# PS Projecting Cores into the Time Dimension*

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Search and Discovery Article #41663 (2015)**
Posted August 17, 2015

*Adapted from poster presentation given at AAPG 2015 Annual Convention and Exhibition, Denver, Colorado, May 31 – June 3, 2015


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## Abstract

Cores allow us to measure physical properties (such as porosity and permeability), and to associate such measurements to observed textures and contextual (facies) frameworks. It is widely understood how to project that core information into the spatial domain, via geomodelling that creates 3D distributions of geobodies and their properties. After we have determined the paragenetic sequence (i.e. diagenetic evolution) of the cores, we can project core-derived properties into the dimension of time, as described below. If the current spatial arrangement is also projected into a time sequence (restoring the shape changes, for example), then the approach described here provides the property information that adds value to those geometric restorations. This time-projection of core observations is possible because: (1) rock textures record the geohistory processes (e.g. diagenetic changes and past mechanical responses) that have operated on that rock; and (2) the textures, and their associated 3D pore-space architecture, determine the properties. Using concepts about how these processes alter textures, core observations and measured properties can be extended into the time domain, in both backward and forward directions. The backward direction is addressed by sequential removal of diagenetic features (i.e. diagenetic back-stripping sensu van der Land et al. 2013), or deformation effects. These textural "restorations" can be accomplished in 2D (observed in thin section, or via SEM and auto-determination minerals/orientations), followed by creating digital rock models, which allow property calculations for each of the past states. The methods can also operate directly on 3D digital rock models. (The digital rock methodology has been documented elsewhere, but key aspects will be reviewed in this paper.) The main challenge for this approach is how to take account of the textural consequences of compaction/consolidation, which results in grain rearrangement and thus alterations of the pore space. Forward projection can be literal or figurative. If literal, this might address texture and property changes resulting from reservoir operations (e.g. scale deposition, consolidation from pressure depletion, or even activities such as fracturing). Figurative forward models can estimate how the equivalent rock would have changed in, say, a deeper and un-sampled location, or in a location where deformation occurred (but was not sampled), such as in a fault zone.

## Reference Cited

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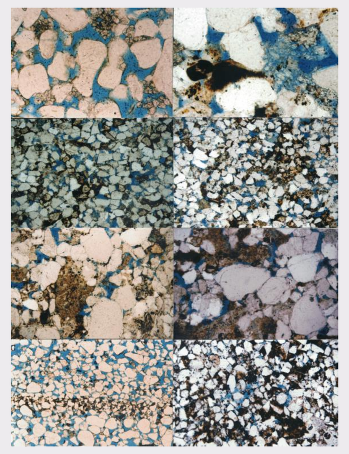
## Rationale

### Cores Provide:

- Visual information enabling geologists to interpret depositional setting
- Material that can be used to make measurements (mechanical, petrophysical, acoustic, Core-GR, etc)
- Source of thin sections: textures record events affecting that sample

Other data (maps, seismic, basin modelling) used to derive geological history

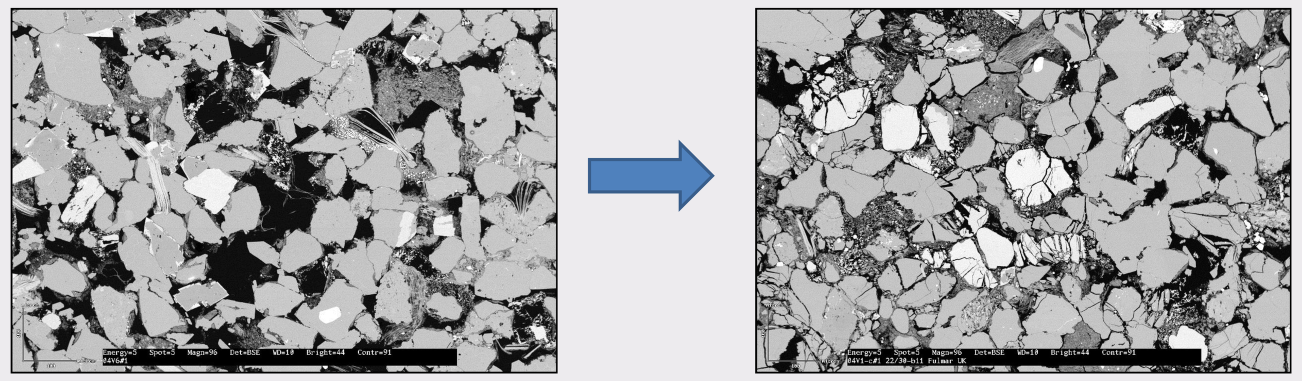
### Processes = f (time)



This poster outlines methods to extend cores (and their properties) forwards or backwards in time, based on textures, which means that we can account for processes that we believe to be “out there”, but which we have not sampled.

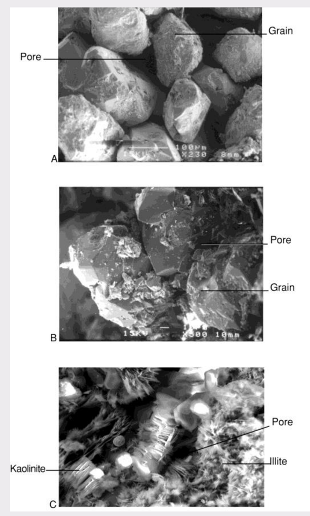
### Reservoir Compaction (by Depletion):

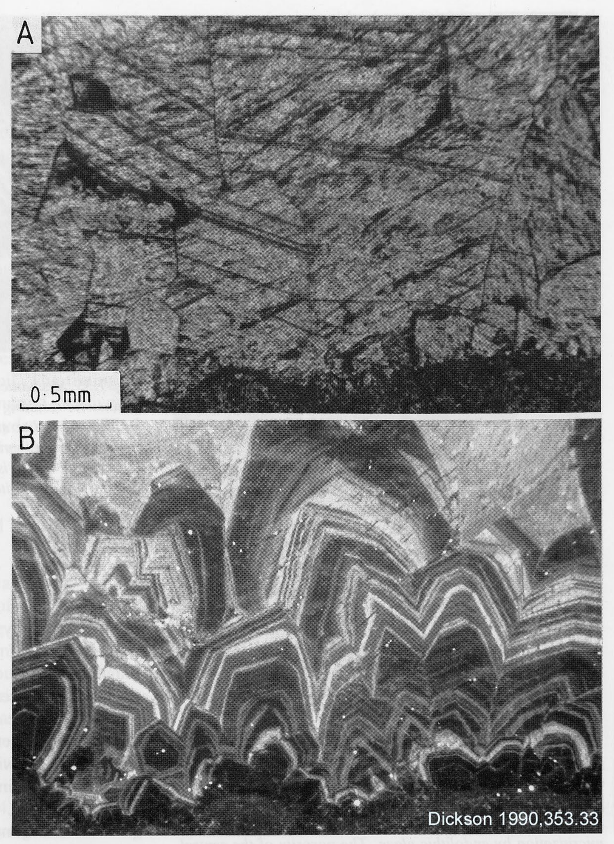
Example shows a turbidite sandstone in original state on left, and cored in a later well, after depletion and consolidation enabled by distributed grain crushing, on right. Without the later core, we might be left guessing about the textural consequences. We certainly would not have samples to allow measurements.



### Diagenesis (Cementation Episodes):

Examples shows some carbonates that have experienced a progressive series of cement emplacements. This sample, from the water leg, has more diagenetic events than the same rock in the oil leg. What if we do not yet have cores of the reservoir material?

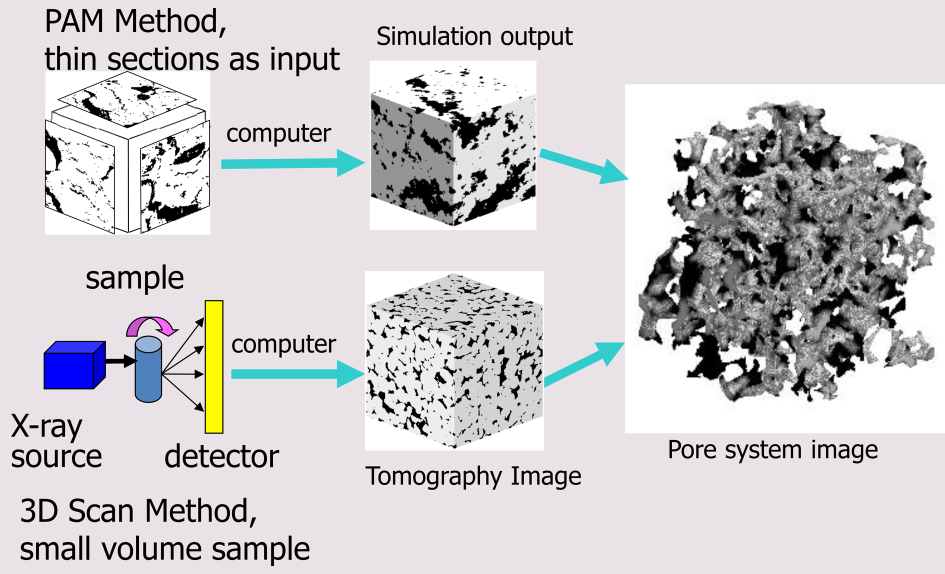




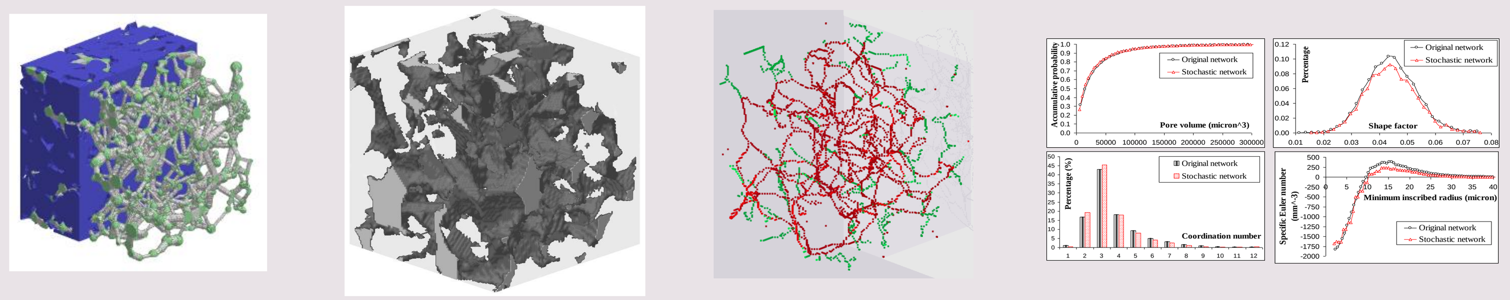

## Digital Rock Approach

### Texture to 3D Model to Pore System to Properties:

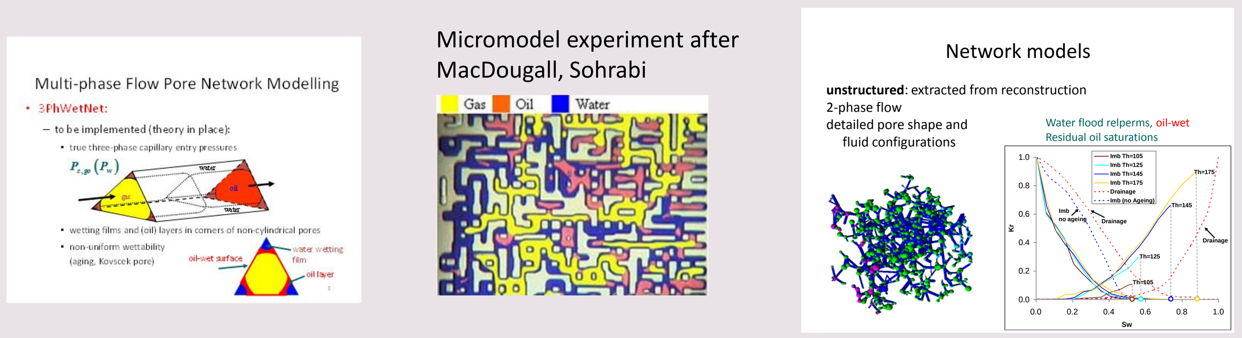
The key technology is a method that creates a 3D reconstruction at grain/pore scale using 2D images as input (Wu et al 2006). The resulting model is partitioned into the pore system and the solid components (Jiang et al 2007).



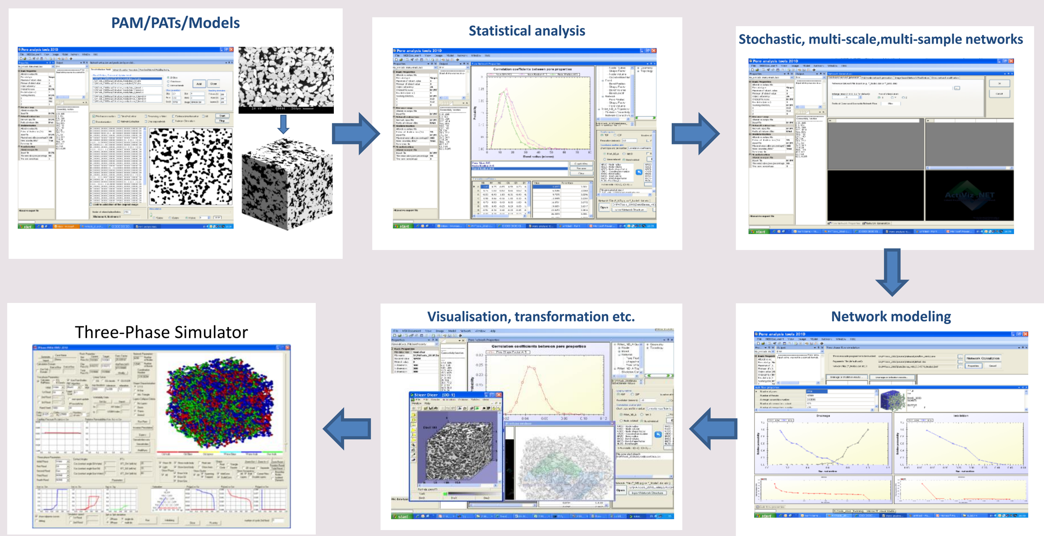

As an example of property estimation, the pore system can be used to calculate fluid flow. We can use multiple methods, but one that is useful is to derive a network model of the pore system, which retains both the geometric and topological characteristics in a reduced-dimension form.



Based on both theoretical understanding and “micro-model” lab observations, the pore network is used to calculate multi-phase flow, from which we construct rel-perm curves and capillary pressures (Ryazanov et al 2009).



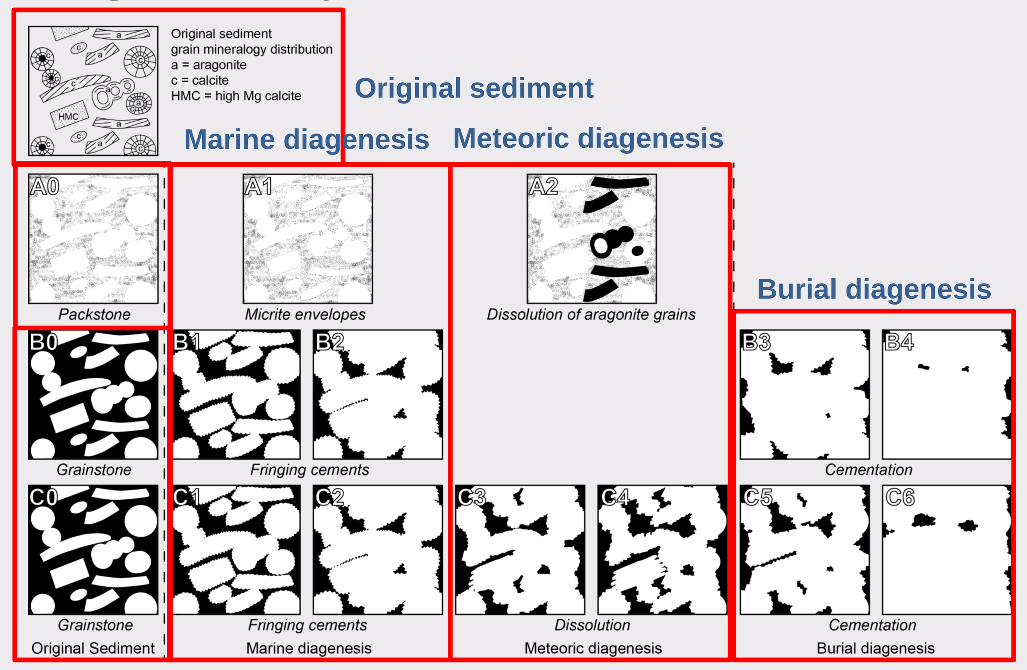

These tools are combined into an integrated software system.

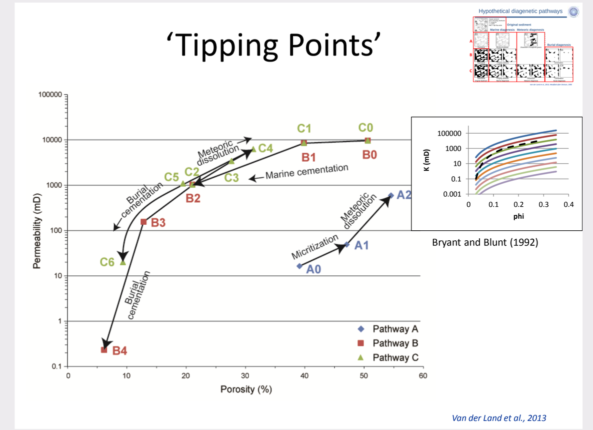


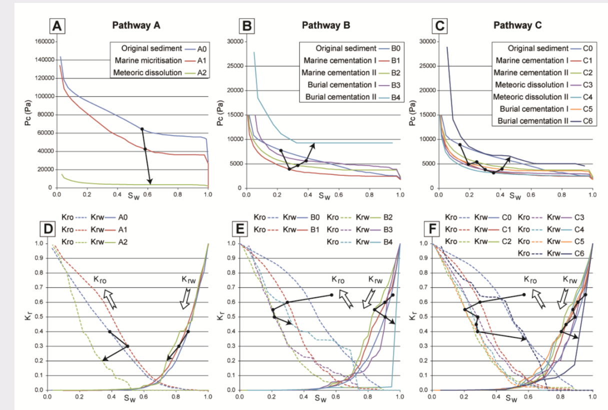

## Application Examples

### Carbonate Diagenesis:

Example from van der Land et al (2013) illustrating synthetic burial diagenesis of carbonate sediments, and the subsequent evolution of petrophysical properties. This example shows how geologically-understood textural changes can be used to calculate property evolution during basin history.

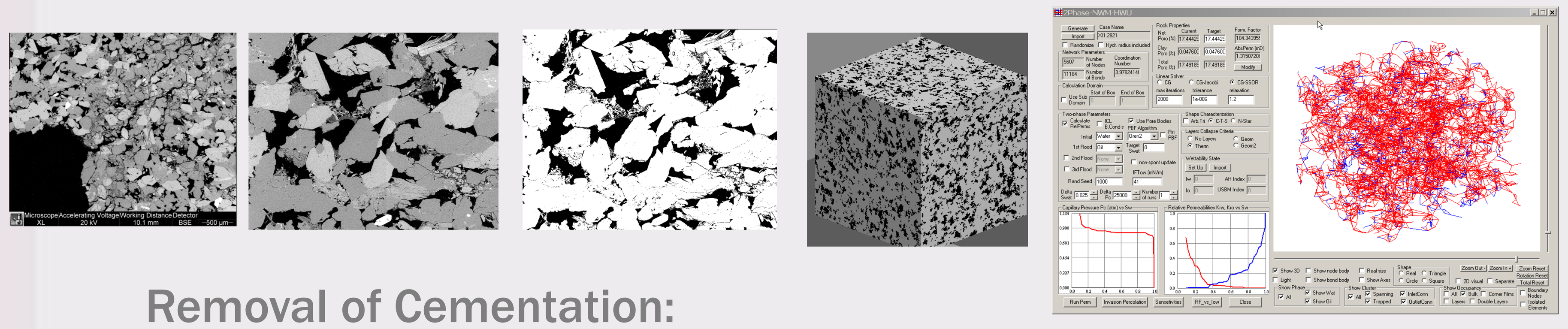


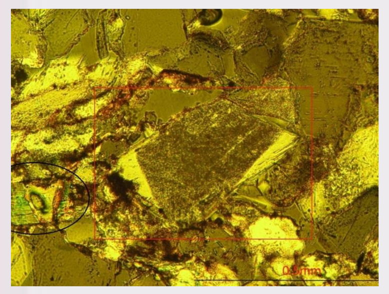
### Localised Deformation Features:

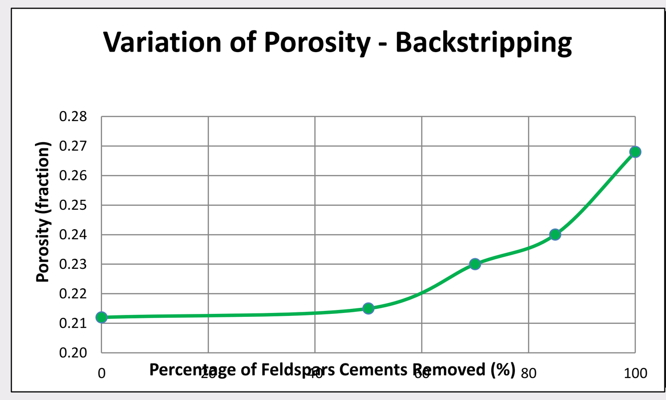
Example of a lab-deformed sandstone sample, which developed a local shear band. The band exhibits crushed grains leaving a poorly-sorted region in which the porosity has been reduced. Other data (not shown here: including before/after X-ray comparisons, Acoustic Emission locations and typing, etc) reveals that the shear band contains both dilated and compactive regions, plus high values of shear strain. These regions are on the order of 1mm in size, and cannot have their properties determined experimentally. The illustration shows how the 2D textures can be used to calculate the flow properties.

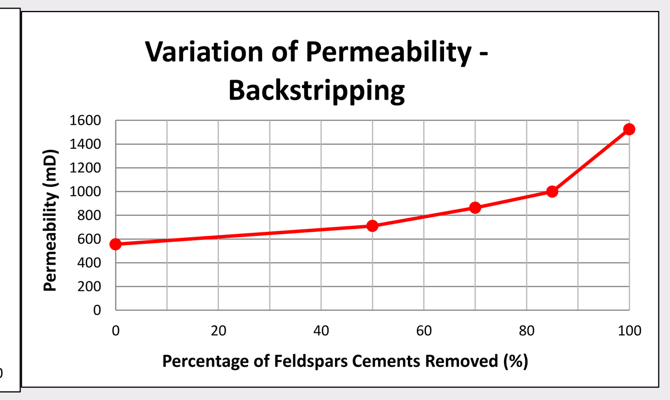


### Removal of Cementation:

Example of arkosic sandstone, with feldspar grains AND cements. BSE and CL images from SEM combined to identify minerals. Image processing allows removal of these textural elements, and digital rocks approach allows calculation of former properties.







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