

## FNR 66 Lab 5

### Slip Rates and Uncertainty at Wallace Creek

**From: Workshop 4A: Identifying and mapping landforms and quantifying fault displacement with lidar digital topographic data**

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#### **Introduction**

Any successful study of tectonics and topography must begin with a detailed analysis of the landscape. A key component to many recent fault system investigations is airborne lidar digital topographic data. These data facilitate the efficient identification, mapping, and analysis of deformed landforms in unprecedented detail (e.g., Carter et al., 2007; Hudnut et al., 2002; Arrowsmith and Zielke, 2009; Frankel et al., 2007a,b; Oskin et al., 2007). Lidar data have several great advantages over previously available forms of remotely-sensed and digital topographic data. In particular, surveying of deformed geomorphic features (e.g., offset channels and alluvial fans) and the construction of high precision topographic maps, which would take days to weeks with traditional surveying methods, can be accomplished in minutes with lidar data.

Moreover, the high-resolution topographic data can be digitally manipulated to enhance and reveal subtle topographic features, something not possible with most aerial photographs, satellite imagery, or lower-resolution digital elevation data. For example, the landscape can be artificially illuminated from any angle to highlight previously unrecognized features of the landscape and surface slope and slope aspect maps can also be easily constructed to reveal and retrodeform subtle topographic features (e.g., Frankel, 2007; Frankel et al., 2007a,b; Oskin et al., 2007; Arrowsmith and Zielke, 2010; Zielke et al., 2010). Furthermore, this technology holds the ability to “see through” canopies in vegetated regions, thus revealing an image of the “bare earth” beneath the trees and illuminating landscapes that could not previously be investigated in detail with aerial photographs or other forms of remotely-sensed images (e.g., Carter et al., 2007; Prentice et al., 2009). These data can also be used to more objectively map and quantify the evolution of alluvial landforms through time by developing various algorithms to measure surface roughness characteristics (e.g., Frankel and Dolan, 2007; McKean and Roering, 2004; Glenn et al., 2006). By combining detailed landform analyses from lidar data with age control from improved Quaternary geochronometers researchers are gaining unprecedented insight into the rates and patterns of lithospheric deformation and landscape evolution.

#### Slope Maps

Slope maps can be extremely useful for identifying faults, particularly in a low-relief landscape as is common where faults cut alluvial fans. Often, active faults are expressed geomorphically as scarps cutting alluvium. These scarps tend to be significantly steeper than surrounding topography and thus, slope maps often reveal the scarp topography in dramatic fashion (Figure 5). In addition, slope maps can aid in the identification of secondary fault strands and off-fault deformation. To produce a slope map, follow the directions below:

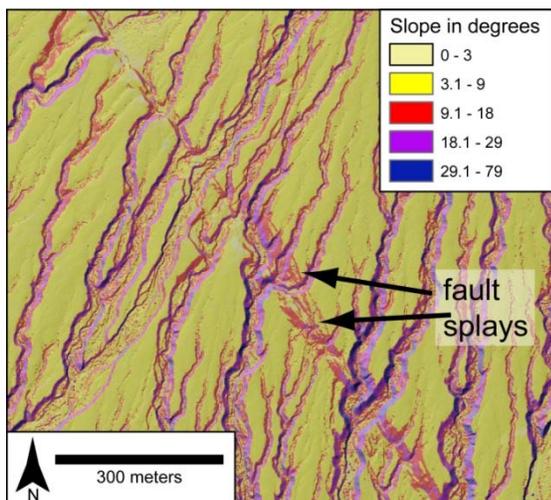
1. Enter ArcToolbox  
navigate to 3D Analyst Tools → Raster Surface → Slope
2. Select your input dataset (Input raster)
3. Define the name for your slope
4. Click “OK”

By default, a “classified” slope map will be produced and displayed. To improve the clarity of the map, you will want to turn this into a “stretched” slope map, which can be displayed by the following.

1. Double click on the slope map title in the “Layers” menu on the left of your screen.
2. Click on the “Symbology” tab.
3. On the left side of the Symbology window, select “Stretched”
4. Select the color ramp you want to use
5. Click OK

Optional:

You may want to display the slope map either as a pseudo-hillshade or “draped” over the hillshaded topography. To do this, you can click on “Use hillshade effect” beneath the color ramp. Alternatively, you can click on the “Display” tab under Layer Properties and make the slope map semi-transparent (~25%). Then, in the Layers window, position the slope map directly on top of the hillshade to produce a 3D effect.



**Figure 5. Slope map derived from lidar for the Red Wall Canyon alluvial fan in Death Valley. Image shows the multi-stranded nature of the fault.**

## Surface Roughness Maps

Surface morphology is one of the most widely used criteria to distinguish alluvial fans of different ages (e.g., Wells et al., 1990; Bull, 1991; Ritter et al., 1993). Previous studies suggest that the relative age of alluvial deposits is manifest by topographic variability, with fan surfaces tending to become smoother with increasing age (Bull, 1977; 1991; Matmon et al., 2006). As a more objective way to map alluvial fan deposits, lidar topographic data can be used to quantify differences in alluvial fan surface roughness, thereby helping identify individual fan units. Although there are many ways in which to measure the texture of alluvial and colluvial material (e.g., McKean and Roering, 2004; Glenn et al., 2006), here surface roughness is defined as the standard deviation of slope. The roughness metric in this way because it allows us to average out surface features over a five-meter by five-meter area, thereby eliminating any anomalies related to individual boulders or the occasional creosote bush. Furthermore, taking this approach to calculating surface roughness accounts more readily for the wavelengths (~5 to 10 m) of typical bar and swale morphology that are commonly observed in arid alluvial environments. For a detailed description of this methodology, please see Frankel (2007) and Frankel and Dolan (2007).

In order to produce a surface roughness map it is easiest to issue the commands for this operation manually using the command line window. Do this via the following steps.

1. Open the command line window by clicking on the “Window” tab on the main ArcMap menu

Window → Command Line

2. Once the command line window is open, make sure you are in the correct workspace by issuing:

workspace c:\workspace

You should now be in the directory where your slope map resides.

3. Now, you will issue the following command to calculate the standard deviation of values in your slope map:

```
FocalStatistics name_slp name_std 3 STD
```

The first part of this command calls the “Focal statistics” tool, which allows for the analysis of values within moving window; the second term – “name\_slp” – is the name of your slope map; the third term – “name\_std” – is the name of your surface roughness map; the fourth term – “3” – is the cell size of the moving analysis window, which in this case is 3 x 3, or 3 m by 3 m; and the fifth term – “STD” – means you are calculating the standard deviation of values within that moving window.

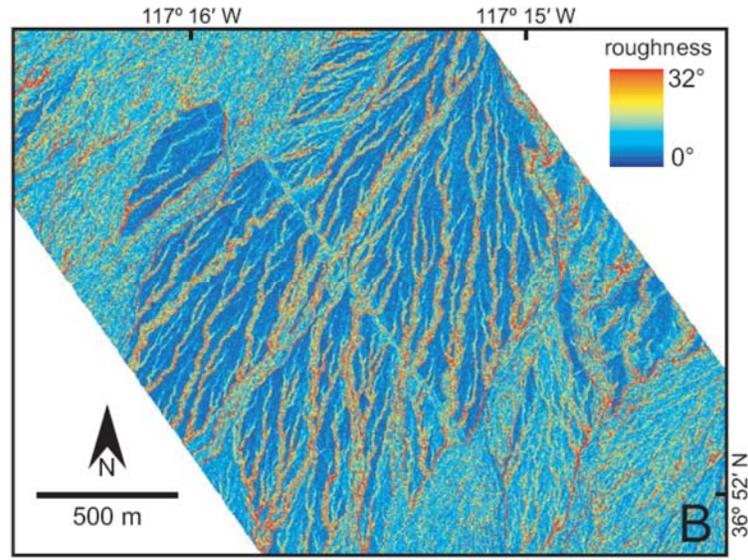


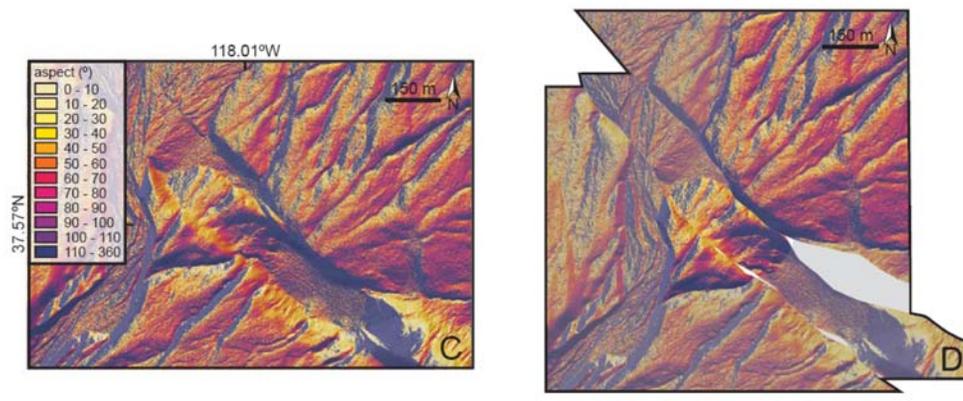
Figure 6. Surface roughness map of the Red Wall Canyon alluvial fan in northern Death Valley. Surface roughness is calculated as the standard deviation of slope in a 3 cell x 3 cell moving window. Modified from Frankel and Dolan (2007).

### Optional: Slope Aspect Maps

Slope aspect maps can also be useful in quantifying fault displacement. This is particularly true in regions with well-developed alluvial fans in strike-slip tectonic settings. Slope aspect maps aid in the reconstruction of the fan apex as well as offset channels because they can highlight subtle topographic features by abrupt changes in slope direction (Fig. X). Slope aspect maps can be produced as follows.

1. Enter ArcToolbox  
navigate to 3D Analyst Tools → Raster Surface → Aspect
2. Select your input dataset (Input raster)
3. Define the name for your aspect map
4. Click OK

Note: Slope aspect maps made need to be classified to highlight the slope directions that best define the landform you are interested in. To do this, click on the “Symbology” tab under Layer Properties and select “Classified” on the left. From here you can assign specific values for azimuth directions and ranges to highlight.



**Figure 7. Slope aspect map derived from lidar topographic data for the Furnace Creek alluvial fan in central Fish Lake Valley (location 2 in Figure 1). The slope aspect map aids in the reconstruction of the right-laterally offset fan to quantify fault displacement. After Frankel et al. (2007b).**