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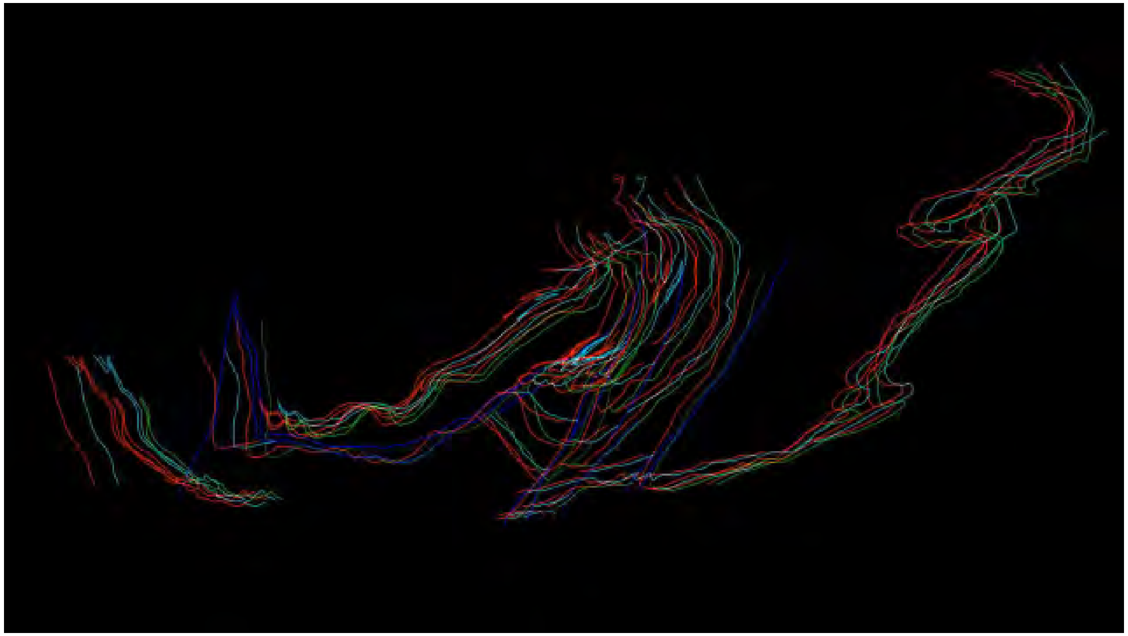

Animation 3. Comparison of major lithologic contacts on the north wall of lower Pleasant Canyon mapped using 2.5-dimensional (2.5-D) methods on a 30 m digital elevation model versus those mapped on the high-resolution MVS model using 3-D methods. Note that this video is meant to be viewed with anaglyph glasses. Yellow and orange lines are lithologic contacts and faults or shear zones, respectively, mapped on an orthophoto. White and blue lines are lithologic contacts and faults or shear zones, respectively, mapped on the 3-D model. These same colors are used for this scene in Figure 13. Note the systematic shifts between the two sets of lines. Of particular note is the poor rendering of the isoclinal fold in the center in the conventional 2.5-D rendering versus the true 3-D rendering. See text for discussion of the origin of the discrepancies. Refer to Figure 3B and 13 for scale. This video was made using Move software. If reading the full-text version of this paper, please download article PDF to view Animation 3 in Adobe Acrobat or Adobe Reader. It is also available by visiting http://doi.org/10.1130/GES01691.a3 or the full-text article on www.gsapubs.org.

This conclusion arises from previous experience with orthorectification of high-resolution, off-nadir satellite imagery in steep terrain (Pavlis et al., 2012), where orthorectification software cannot faithfully orthocorrect the much higher-resolution image using the low-resolution DEM, and this orthocorrection error is propagated into the 3-D line traces in the 2.5-D method. In Pleasant Canyon, the most likely origin of the observed distortion in the 2.5-D model is a combination of georeferencing errors that are artifacts of the orthorectification and an additional effect resulting from the look angle. To understand the latter, consider the case of a satellite image taken off nadir with a look angle from the south. In such an image, the Noonday site cliff face would occupy a larger fraction of the resulting scene relative to a nadir-looking view. If that image were draped onto a high-resolution terrain model with extensive ground control on the image, orthorectification software could correct for this geometry. However, in cases like this one where the image is draped on a low-resolution DEM, the orthorectification introduces a systematic error. This effect is well known in orthocorrection and is essentially the complementary effect of pixel smear; i.e., pixel smear is generated when the look angle of an image is close to parallel to the topographic slope, smearing pixels along the look direction, whereas in the Noonday case, the slope is at a high angle to the view and excess pixels allow a clear but distorted image of the cliff. Note that had we limited our work to the 2.5-D method, this error in 3-D geologic interpretations would have been undetectable and the resultant geologic model distorted from its true geometry.

Finally, we consider the case of Wildrose Canyon where there is significant topographic relief but modest slopes of <45° (Fig. 8B). Here, lithologic units are manifest as conspicuous color bands easily seen on all imagery, allowing direct comparison of 2.5-D and 3-D mapping (Fig. 14). In this case, comparison of the same contacts drawn on the TLS 3-D terrain model versus the 2.5-D method produces line traces that are nearly indistinguishable from each other (Fig. 14; Animation 4). Indeed, in this case the 2.5-D method is arguably superior because the imagery used in that model is of higher resolution than 3-D model and the contacts are more easily seen on the vertical-incident flat-map images than in the 3-D model acquired at ground level. Nonetheless, there is a notable systematic shift of ~5 m between the two models that could have resulted from inaccuracy of the image drape onto the DEM, an improper vertical datum correction between the models, or both.

DISCUSSION

Sources of Error Associated with Obtaining Ground Control

The four ground control methods utilized in the uncontrolled photogrammetric modeling scenarios had varying combinations of error sources that effected model accuracy. The discussion here is focused on ground control accuracy and how the process of obtaining ground control might be improved