MEMO: Formation Top Mapping
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Formation tops are necessary to calculate the thickness of formations for the volumetric calculations of water and heat within a reservoir. For this project, two formation top data sources were available: the Texas Railroad Commission (RRC) formation tops reported in wells by operators – collated and downloaded through DrillingInfo.com, and formation and thickness maps for the Travis Peak and Cotton Valley sandstones, previously published by the United States Geological Survey (USGS) as part of a resource assessment program (Dyman et al., 2006).

The previously published tops and thickness layers (Dyman et al., 2006) are easily accessible through a quick online download; however, the USGS layers were not used for this project because they are heavily processed and smoothed to 200 feet contour intervals. The heavy processing filters out small heterogeneities in formation structure depths and instead highlights the regional structural trend. Because of the filtering, new input data appears as anomalous values and hinders interpretation. Here, the focus is the local structure to quantify reservoir thickness, not the regional structural trend and therefore the small heterogeneities are important for proper reservoir thickness calculations.

The RRC formation tops are used here to develop high resolution formation top layers and calculate formation thickness to calculate reservoir volume and productivity potential. Steps to develop and calculate formation tops for interpretation in grid format is listed below.

1) Download formation top information
    a. Formation top data is publically available through the Texas Railroad Commission on a single well at a time basis. Likewise, Drillinginfo.com has formation top information, from the Texas Railroad Commission available for download through the Drillinginfo.com user interface. We received permission for this NREL project to downloaded formation tops through Drillinginfo.com. Their interface allows the user to download multiple wells at a time, saving significant amounts of time.
    b. Data through Drillinginfo.com are downloaded as two files: 1) the well list includes surface ownership, operation details, production type, API, etc. and location referenced WGS 84 latitude/longitude as a *.csv file, and 2) Formation tops file includes the API, formation name, formation top depth as measured depth (md) or total vertical depth (TVD) or unknown, field and basin name as a *.csv file.
2) Filter for Formation Tops of Interest
    a. The data available are all tops picked in wells from surface to total depth. For this project we are interested in the Pettet/Sligo, Travis Peak, Cotton Valley, and Bossier as the base of the Cotton Valley. We filtered the formation tops to remove any tops that were not a top of interest. This was completed using MS Excel.
3) Link Formation Top information to well location

   a. The FormationTopsRAW.csv was separated into a new MS Excel workbook (FormationTopsWellsWithTops.xlsx) with a unique Excel sheet for each formation top of interest (Pettet/Sligo, Travis Peak, Cotton Valley, and Bossier.
   b. New columns were added within the WellList.csv using vlookup to examine the formation top excel sheets to find if a given well included a specific formation top, and if so, extract the formation top depth value. The depth value was collapsed into one column based on the order of preference TVD, MD, other.
4) Remove erroneous data – first order effort
   a. Sort Excel worksheets data on depth and remove points that are significantly different, that would be outside the approximate 1 standard deviation. This is somewhat subjective as it was done visually, yet in general, values greater than 1000 ft vertically from the next closest value (e.g. a data point at 6000 ft versus the rest of the data being between 7200 ft and 8800 ft) were removed.
5) Preliminary Interpolation of data
   a. Interpolate data to create a formation top raster surface within ArcGIS. This was done using Kriging in the spatial analyst toolbox within ArcMap 10.2. There are several interpolation options, but Kriging seems to work best when using a mixture of spacing from dense to sparse and irregularly spaced data points.
      i. Here specifically, Kriging was run with the default semivariogram properties, default cell size, and using a fixed search radius with the program assigned distance and minimum number of points to be 15. Running Kriging in this way acts as a data filter by forcing every cell to use a minimum of 15 data points.
6) Remove anomalous data creating point source data anomalies – second order effort
   a. There will be obvious anomalies (point bullize) within the interpolated surface. The anomalies are examined to see how many data points are responsible for producing the anomalous values. If there is contouring generated by one data point that is approximately >20%, that data point is considered erroneous and is marked for removal (steps below). If the anomaly is created by more than one point, it is considered real and is left. This is also subjective, but is a way to quickly assess the dataset for general consistency. Steps to remove the erroneous data points are below:
      i. With the drawing toolbar – draw a rectangle or circle around each data point to remove.
      ii. Highlight all of the drawn figures and in the drawing toolbar dropdown menu, choose “Convert graphics to features” to make a feature layer out of the drawn graphics.
      iii. With the ArcGIS “Erase Point” tool – erase the erroneous data points
         1. Input feature – the depth points data layer
         2. Remove features – the feature layer you created circling all of the erroneous data
         3. Operation type – inside. Inside will delete all of the data points inside the remove features feature layer.
7) Re-interpolate the new depth point data layer to create a working formation top raster layer.
8) “Smooth” the raster surface to further remove erroneous gridding

a. Kriging produces sharp, unrealistic and geologically irrelevant edges when producing a data grid; therefore, a smoothing process is necessary to produce a final raster that is more similar and representative to the subsurface geology.
b. Smoothing is done using the focal statistics tool within the spatial analyst toolbox. Here specifically, we use a rectangular neighborhood of 9x9 cells, and run statistics type MEAN.

REFERENCES

Dyman, T.S. and Condon, S.M., 2006. *Assessment of undiscovered conventional oil and gas resources--Upper Jurassic-Lower Cretaceous Cotton Valley group, Jurassic Smackover interior salt basins total petroleum system, in the East Texas basin and Louisiana-Mississippi salt basins provinces* (No. 69-E-2).