Inter-Granular Relationships and Characterization of Bed Structures for Fluvial Sediment in Gravel-Bed Rivers Using Computed Tomography (EP51B-0919)

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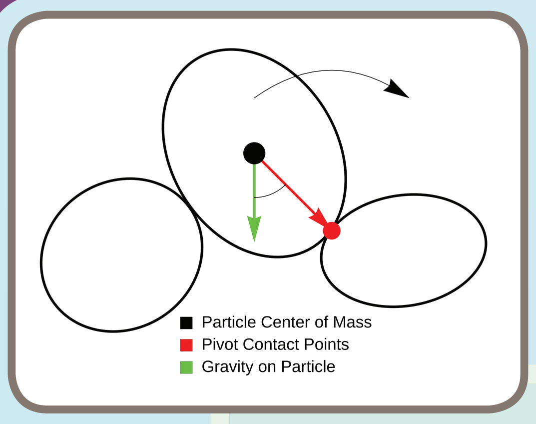
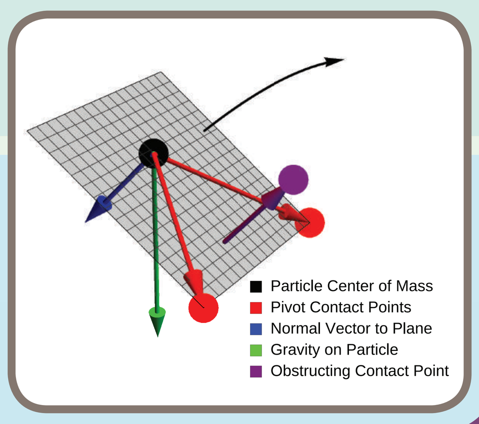
PATCheS Particle Arrangement to Channel Shape

NERC SCIENCE OF THE ENVIRONMENT



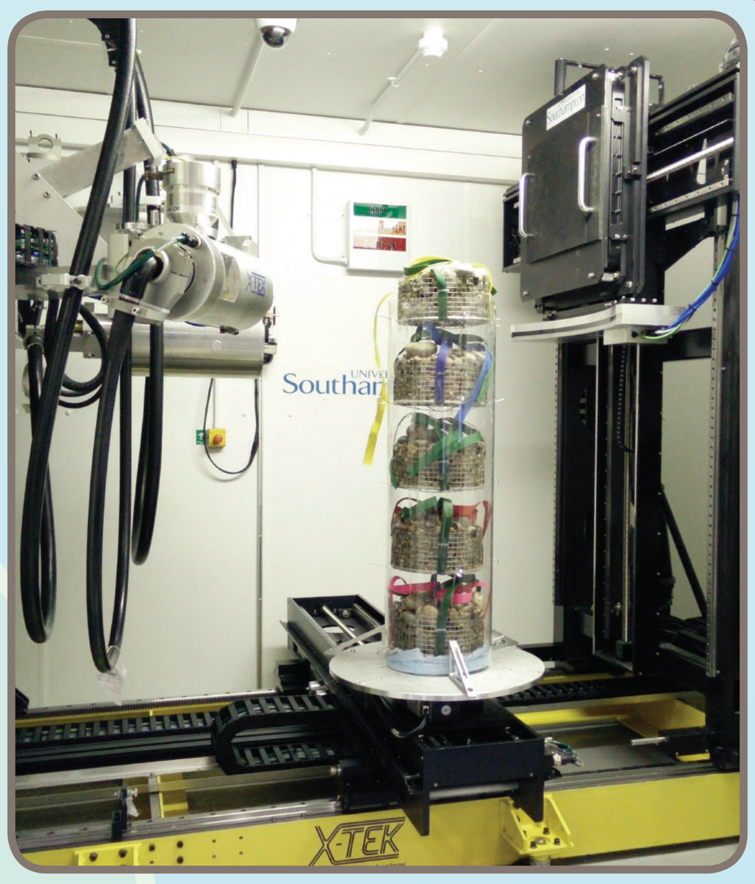
2 Consider empirically finding pivot angles from 3D images of water-worked, representative samples of sediment taken from a river. We then model critical shear using a 3D diagram (below) where a pivot angle is formed between gravity and the plane spanned by two contact vectors.

1 We use simple moment diagrams of forces acting on river sediment in 2D space to determine a particle's critical shear stress. The angle between the gravitational vector (above in green) and the contact point vector (red) is the pivot angle, which is an important metric used in estimating a threshold of motion.

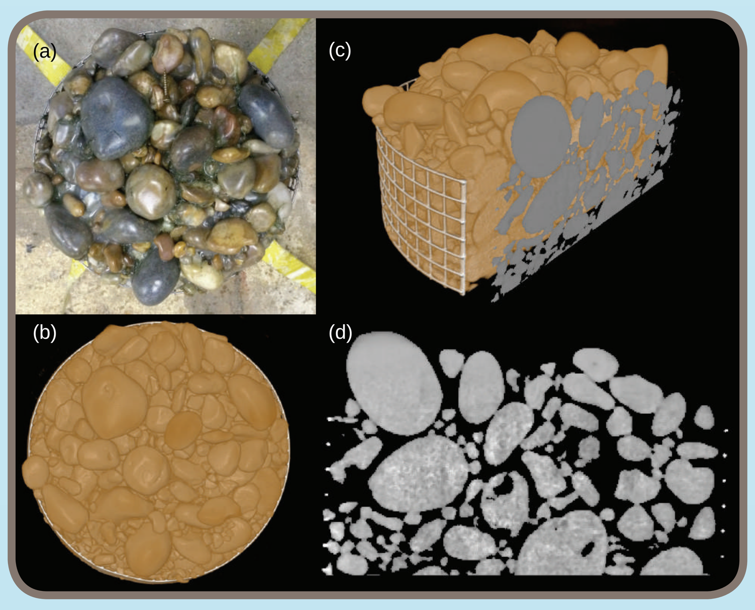


3 Sub-threshold flows were used in a 24m-by-1.8m experimental flume to water work sediment across a field-scale, pool-riffle sequence. Different mixtures of fine sediment (coarse sand through clay) were incorporated into gravels where randomly placed pots were used to collect samples.

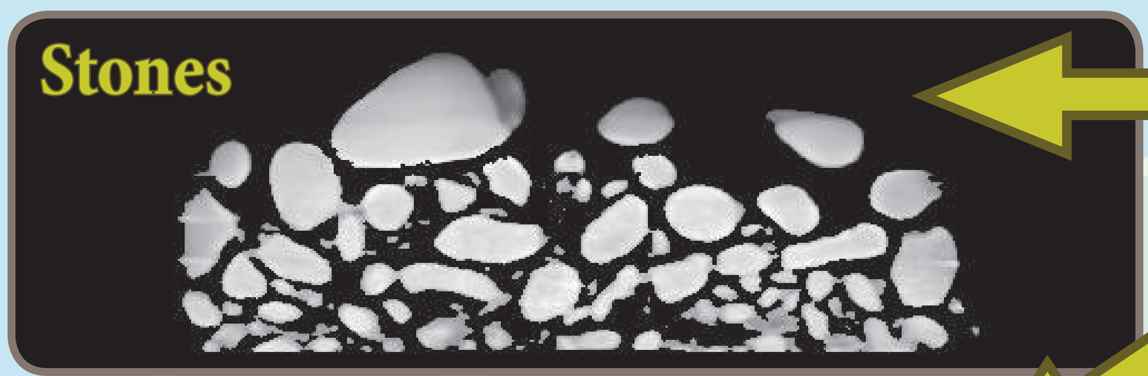
4 After a 12 hour flume run at steady-state flow, pots were excavated and waxed to prevent shifting sediment. Collocated "tilt-table" pots were also used to obtain a set of physical pivot angles, which were later used for validating pivot angles derived from CT scanned images.

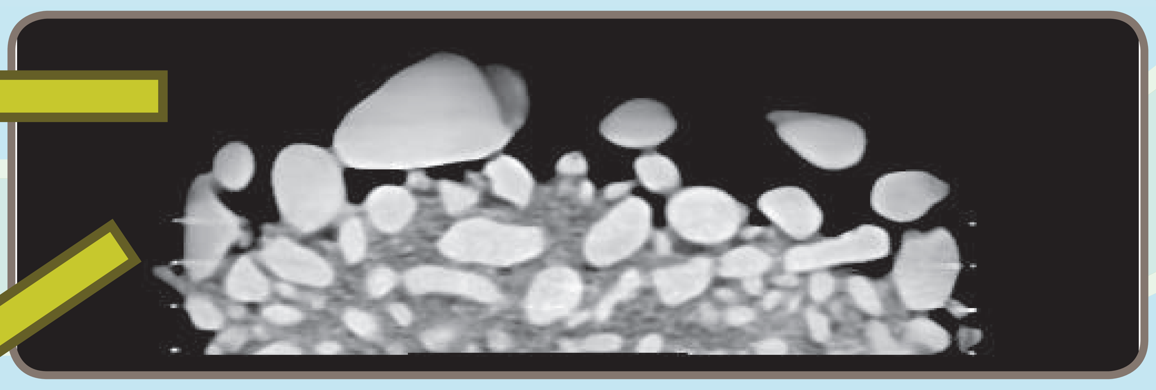


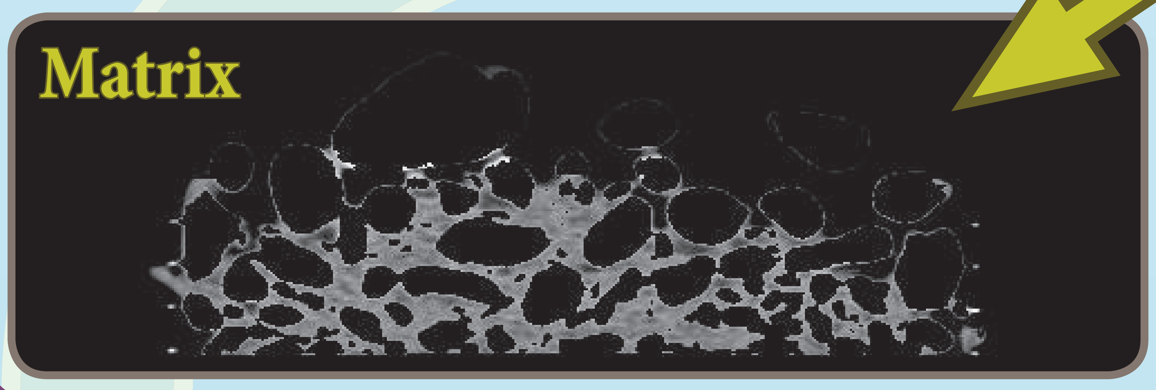
5 Pots are stacked atop a high-precision turnstile base where they are scanned at 1/2 degree turns using high-powered X-ray (above figure). Prior to scanning, each pot is marked (below figure) for their downstream direction(a). Scanned images with 0.599mm voxel length resolution are reconstructed from sinogram images in the visualization laboratory (b). Images are processed further with filter algorithms to clean up noise and to remove any scanning artefacts (c). Preprocessed images are ready for registration (d).



From CT scanning and image processing...

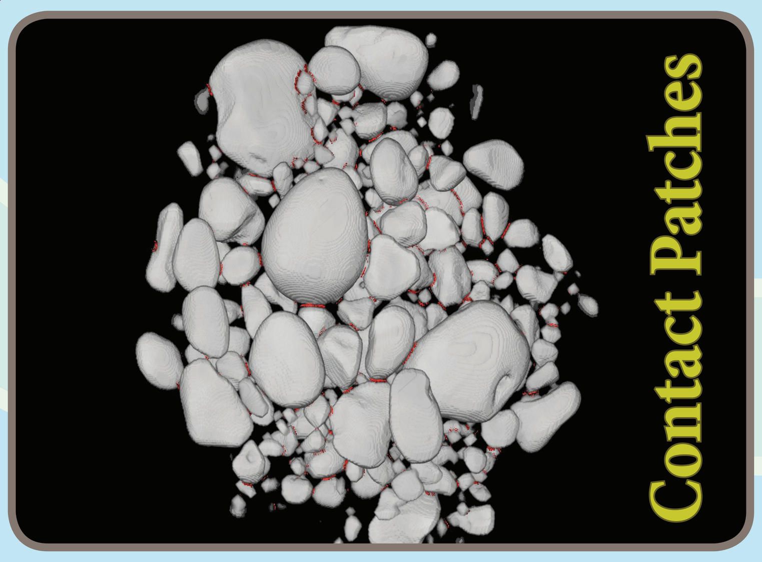




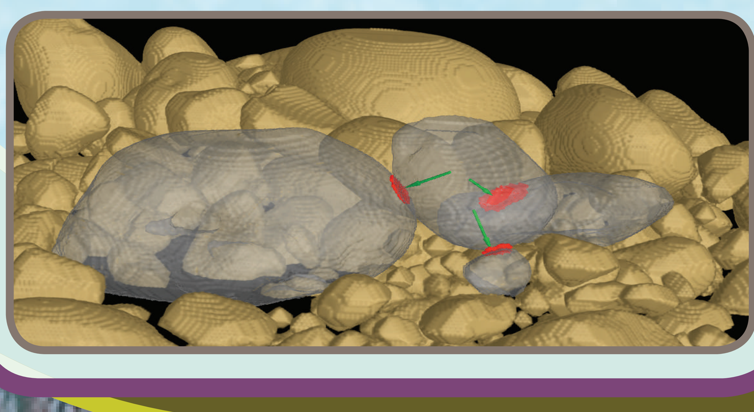


6 Registration involves reorienting the image reference frame such that the top rim of the pot is parallel to the x-y plane, the z-axis is the direction of gravity, and the x-axis is the direction of flow. The registered images are then clipped to the zone of interest (above). Trainable segmentation is used to partition stones (top left) from matrix (bottom left) in a series of binary stages: material and air, metal and material, stones and pores, stones and matrix. Segmented images are then ready for separation where each stone is identified.

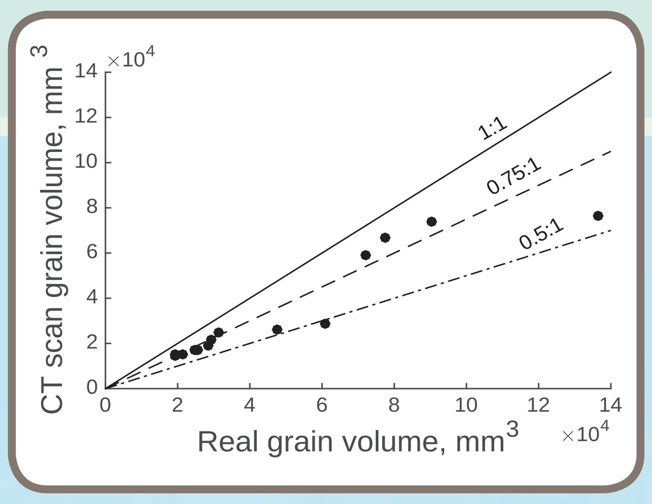
...to segmentation and analysis!

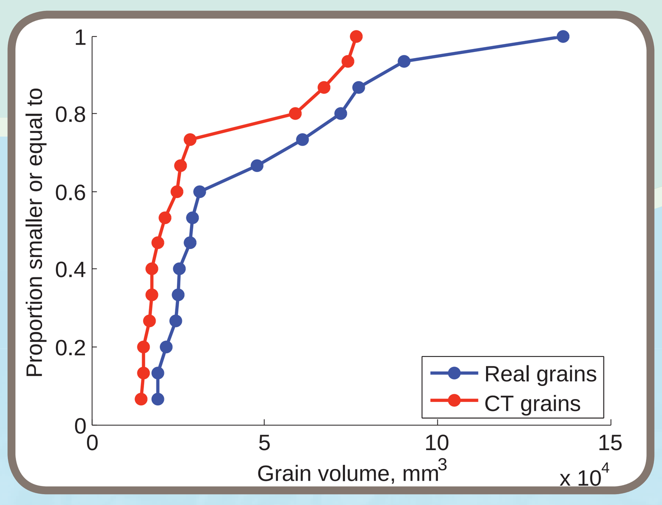


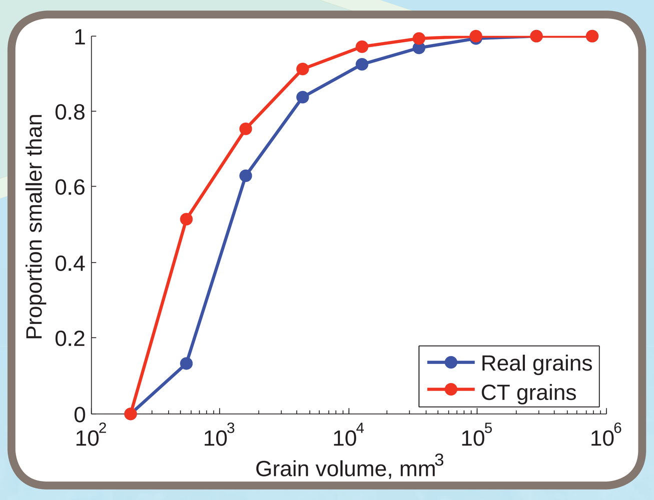
7 Once stones have been separated, contact patches (above in red) between stones are found. We then find metrics for each stone such as volume, centre of mass, axis lengths and orientation. From centres of mass for each contact patch we generate a particle-to-contact vector space (below) where we use simple vector algebra to construct a table of potential contact pairs that form pivot angles, and then we choose the minimum angle that meets further criteria.



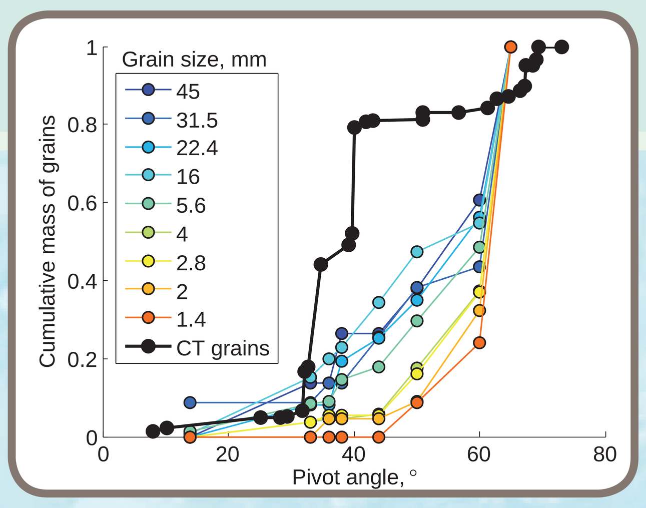
8 Grain volumes from CT scan images are compared with real, density-based grain volumes for the 15 largest stones from a sieving analysis (below left). Volume bias is due to voxel (i.e. 3D pixel) erosion that typically occurs during the trainable segmentation phase of processing (see matrix segmented image in Block 6). An error analysis that includes bias correction estimates are planned in a later phase of the project once all images are processed. Distributions of grain volumes for the 15 largest stones (below middle) and for all stones (below right) indicates bias is somewhat consistent across grain sizes. Similar distributions are possible for any principal axis length as well as any of their orientation angles. Aside from median axis lengths, distributions of these other metrics are only possible using scanned 3D images.

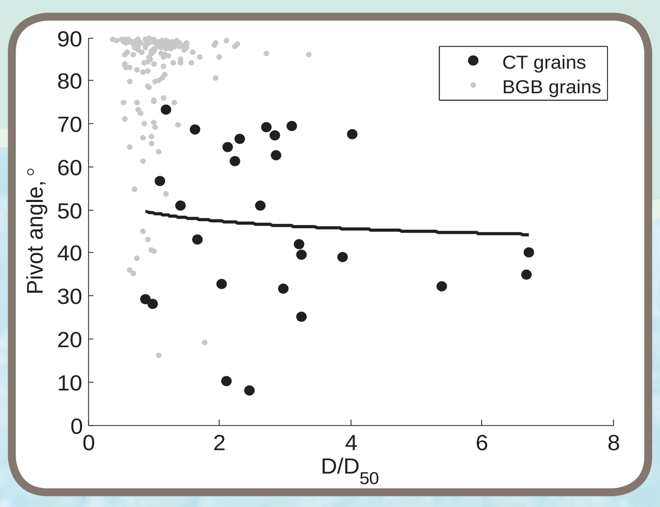


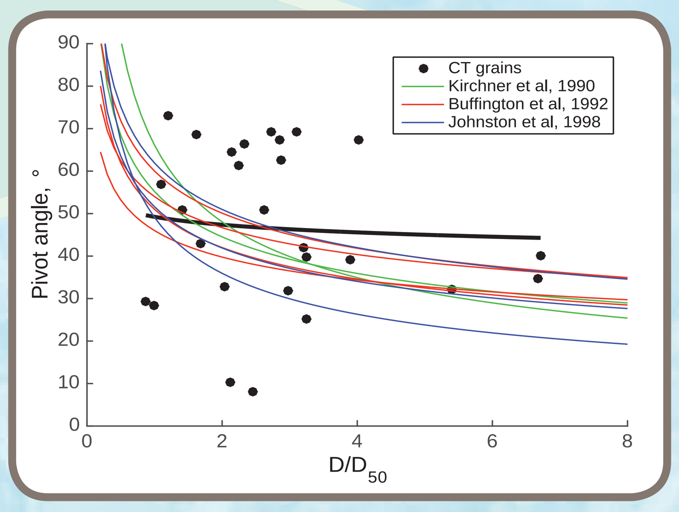




9 Criteria for final selection of pivot angles from the table of potential contact vector pairs include: direction of grain tilt, orientation of contact vector pairs, and whether there are any other obstructing contacts in the direction of tilt. A comparison is made between pivot angles measured from the CT images and those measured using a tile table (below left). Tilt table data were from a collocated pot that was adjacent to the pot used in scanning, and shows the mass and size of all grains that were mobilised at increasing angles. CT grains range in diameter from 7 to 54mm. Comparisons are also made between pivot angles calculated from the CT data and pivot angles measured from our field site Bury Green Brook (BGB) using a force gauge (below middle), and pivot angles recorded in the literature (below right).







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