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3D Visualization of Sheath Folds in Roman Marble from Ephesus, Turkey

Sebastian Wex (1), Cornelis W. Passchier (1), Eric A. de Kemp (2), and Sinan Ilhan (3)

(1) Institute of Geosciences, University of Mainz, Germany, (2) Geological Survey of Canada, Ottawa, Canada , (3) Curator, Ephesos excavations, Selçuk, Turkey

Excavation of a palatial 2^{nd} century AD house (Terrace House Two) in the ancient city of Ephesus, Turkey in the 1970s produced 10.313 pieces of colored, folded marble which belonged to 54 marble plates of 1.6 cm thickness that originally covered the walls of the banquet hall of the house. The marble plates were completely reassembled and restored by a team of workers over the last 6 years. The plates were recognized as having been sawn from two separate large blocks of "*Cipollino verde*", a green mylonitized marble from Karystos on the Island of Euboea, Greece. After restoration, it became clear that all slabs had been placed on the wall in approximately the sequence in which they had been cut off by a Roman stone saw. As a result, the marble plates give a full 3D insight in the folded internal structure of $1m^3$ block of mylonite. The restoration of the slabs was recognized as a first, unique opportunity for detailed reconstruction of the 3D geometry of m-scale folds in mylonitized marble.

Photographs were taken of each slab and used to reconstruct their exact arrangement within the originally quarried blocks. Outlines of layers were digitized and a full 3D reconstruction of the internal structure of the block was created using ArcMap and GOCAD. Fold structures in the block include curtain folds and multilayered sheath folds. Several different layers showing these structures were digitized on the photographs of the slab surfaces and virtually mounted back together within the model of the marble block. Due to the serial sectioning into slabs, with cm-scale spacing, the visualization of the 3D geometry of sheath folds was accomplished with a resolution better than 4 cm. Final assembled 3D images reveal how sheath folds emerge from continuous layers and show their overall consistency as well as a constant hinge line orientation of the fold structures. Observations suggest that a single deformation phase was responsible for the evolution of "*Cipollino verde"* structures. Furthermore the XY plane of all analyzed sheath folds was orientated perpendicular to the layering of the marble, indicating a compressional component during shear deformation.

This study sheds light on the general evolution and possible interpretation of sheath folds, currently still subject of debate, and on the structural evolution of "*Cipollino verde"*, which is still used in modern architectural design. Furthermore, the detailed analysis of the slabs helps in the interpretation and reconstruction of Roman stone saws. For future applications this work could serve as an excellent 3D test set for geologic reconstruction methodologies and interpolation algorithms. The results presented could only be obtained by close cooperation of workers in geology and archaeology.