reduction is largest in the horizontal direction perpendicular to the dykes margins. Tighter packing of grains may reduce porosity, but tighter packed areas might not be as severely overprinted by cementation as more openly packed grains. Whether any remaining porosity is cemented or not depends on the geochemistry of the fluids flowing through the injection and on extrinsic parameters such as pressure and temperature. A detailed analysis of these problems is beyond the scope of this analysis. The methods here described can be as easily used to quickly asses textural variations in both cemented and uncemented samples from cores of remobilized hydrocarbon plays in the North Sea area.

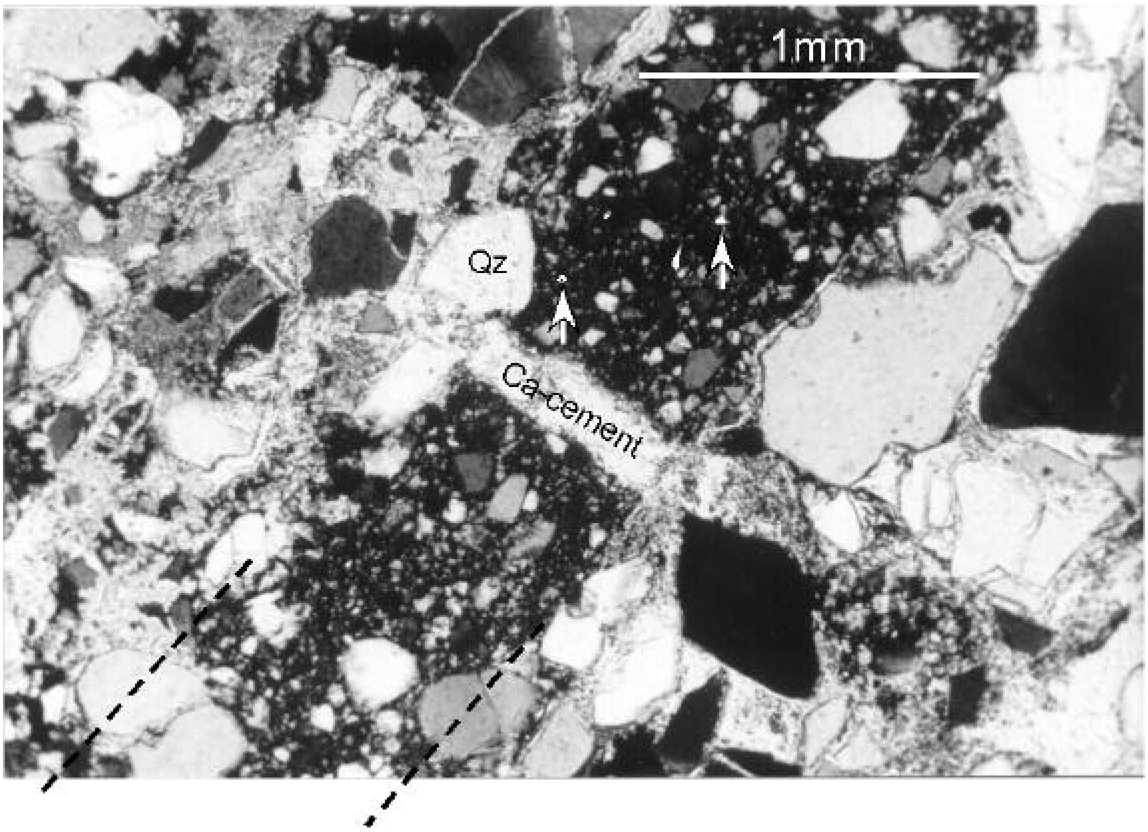


Figure 4: Granulation seam (indicated with dashed lines), consisting of comminuted quartz-grains. Calcite cement is pervasive outside the granulation seam, but only overprints the granulation seam by clear fractures. Some porosity (bright spots, indicated with arrows) is left in the granulation seam.

References

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