AAPG HEDBERG CONFERENCE
"Structural Diagenesis: Fundamental Advances and New Applications from a Holistic View of Mechanical and Chemical Processes"
February 8-11, 2004 -- Austin, Texas

A New Approach for Looking at Quartz Overgrowths; An Electron Backscatter Diffraction Study

Sasha C. Haddad[1], Richard H. Worden[1], David J. Prior[1], P. Craig Smalley[2]
[1] Department of Earth and Ocean Sciences, University of Liverpool, Jane Herdman Labs, Liverpool, L69 3GP, UK, email: shaddad@liv.ac.uk
[2] BP Exploration, Sunbury on Thames, Middlesex, TW16 7LN, UK

This study examined quartz overgrowths and their crystallographic relationship to the detrital grain with the use of automated electron backscatter diffraction (EBSD) on the scanning electron microscope (SEM), with the purpose of determining whether detrital grains and their authigenic overgrowths are in crystallographic continuity. This technique has been used previously for study of metamorphic rocks, but is a new tool to the sedimentological world. The results may have implications for the prediction of the rate of quartz cementation and porosity-loss during burial.

Material from the shallow buried Oligocene Fontainebleau Sandstone from the Paris Basin was collected and analysed using a variety of SEM-based techniques. Very high magnification (resolution up to 1μm) SEM-CL images were recorded to create detailed montages of sand grains with well developed, angular, euhedral quartz overgrowths. The same area was then analysed in a CamScan x500 crystal probe, which is capable of resolving the crystallographic orientation of an area up to $1\mu m^2$ at the speed of 0.18 seconds per point. An image of the lattice plane was projected onto an on-line computer screen where it was processed, allowing the diffraction pattern of a point to be resolved by indexing it and finding a solution based on the parameters inputted for the material being analysed, in this instance quartz. Thousands of individual data points were collected, which together created an EBSD map, which allowed direct comparison of crystallography with the SEM-CL maps

Images revealed the form of the overgrowth changes with distance away from the grain upon which it has nucleated; there is also a quartz outgrowth zone (Fig. 1, zone C). Within some grains, a concordance between EBSD and SEM-CL images is displayed (i.e. Fig. 1, zone A). There is consistently an area of “zero solutions” (Fig 1, zone B) which likely indicates that this is SiO_2 but not quartz. The crystallographic orientation across most of the overgrowth appears to be consistent with that of the detrital grain. However, the most striking result is that the crystallographic orientation across the grain to the *outgrowth* displays a systematic mis-orientation, varying between 7° and 30°. This would indicate that quartz cement (or part of it) is not in crystallographic continuity with the substrate grain. Further analysis (Fig 2) indicates there is a rational crystallographic rotation around a variety of axes, which would mean that the orientation of the final growth stages is not random but that something is controlling it. These observations have implications for quartz growth kinetics and prediction, since not all of the quartz overgrowth is actually quartz and some overgrowths may not have formed by heterogeneous nucleation and growth.

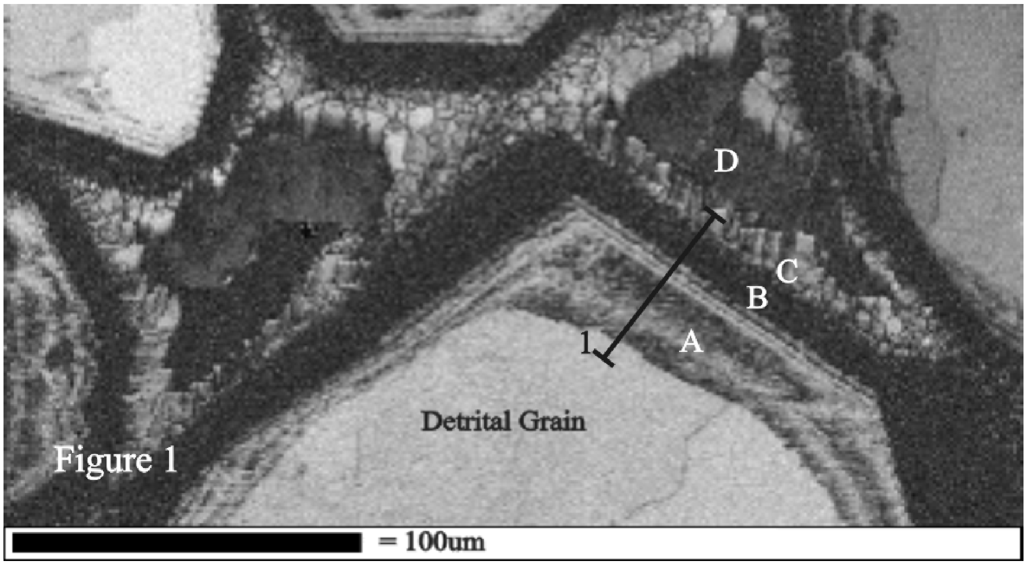

Figure 1. – This is a band contrast image which results from an EBSD run, whereby every pixel has a corresponding EBSD measurement. The grey scale relates to the quality of the data measured – the brighter the area, the better the quality. Zones A-C are progressive overgrowth forms. Zone A is characterised by zoning, which is clearly depicted in CL images. Zone B is a zone of “zero solutions”(i.e., no indexing, which makes it likely that this area is SiO_2 but not quartz) and is hence black. In the CL image of this same area, definite overgrowth is displayed that is chalcedony-like in appearance. Zone C is characterised by small, euhedral quartz crystal outgrowths and zone D is porosity, filled with epoxy resin. Transect line 1 relates to Figure 2. The sample has no topography.

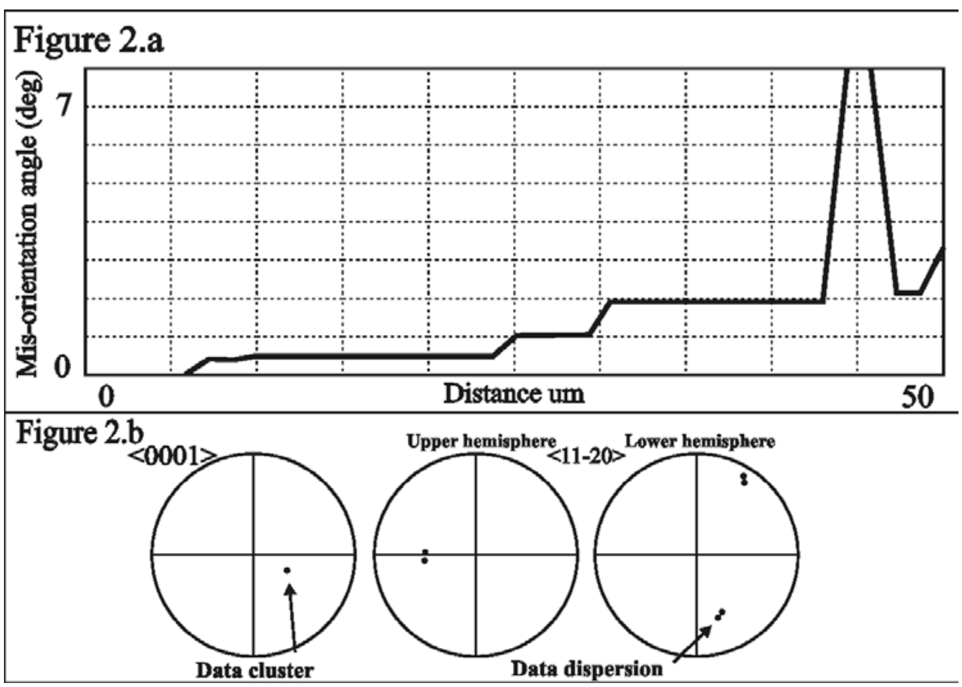

Figure 2.a – This is a mis-orientation profile graph corresponding to transect line 1 on Figure 1. It shows the changing mis-orientation angle from the start point (detrital grain) to the outgrowth, which in this instance is 7°. Therefore the detrital grain and the outgrowth are *not* in crystallographic continuity.

Figure 2.b – This is a set of pole figures plotted on stereonets. It shows data for 6 data points picked from the detrital grain and the outgrowth area (from transect line 1 in Figure 1) in order to represent the misorientation as a rotation. The pole figures for <11-20> (a-axes) show a dispersion of data. The pole figure for the <0001> (c-axis) shows a cluster of data and therefore that a rotation axis for the misorientation rotations represented by transect line 1 is parallel to the direction of this cluster, i.e. parallel to the c-axis. This would indicate that there is a *rational* crystallographic rotation, i.e. that final growth stages were controlled and not random. (N.B. a range of rotation axes has been found, not only those that are parallel to the c-axes.)