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Preliminary LIDAR survey results from Peak Cavern Vestibule, Derbyshire, UK

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Abstract: A third phase of investigation of the Peak Cavern Vestibule, using cutting-edge LIDAR total station equipment, obtained a 16.8 million co-ordinate data point cloud, which was re-sampled into a digitally-rendered, 3-D triangular surface model. Visualisation software allows dynamic viewing of the data model from any angle or orientation, with editing software allowing picking, interpretation and horizon generation of geological features of interest. Model analyses of surface 'en-echelon' joints reveal an anticlinal fold hinge mid-way through the Vestibule. Bedding planes were found to be sub-horizontal but parallel to the Vestibule main body axis.

A CD-ROM of the data model and IMView visualisation software is freely available on request, contact Robin.Westerman@pet.hw.ac.uk

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INTRODUCTION

This paper introduces a third phase of site investigation in The Vestibule, or entrance chamber, of Peak Cavern, Derbyshire, UK. Hancock (1999) used ground resistivity geophysical techniques to profile the cave earth deposits along a rope-walk and five artificial benches descending to a stream-bed at the side of The Vestibule. Pringle *et al.* (2002) built a multidata 3D-CAD model from Hancock's geophysical results plus new Ground Penetrating Radar (GPR) data and a Total Station laser theodolite survey.

The Peak Cavern Vestibule was re-surveyed on the 2nd June 2003 with ground LIDAR (LIght Detection And Ranging) equipment. Ground LIDAR is the next-generation surveying technique, wherein very rapid acquisition of co-ordinate data points creates a highly-detailed data point cloud of the object or area. LIDAR acquisition equipment scans objects in an 80° vertical range and a 150° lateral frame scan. A fully three-dimensional digital model of an object or survey area can be produced by combining scans, if artificial reflector patches are placed in overlap zones between survey swaths. LIDAR technology is developing rapidly and both the image quality and the scan rate are ever improving. However, equipment is relatively expensive and in short supply at the time of writing.

VESTIBULE SURVEY AND RESULTING DIGITAL MODEL

A Riegl LMS-Z360 high-speed scanner acquired 16.8 million co-ordinate points of the Vestibule in 8 surveys (termed swaths) in four hours. Data points had a 1cm sample interval and 1.2cm resolution. The previous professional Total Station survey acquired 400 xyz points in four hours. The LIDAR data rate peaked at 18,000 data points per second. After combining separate swaths, the resulting data point cloud was re-sampled by InovMetric IMAlign software, firstly to remove duplicated swath points, then re-sampled into 8.5 million triangular apex points. A triangulated surface was then fitted through these points and rendered, vertex separation of the model being ~4cm in resolution. The vertex model however was still 200 Mb in xyz ASCII format.

Figure 1 shows a rendered model view of the Vestibule in IMView visualisation software, as would be seen by a very tall person on the approach pathway. This view is similar to Figure 1a of Pringle *et al.* (2002). Note the person of normal height standing on the path at lower right and the partial image of the kiosk above him (marked). The rope-walk benches are beyond the kiosk at lower centre. The upper half of the picture shows the vertical head of the gorge approaching Peak Cavern and the Vestibule roof.

The advantage of viewing the digital model in IMView software is the ability to remove designated areas of the model, i.e. a cave side, so the viewer can see the model from any view and orientation, without the restriction of being either land-based, or of a particular view from conventional photography. Figure 2 shows a rendered view of the model, as though looking down through the country rock from Peveril Castle on the surface above the cave mouth. The Swinehole entrance extends towards the viewer at lower centre. The head of the approach gorge abuts the right-hand margin. Note the subhorizontal bedding surfaces etched into the external cave wall. Subvertical, conjugate joint surfaces offset the cave axis.

Figure 3 shows a rendered orthogonal view of the digital model, as though seen through the country rock (with the back of the Vestibule removed), but from a position above Lumbago Walk. The line of sight is towards the entrance to The Vestibule and so opposite in direction to that of Figure 1. The stream down-cut and top bench areas are marked.

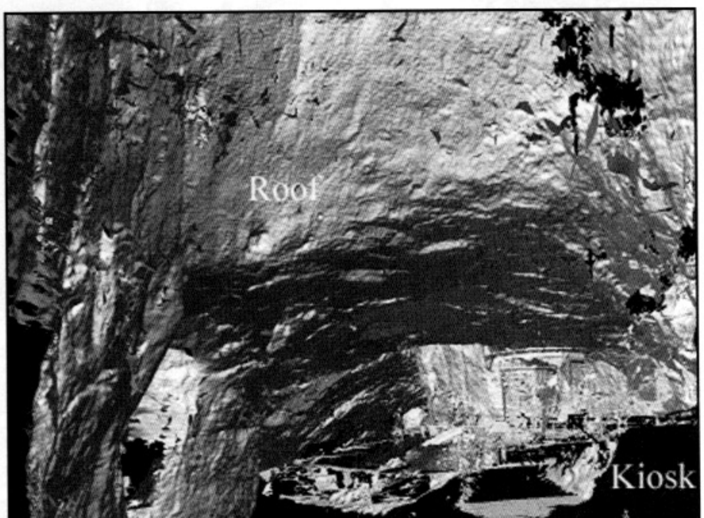

***Figure 1.** Rendered view of the Peak Cavern Vestibule digital model in InnovMetric IMView visualisation software, looking past the kiosk (marked) to the rope-walks. Black areas indicate holes in the dataset.*

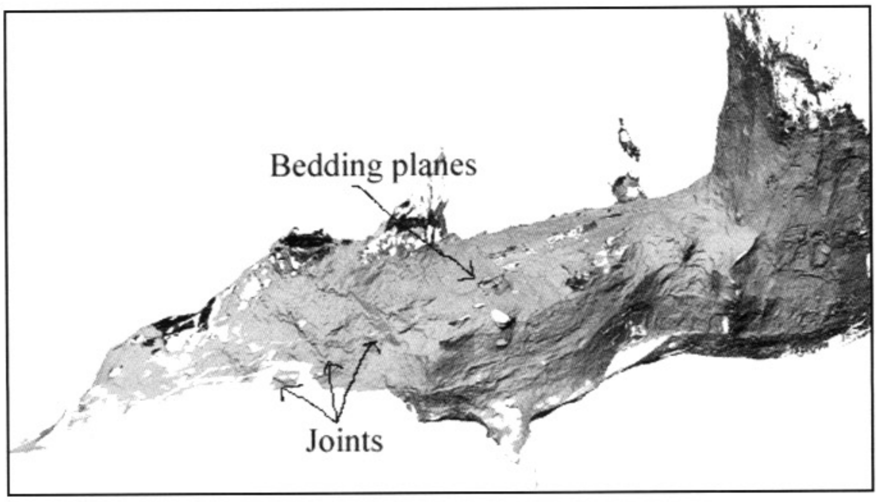

Figure 2. Rendered view of the digital model, as though looking down through the country rock from Peveril Castle. Note the sub-horizontal bedding sections and 'en-echelon' joints.

MODEL INTERPRETATION

From analysis of the digital model, stratigraphical and structural features can be discerned that are not immediately obvious from visual inspection of the Vestibule. A set of sub-vertical, 'en echelon' joints is observed in the digital model for example, and interpreted as controlling the main line of avens, though they are not well discerned in Figure 3. The 'en-echelon' joints also appear to pick out a subtle anticlinal fold hinge.

Bedding planes, which can be observed by visual inspection of the Vestibule, show interesting variations in the digital model. To the southwest of the visible aven, the bedding planes are sub-horizontal, whereas to the northeast of the aven, the bedding plane dip is towards the northeast. These abrupt dip variations seem to be aligned parallel to the axis of the main body of the Vestibule (Figure 2). Furthermore, the northeasterly dipping bedding plane, in the roof to the right of the visible aven, is parallel to a strong bedding plane etch feature beneath. Both bedding planes are sub-parallel to the diagonal line formed by the surface of the cave earth. As noted by Pringle *et al.* (2002), the slope of the cave earth deposit extrapolates along the base of the Swinehole, so evidence suggests the bank of cave earth deposits in The Vestibule may share the same lithological and structural controls as the processes that formed their host chamber. Indeed, the processes that formed The Vestibule might have left the cave earth bank as a residue (compare the discussion with Dr T D Ford in the Forum section of *Cave and Karst Science*, Volume 30, No.1, pp.44–45).

CONCLUSIONS AND COLLABORATION SUGGESTION

Additional LIDAR swaths are needed to fill existing holes in the data model. A more detailed analysis of the rendered LIDAR data model may resolve outstanding issues mentioned in this paper. As an inducement to further collaborative work, Laser Mapping Ltd. have agreed to make the Peak Cavern LIDAR digital dataset freely available to interested parties. The IMView LIDAR visualisation program used to view the model is also freely available from InnovMetric. A CD-ROM of the data model and software is available on request from Robin Westerman (contact details above).

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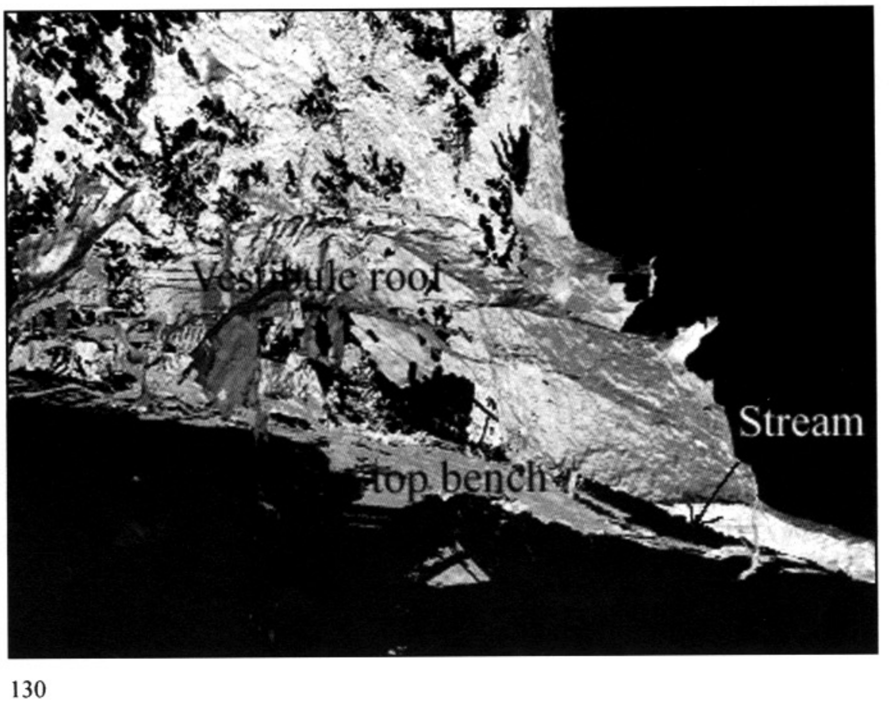

Figure 3. Rendered view of the digital model from the rear of The Vestibule above Lumbago Walk, with the near-back surface removed. The lowest surface is the top bench forming the cave earth fill.