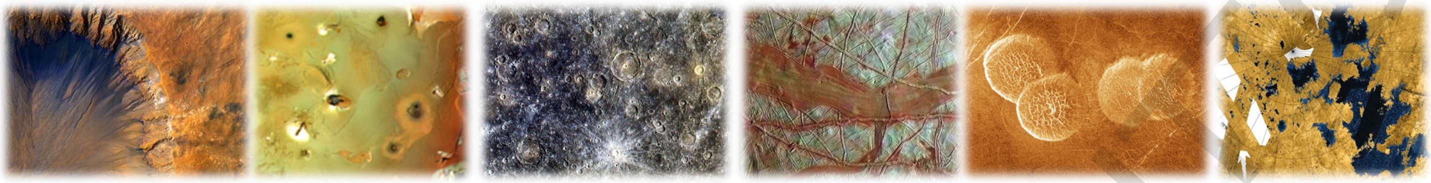
Spacecraft Planetary Image Facility



Introduction to ArcGIS® Pro for Planetary Science

Exercise Workbook

Presented by the
Spacecraft Planetary Imaging Facility (SPIF), Cornell
Sponsored by the
Planetary Data Training Workshops
NASA Topical Workshops, Symposia, and Conferences

USGS science for a changing world

Lunar & Planetary Laboratory

Lead Author

Zoe Learner Ponterio

Manager, Spacecraft Planetary Image Facility (SPIF)

Cornell Center for Astrophysics and Planetary Science

Collaborating Authors

Sayed Najiullah Basharat & Nina Ellison

Cornell Undergraduate Student Assistants

The Planetary Data Training Workshops Team

David Williams (PI) & David Nelsen

Arizona State University, Ronald Greeley Center for Planetary Studies

Alexander Hayes

Cornell Department of Astronomy, SPIF

Marc Hunter & Sarah Black

US Geological Survey, Astrogeology Science Center

Shane Byrne, Christopher Hamilton, & Brett Carr

University of Arizona, Lunar and Planetary Laboratory

Additional Authors of the ArcGIS® Desktop Edition Workbook

Nick Gershfeld, Anjali Rajesh, & Revati Athavale

Cornell Undergraduate Student Assistants

Trent Hare

US Geological Survey, Astrogeology Science Center

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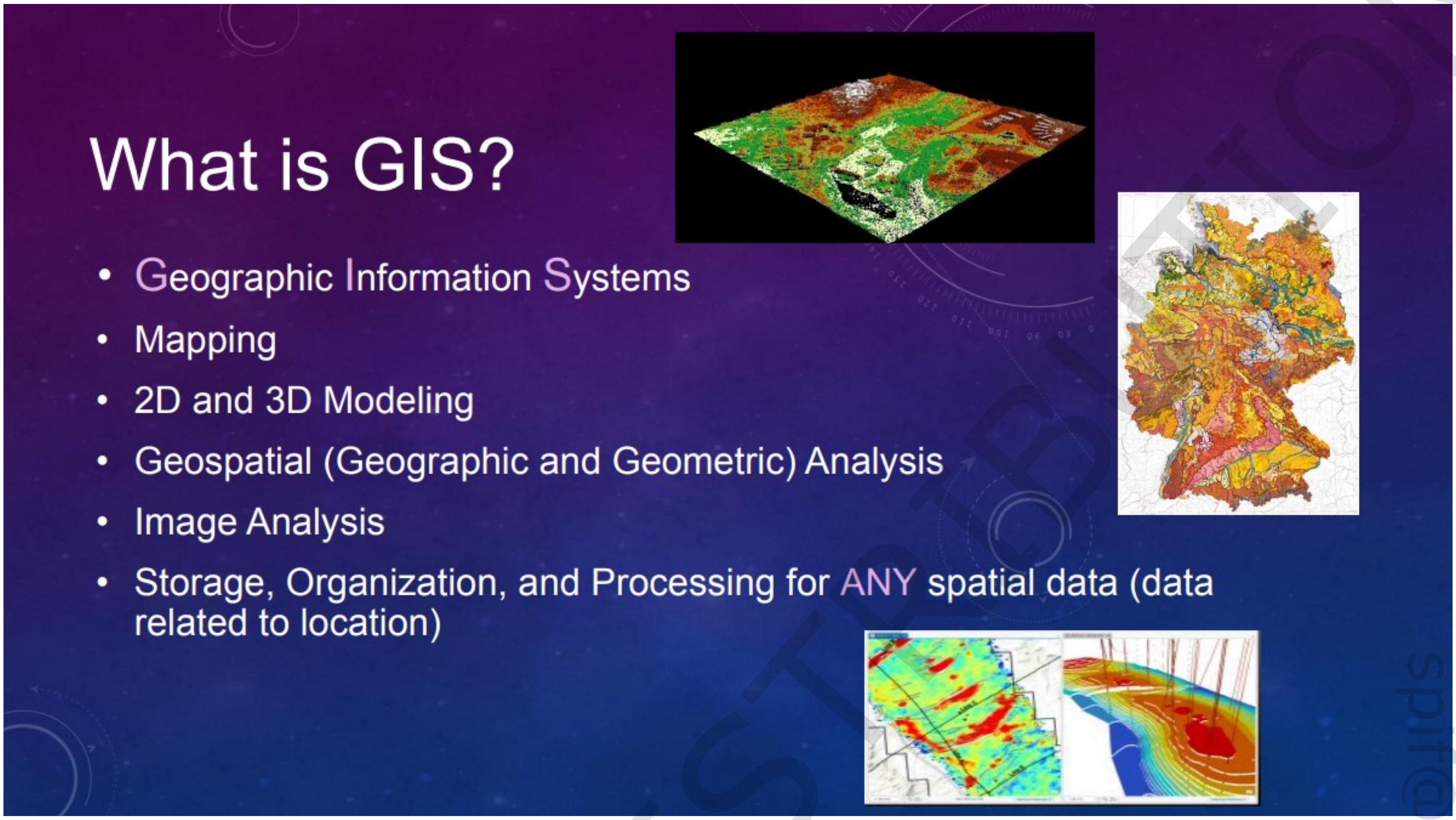
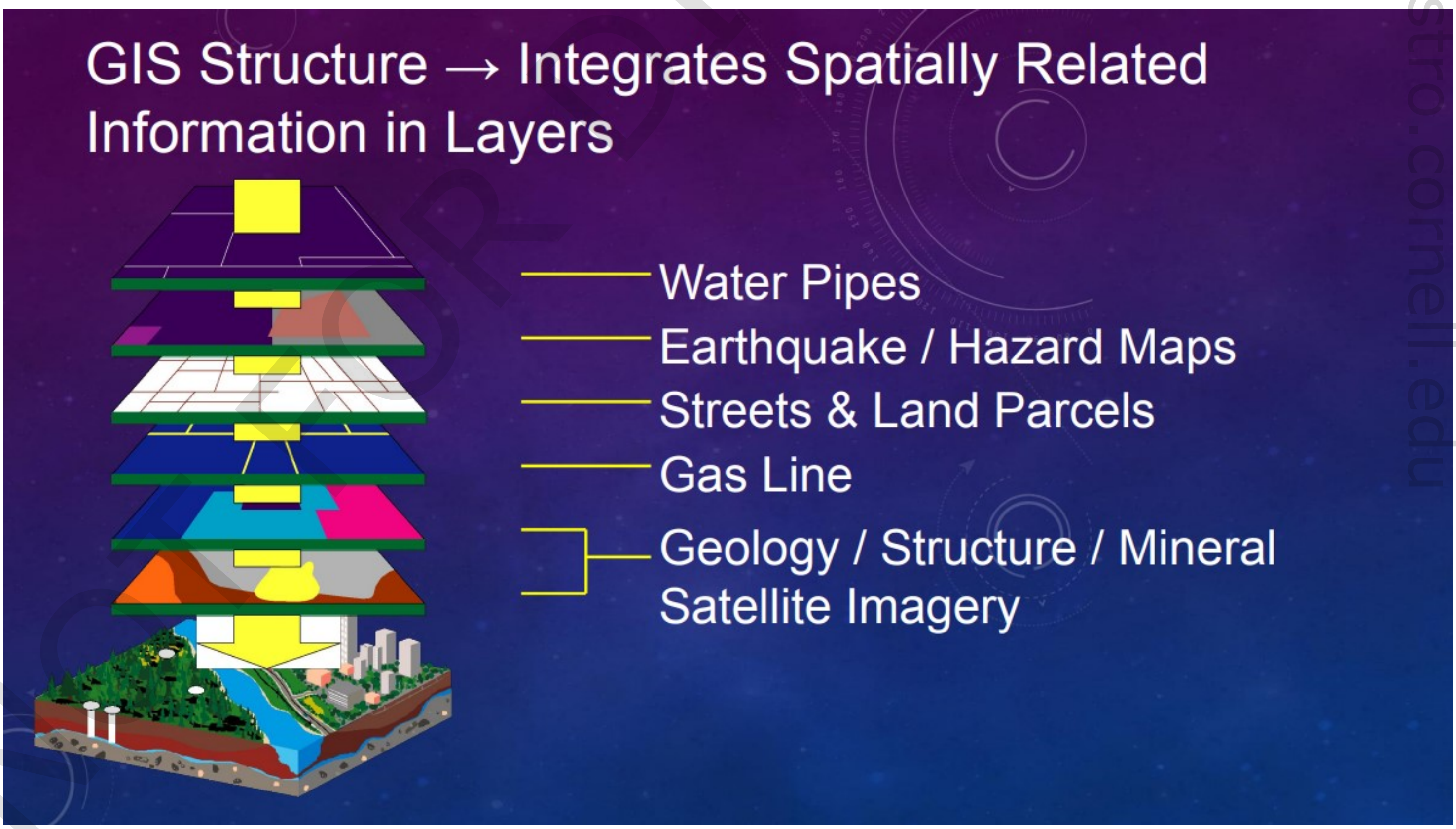
Table of Contents

Introduction

Lecture Slides

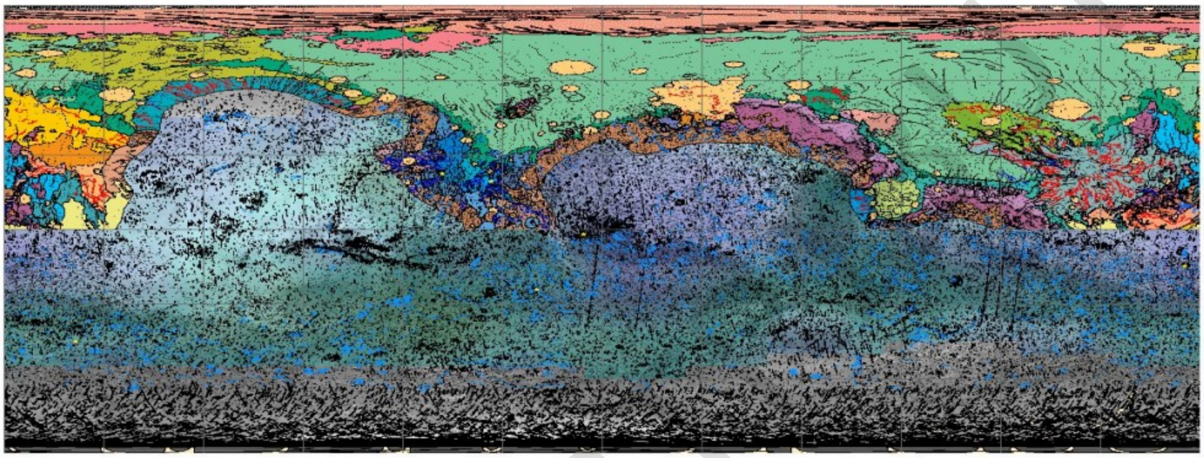
Lecture Slides



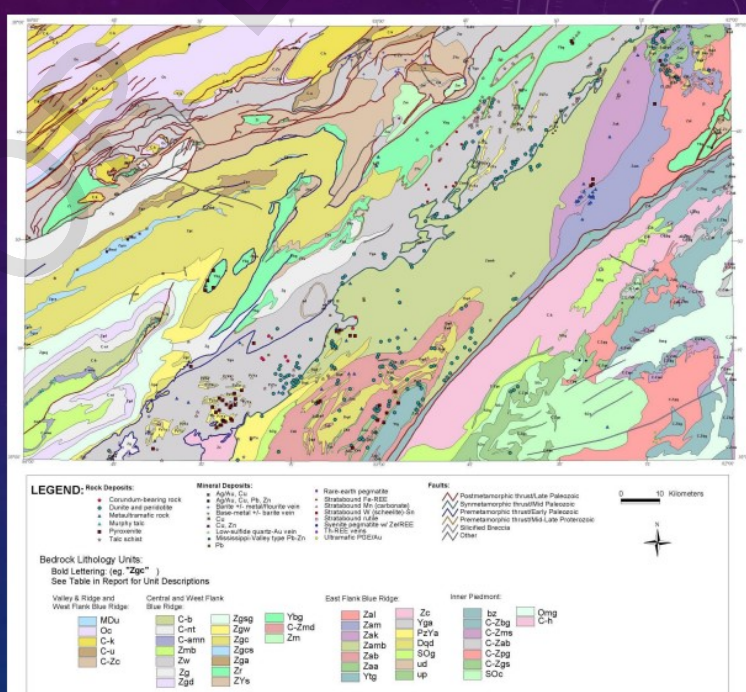


GIS Structure → Integrates Spatially Related Information in Layers

GIS map of Mars showing 64 layers, many PDS releases



Final Goal → Analysis Results AND Publishable Map



Types of Data

Vector

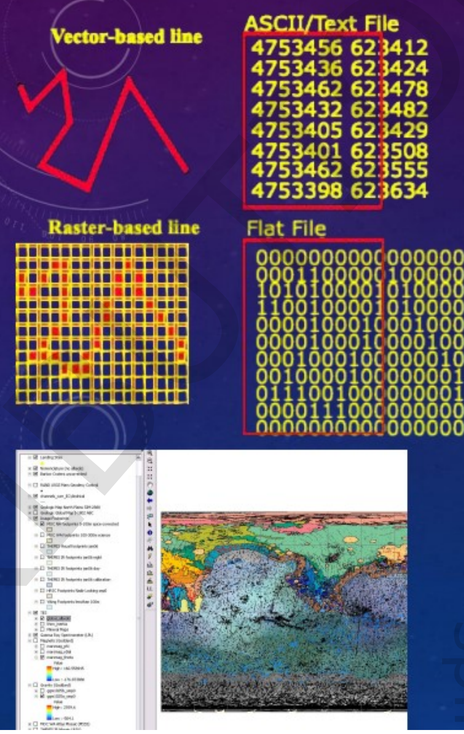
- Geometric features such as points, lines, and polygons
- Stores geometry, spatial data, and additional information for each feature (numerical, descriptive, images, hyperlinks)

Raster

- Image files, or other similar data
- Array of cells (pixels), each with location in the array and a single numerical value, possibly spatial data (coordinate systems)

Map

- Contains information for how to **display** data
- Order of layers, symbols and colors, labels, projections
- Does **NOT** contain any source data such as feature and rasters



Components of ArcGIS Pro

(previously separate programs in ArcGIS Desktop)

Map (formerly ArcMap)

- Where you will be working in this workshop
- Used to visualize, explore, and analyze data in 2D

Local Scene (formerly ArcScene)

- Used for 3D orthogonal data (eg. local terrain, outcrop)

Global Scene (formerly ArcGlobe)

- Used for global data (ie. working on a curved surface rather than a flat surface)

These can all be part of a single Project, along with tables, layouts, and charts. Tools and catalogs are also accessed within Pro and can be customized to each Project.

Common File Types in Pro

Geodatabase (*.gdb)

- ArcGIS file structure for storing, organizing, and sharing data with other ArcGIS users

Image File, Raster

- Common: TIFF (regular or GeoTIFF), JPEG, JPG2, PNG, BMP, GIF, etc.
- Dataset specific: SAR, SRTM, DEM, DOQ, LAS, many more

Shapefile (*.shp), Feature Class

- Stores spatial and geometric data for features

Project (*.aprx), Map Document (*.mapx), Layer (*.lyrx)

- Stores information for how to display data
- Does NOT store any source data

Packages (*.ppkx, *.mpkx, *.lpkx)

- Stores both display instructions AND source data
- Good for sharing with other ArcGIS users who do not have access to your geodatabase

Coordinate Systems and Projections

Anytime you are modeling a curved surface (planet, moon, etc.) as a flat surface (map displayed on paper or a screen), all cartographic issues are present and must be considered!

Geographic Coordinate Systems

- Longitude and latitude measured from a globe's center
- Requires a defined prime meridian
- Includes a datum (spheroid model of the planetary body)

Projected Coordinate Systems

- Takes latitude, longitude, and datum and converts it to a flat array
- Points are assigned orthogonal positions with a defined origin
- Drawing and editing vector data is affected by the projection

Measurements

- Distortions are UNAVOIDABLE; all measurements are APPROXIMATIONS
- If data are projected:
  - Planar measurements assume the surface is truly flat
  - Geodesic measurements assume a curved shape based on the datum

Setting Coordinate Systems

- Thankfully, non-Earth bodies only have a few (or even just one) geographic coordinate system, and a few projected coordinate systems. Coordinate systems for planetary bodies are in ArcGIS Pro's database, and growing with new versions.
- IF you turn off loading a default basemap, then the coordinate system of a map will be set by the first layer added. If layers with different coordinate systems are added after that, they will be 'projected on the fly', which for our purposes is usually sufficient. This is typically the source of the transformations errors you get when loading a project.
- You can save coordinate systems as 'Favorites' to find them more easily in the future. You will see these Favorite coordinate systems in other Projects you open on that same installation of ArcGIS Pro.

Saving your work

- In ArcMap you must enter an "Editing Session" to make changes to data (exception, you can edit attribute tables without doing this). In Pro, no more editing sessions, just start editing. Delete will erase all edits since you began or since you last saved. You can undo/ctrl-alt-z as you edit, BUT once you save you cannot undo your edits.
- Saving a project saves:
  - Maps, layouts, tasks, charts, geoprocessing history, and animations
  - Connections to items stored outside the project such as folders, databases, servers, toolboxes, locators, and custom styles
  - A list of the system styles available in the project
  - Which views are open, and which view is the active view
  - Your favorite geoprocessing tools and raster functions for the project
- "Saving the project does not require you to save spatial data edits, new fields for a table, or Model Builder changes that are in progress. Each of these environments has its own methods for saving changes and are disconnected from saving changes to the project." (It will ask you if you'd like to save any unsaved edits.)
- Saving a map/project package also includes source data and consolidates everything into a single file.

Tips, Tricks, and Quirks

- Arc doesn't allow spaces or special characters (except for underscores) for data file and folder names, BUT, aliases (nicknames, shortcuts and labels) can have any characters, **and so can file names of Projects, geodatabases, and Maps**
- ArcGIS can make very long file paths hard to navigate, so try to keep them as short as possible, while still keeping your files organized and easy to manage
- Geodatabases: feature classes must be INSIDE, shapefiles must be OUTSIDE; rasters can be either
- There are usually multiple ways of doing things (menu, button, keyboard shortcut, etc.)
- The Catalog is *better* at refreshing itself than it was in ArcMap, but do not make changes outside of ArcGIS (such as in File Explorer) to files and folders being used by an open Project. If refreshing the Catalog doesn't work, try refreshing the specific folder/database. If that doesn't work, restart ArcGIS.

Tips, Tricks, and Quirks

- Pro is more stable than Desktop was, BUT it will still sometimes freeze/crash, and sometimes the quickest way to fix a problem is to restart the program. Thankfully, Pro now has a "recovery" function after a restart if there were unsaved changes to the Project. However, sometimes this also recovers whatever caused the issue, and once you recover you cannot revert back to the previous version. SAVE OFTEN and VERSION your work.
- Pro is adaptive, so if you don't see a tool, it may be because you don't have any data open or selected on which the tool can be used.
- Some functions will not work if you have unsaved edits, and it may or may not tell you that.
- We highly recommend working on vector data as feature classes in ArcGIS, and storing them in the Project's geodatabase, and converting shapefiles to feature classes and storing them in there as well.
- Geodatabases that are designated as the Default cannot be renamed.
- If something isn't working, try saving (versioned) and restarting ArcGIS.

1

Project basics

Exercise 1: Getting started in ArcGIS Pro

Chapter 1: Project basics

Introduction

In this chapter, you will learn the basics of ArcGIS Pro Projects. You will see how the elements of a Project are organized and presented, and how to view and explore Maps. You will also learn some of the main differences between the ArcGIS Desktop suite of applications and the single application ArcGIS Pro, and how to import data created in ArcMap.

Objectives

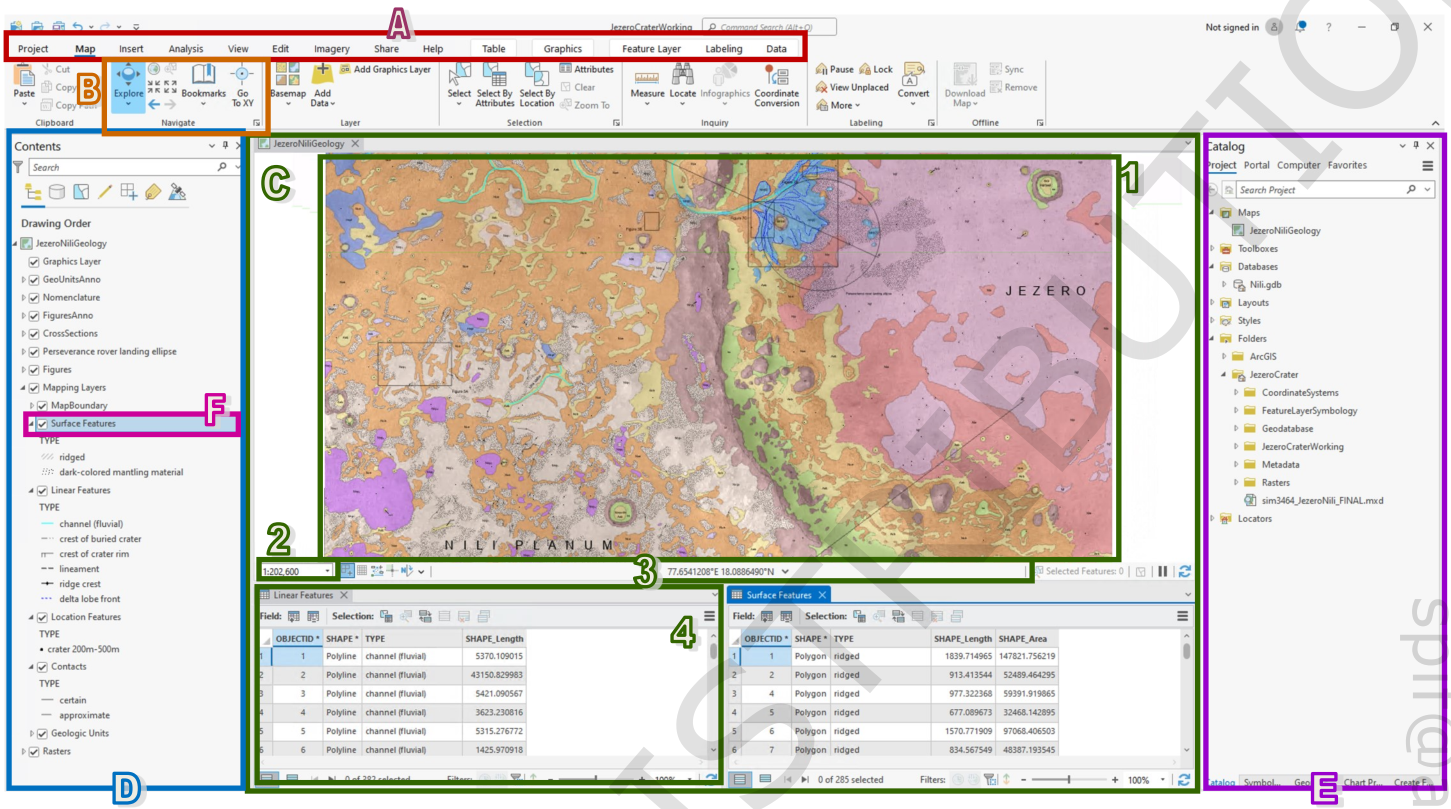
- Create a new Project
- Become familiar with the structure of the ArcGIS Pro window
- Explore data in the Catalog pane
- Import a map document created in ArcMap
- Explore Maps in the View pane
- Edit layers in the Contents pane

Terms

- Attribute Table
- Bookmark
- Folder Connection
- Geodatabase
- Layer
- Map
- Project
- Quick Access Toolbar

Exercise 1: Getting started in ArcGIS Pro.

Main components of the ArcGIS Pro window



A. **Adaptive Tabs** that change depending on what type of data you are viewing or have selected.

B **Tab Ribbon** and **Tool Groups** appear with relevant tools for each of the tabs. There are no longer toolbars that need to be opened individually.

C The **View Pane** is the main workspace where you can view elements of your project, such as Maps, Tables, Local and Global Scenes, and Layouts.

1. A Map displayed within the **View Pane**.

2. This shows the map scale. You can change it from the drop-down menu next to it or by typing the scale you want.

3. This shows the position of the cursor in the coordinates of the map. You can change the units shown here by clicking on the drop-down menu to its right and selecting your desired units.

4. An **Attribute Table** displayed within the **View Pane** that shows data associated with a Map layer.

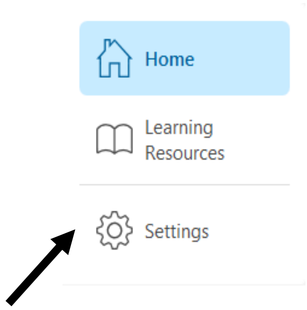
D The **Contents Pane** contains a list of all the layers in the Map.

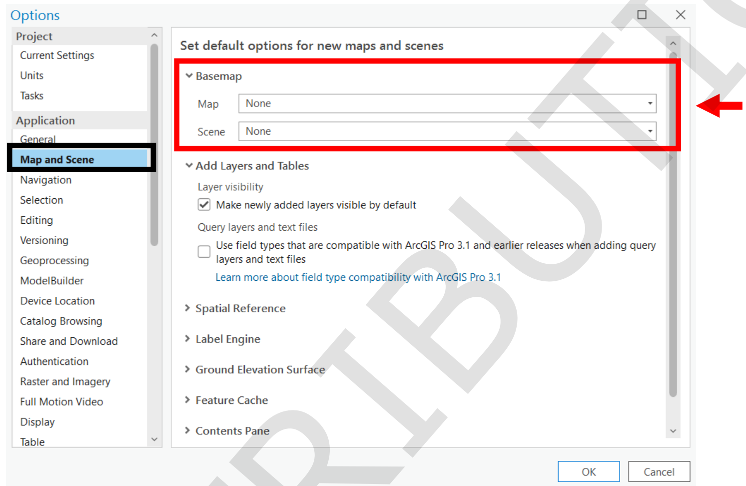
E The **Catalog Pane** is where you manage, organize, and access your geographical data and Project elements.

F A **layer** is a displayed set of geographic features with the same type of geometry (point, line, polygon) or a raster (image).

Step 1: Setting up ArcGIS Pro and creating a new Project

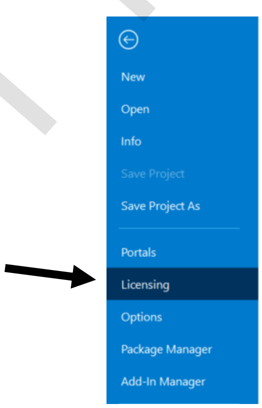
- Start ArcGIS Pro, click on **Settings**, go to **Options** and then click on **Map and Scene**. Under **Basemap**, if it is not already, set the **Map** and **Scene** to **None**. This menu can also be accessed once you have started a Project by clicking on the **Project** tab and then clicking on **Options**.

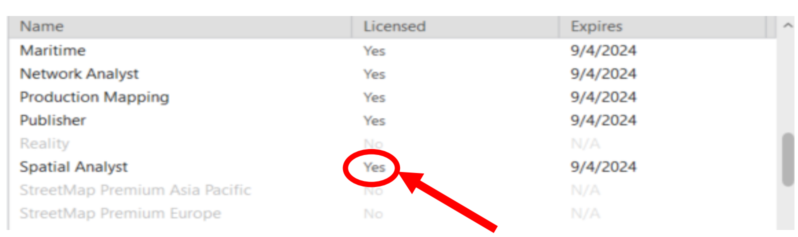




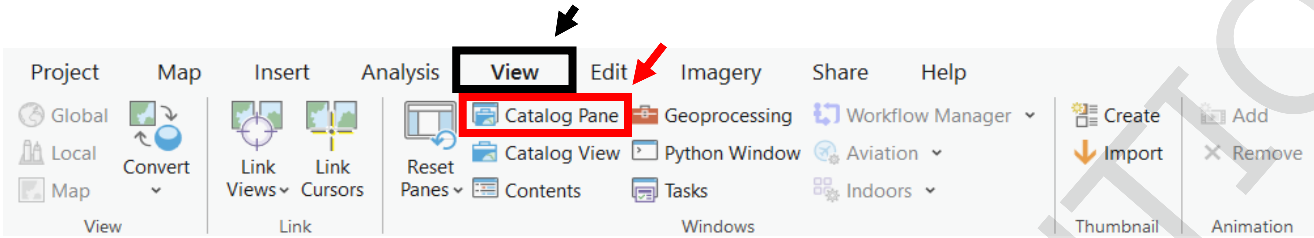
ArcGIS Pro is set to Earth by default, and so it will load an Earth basemap and coordinate system to any new Maps you create. By clicking **None**, Maps will have no initial basemap. You can then set the coordinate system manually, but more commonly it is set by the first layer you add to the Map.

- Click **OK**, and then click **New** from the menu on the left.
- Click on **Start without a template** .
- In the upper left corner of the window, click on the **Project** tab, select **Licensing,** and check if the **Spatial Analyst** extension is licensed. If it is not, there are two steps in the exercises you will not be able to do. In that case, there will be instructions on how to access the necessary data.

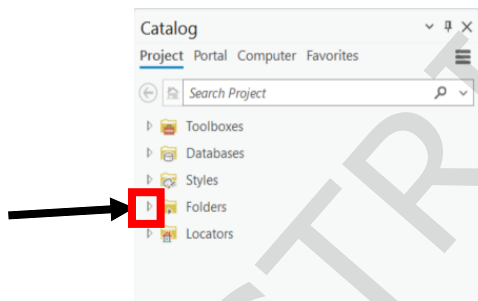




- Click on the back-arrow at the top of the menu on the left to return to the Project window.
- If you do not see the **Catalog** pane on the right of your screen, click on the **View** tab at the top of the window and click on **Catalog Pane.**



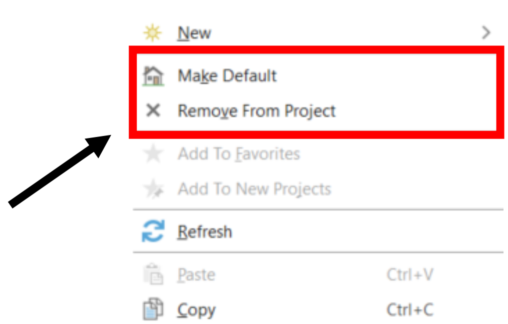
- Expand **Folders** in the **Catalog Pane**.



- Right click on **Folders** and select **Add Folder Connection** . In the **Documents** folder, navigate to the **ArcGIS** folder, where you put the **ExerciseData** folder. Select the **ExerciseData** folder by clicking on it once, then click **Ok**.

When you start a new Project, a default **Untitled** folder and a connection to it is automatically created. Generally, you will have data in a folder you want to work with and will not want to use this default folder.

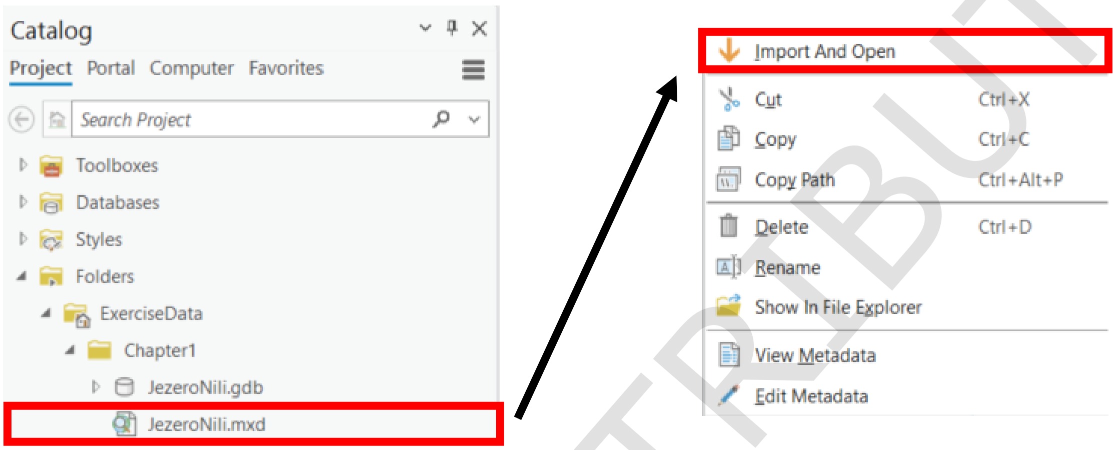
- Right-click on the **ExcerciseData** folder and select **Make Default**. Then right-click on the **Untitled** folder and select **Remove From Project**.



Any time you "remove" something, this does not delete any data or files. You are indicating that you no longer want to see the data.

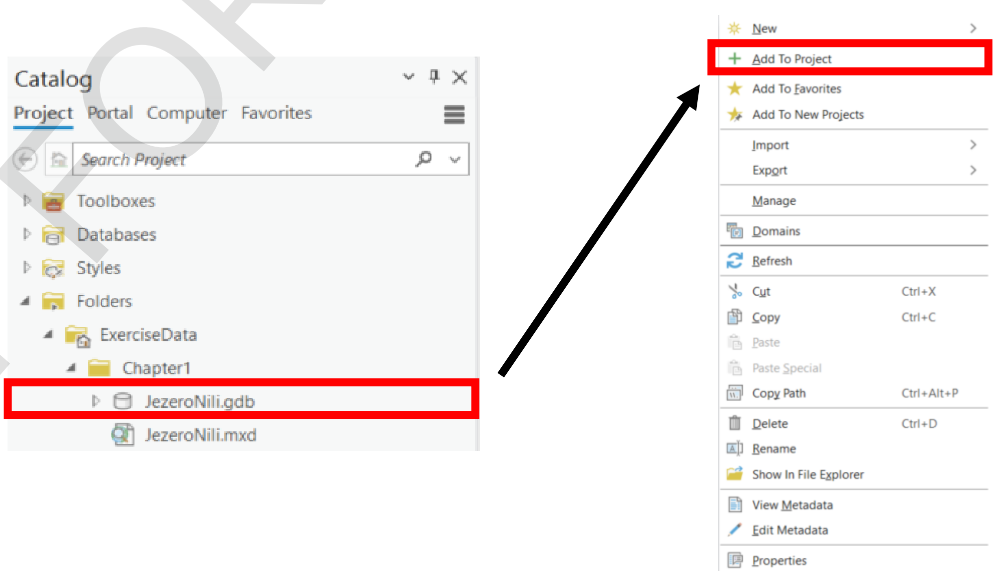
Step 2: Import an ArcMap map document into a Project and explore it

- In the **Catalog** pane, expand the **ExcerciseData** folder connection you just created.
- Expand the **Chapter1** folder. Right-click on **JezeroNili.mxd**, a map document created in ArcMap, and click on **Import And Open**.

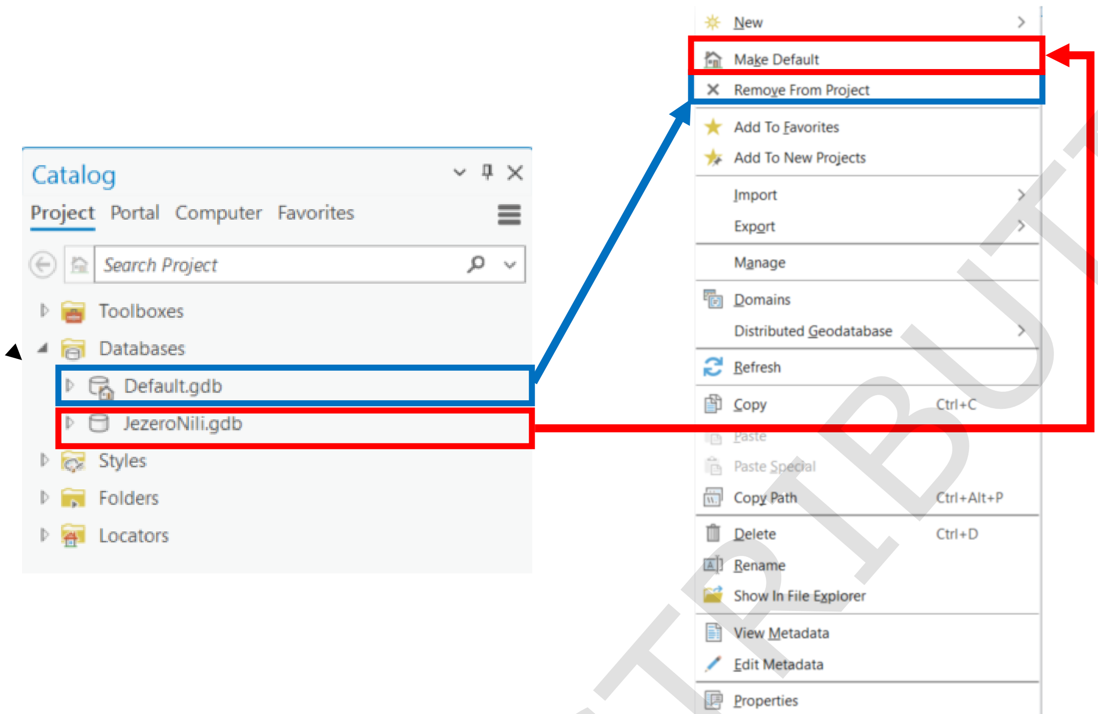


As with folder connections, when you start a new Project, a **Default** geodatabase is created. If you have been given a geodatabase to work with, you can change that to the default similar to how you changed the default folder connection.

- In the **Catalog** pane, expand the **Chapter1** folder and right-click on the **JezeroNili** geodatabase, and click **Add To Project**.

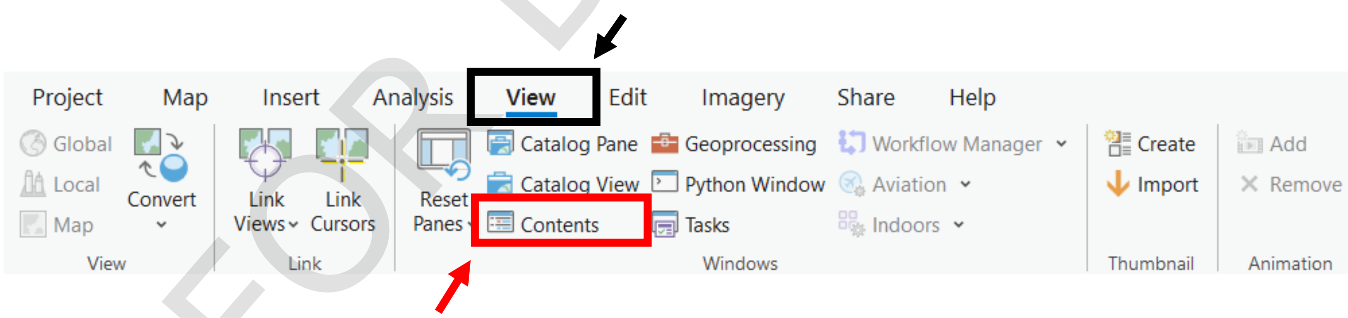


❍ In the **Catalog** pane, expand **Databases**, right-click on the **JezeroNili** geodatabase, and select **Make Default**. Right-click on the **Default** geodatabase and select **Remove From Project**.

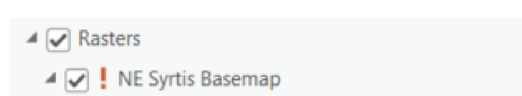


We have to go through this process because **Default** geodatabases cannot be renamed.

❍ If the **Contents** pane is not already on the left side of the screen, then under the **View** tab click on **Contents**.

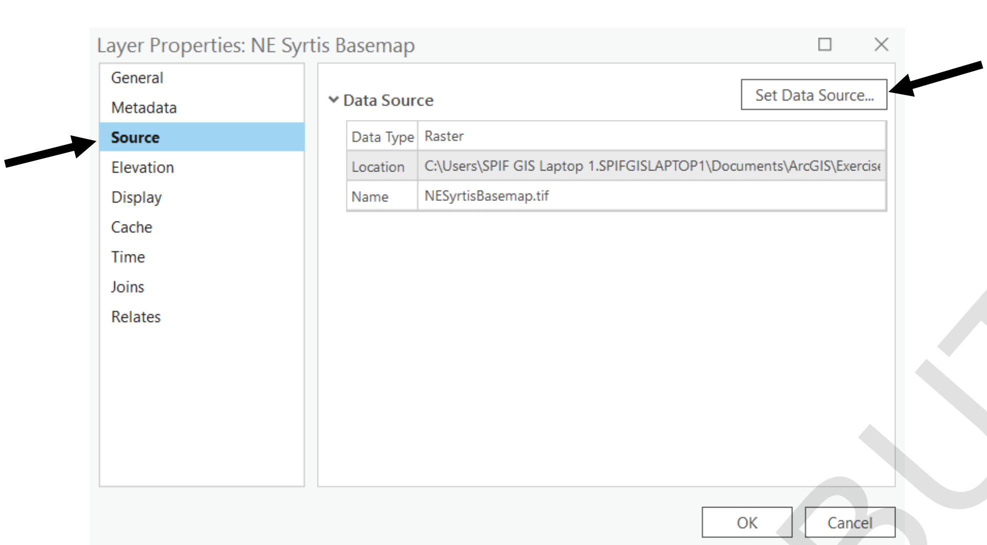


Notice that the **NE Syrtis Basemap** layer has a red exclamation mark next to it. This indicates a broken source path, which means the Map is looking in the wrong place for the data it needs to display the layer.

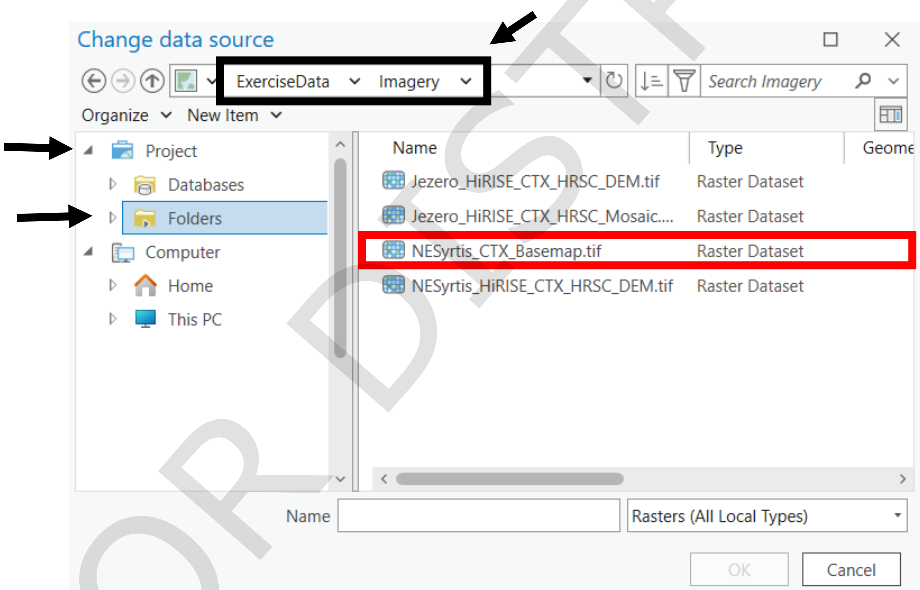


❍ In the **Contents** pane (the one on the left side of the screen), right-click on the **NE Syrtis Basemap** layer and click on **Properties**. Double-clicking on the layer will also open the **Properties** window.

- Go to **Source** and click **Set Data Source**.

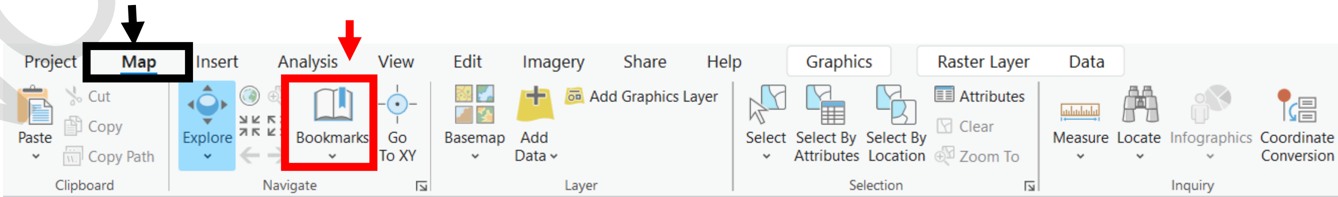


- Navigate to the **Imagery** folder in the **ExcerciseData** folder. (Hint: It's in **Folders** under **Project**) Select the **NESyrtis_CTX_Basemap.tif** file there and click **OK**, and then click **OK** again.



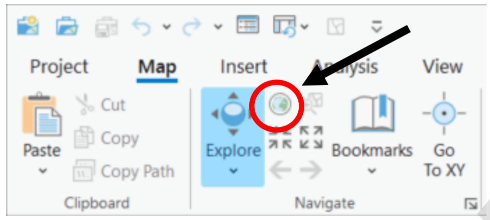
Now the basemap image displays in the Map. You could also have clicked on the red exclamation mark to go directly to selecting a new data source.

- On the **Map** tab, open the **Bookmarks** drop-down menu and select **Perseverance Landing Site**.



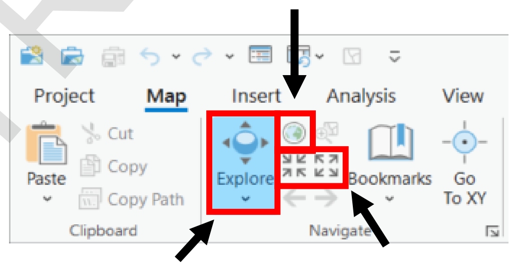
Notice how this zooms and pans the Map display to a specific location and scale. You can create new bookmarks to easily return to specific views of the Map by selecting **New Bookmark** from the **Bookmarks** drop-down menu and naming it. The current view of the Map in the **View** pane will be saved.

- Under the **Map** tab, click **Full Extent**.



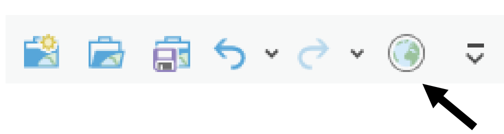
This returns the display in the **View** pane to the entire extent of the Map.

- Explore the Map by using the **Explore** tool to pan by clicking and dragging the mouse in the **View** pane, and **Fixed Zoom In/Out** tools . After you have finished, click the **Full Extent** button .



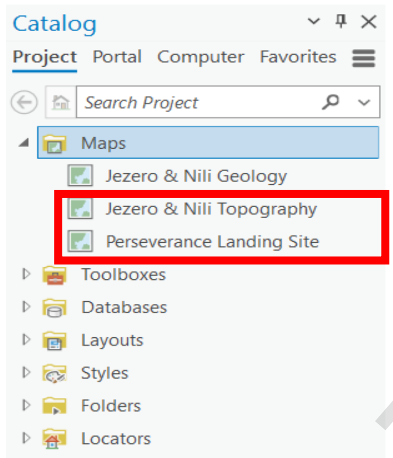
You can also zoom in and out using a mouse wheel or the scroll function on a trackpad when the **Explore** tool is selected. You can move sequentially through extents you have viewed by clicking on the left and right arrows underneath the **Fixed Zoom** buttons.

We will be using certain buttons and tools repeatedly, such as **Full Extent** . You can create shortcuts to any button by right-clicking on the button and selecting **Add to Quick Access Toolbar**. The icon now appears at the very top of the Project window. Remember this throughout the workshop if you find yourself using a button frequently.

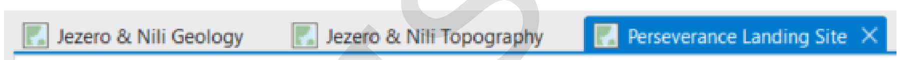


Step 3: Working with layers

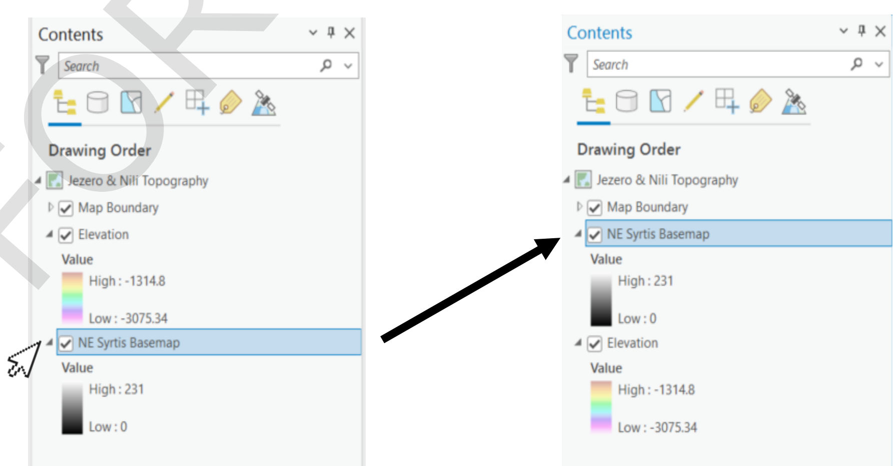
- In the **Catalog** pane, on the right side of the screen, expand **Maps**, double-click on **Jezero & Nili Topography,** and then double-click on **Perseverance Landing Site**.



Unlike ArcMap, you don't need to activate a data frame to view or edit it. What were data frames in ArcMap are now individual Maps within a Project. You can have multiple Maps within a Project, and they can be open on different tabs in the **View** pane.



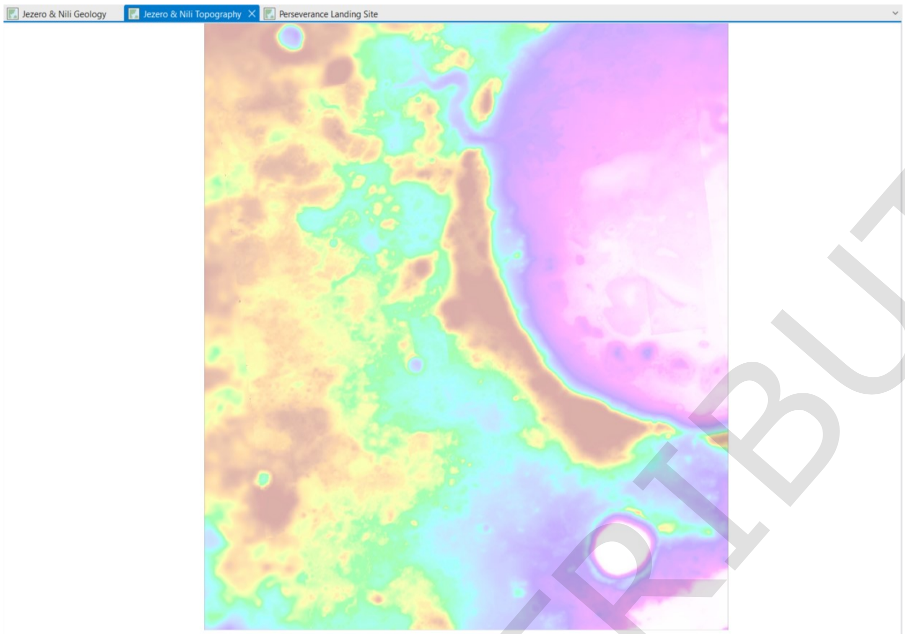
- Click on the **Jezero & Nili Topography** tab at the top of the **View** pane to display it.
- In the **Contents** pane (on the left side of the screen), click and drag the **NE Syrtis Basemap** layer up to just above the **Elevation** layer.



The order of the layers in the **Contents** pane determines what is visible on the Map. Since the basemap is not transparent, the **Elevation** layer underneath is no longer visible.

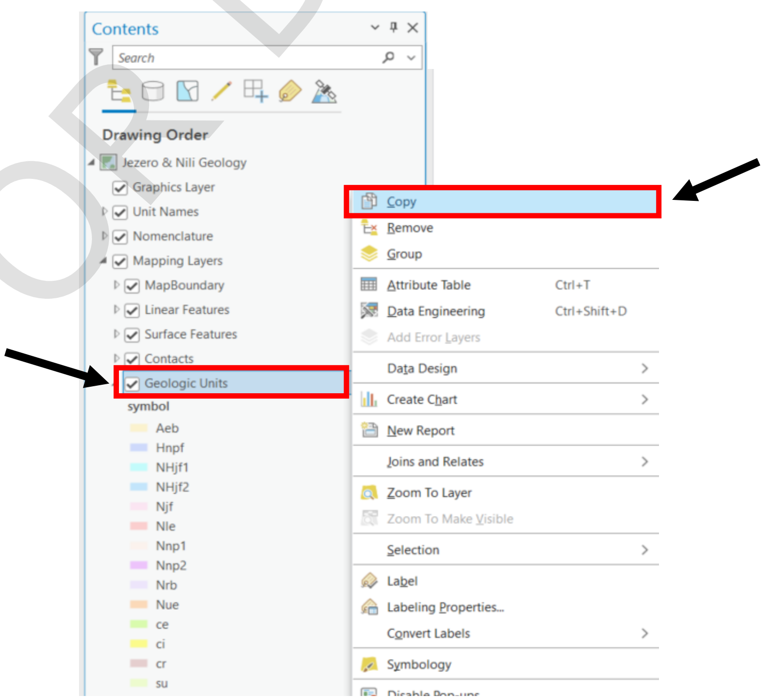
❍ Click to uncheck the box next to the **NE Syrtis Basemap** layer to turn it off.

The **Elevation** layer is now visible.

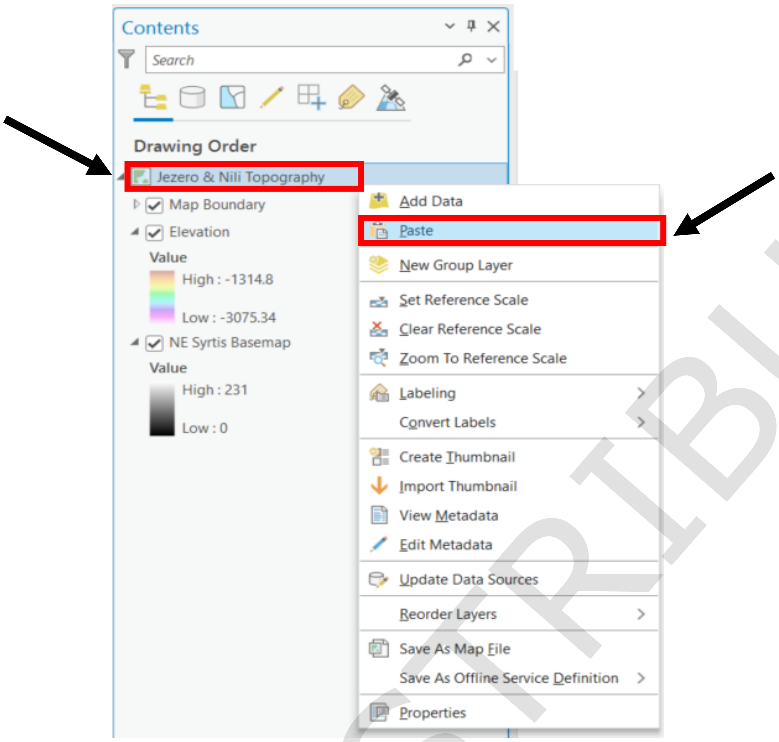


❍ Move the **NE Syrtis Basemap** layer back to the bottom and turn it back on.

❍ Go to the **Jezero & Nili Geology** Map in the **View** pane, right-click on the **Geologic Units** layer, and select **Copy**.



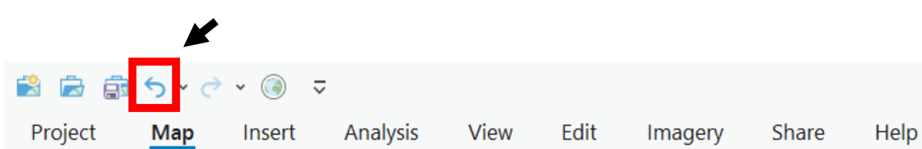
- Now go to the **Jezero & Nili Topography** Map in the **View** pane. In the **Contents** pane, under **Drawing Order**, right-click on the name of the Map and select **Paste**.



When you copy and paste a layer, it will look the same since a layer contains instructions on how to display data. It creates a new layer file in the Project that is a copy of the original layer file. If you edit how the data is displayed in one Map, such as changing the color, it will not affect the appearance of the layer in the Map that it was copied from. However the copied layer is using the same data as the original layer. So, if you edit the features in that layer in one Map, such as drawing new features, you have edited the source data and those changes will appear in all other Maps with layers using the same data.

- Right-click on the **Geologic Units** layer you just pasted and select **Remove** .

Alternatively, you could have clicked **Undo** at the top of the **Project** window on the Quick Access toolbar or Ctrl-Z until the layer was removed.

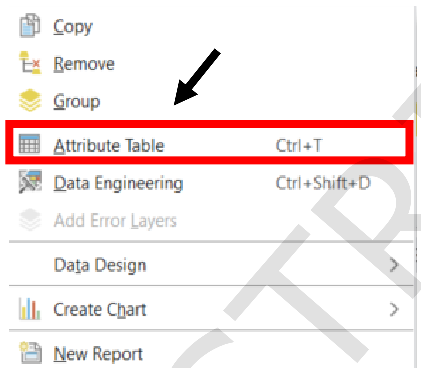


Step 4: Viewing attribute tables

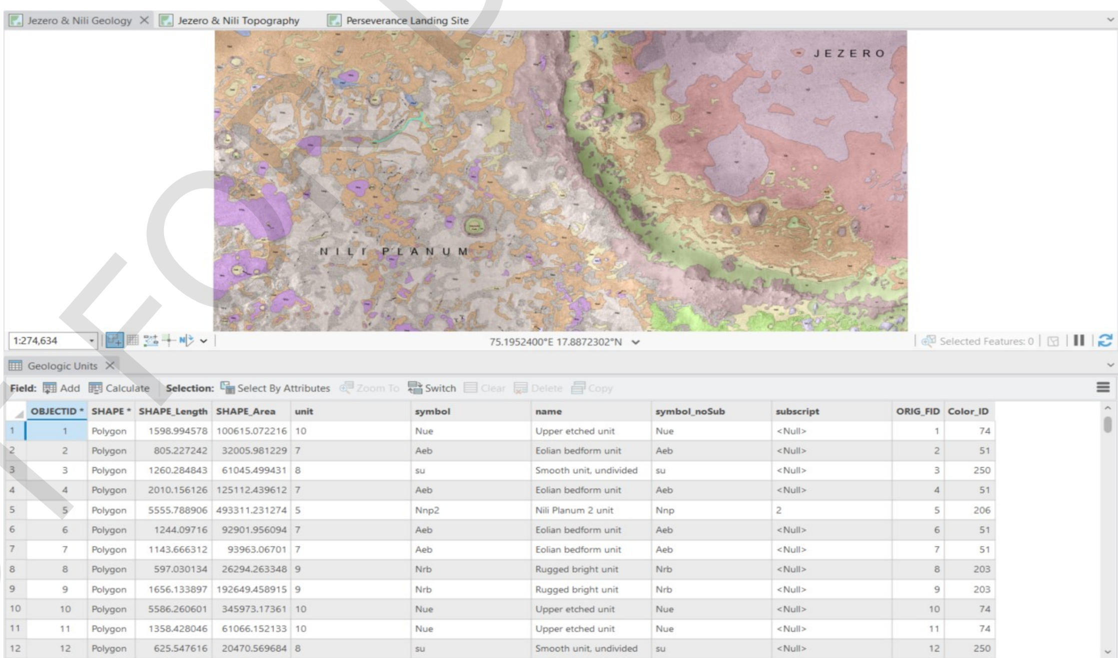
The source data for feature classes, and some rasters, can be viewed in their attribute tables.

- Go to the **Jezero & Nili Geology** Map in the **View** pane. In the **Contents** pane, right-click on the **Geologic Units** layer, and select **Attribute Table**.

  You can also open the attribute table by holding down Ctrl and double-clicking on the layer, or by clicking once on the layer to select it and then doing Ctrl-T.

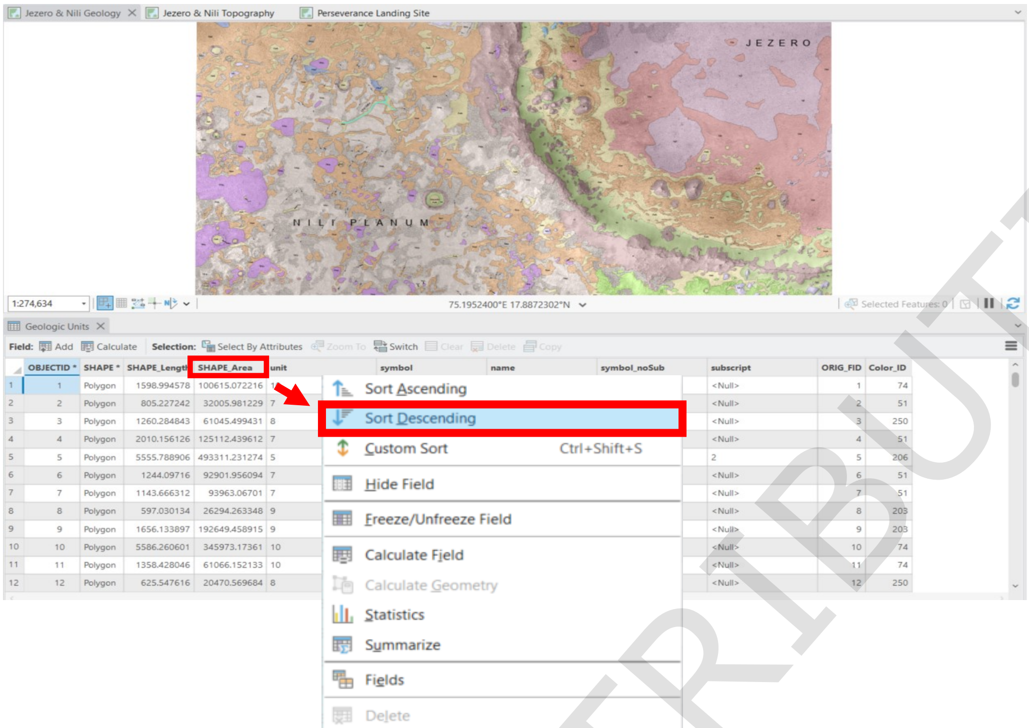


In this table you can view all the geometric, quantitative, and qualitative properties of the features.



	OBJECTID *	SHAPE *	SHAPE_Length	SHAPE_Area	unit	symbol	name	symbol_noSub	subscript	ORIG_FID	Color_ID
1	1	Polygon	1598.994578	100615.072216	10	Nue	Upper etched unit	Nue	<Null>	1	74
2	2	Polygon	805.227242	32005.981229	7	Aeb	Eolian bedform unit	Aeb	<Null>	2	51
3	3	Polygon	1260.284843	61045.499431	8	su	Smooth unit, undivided	su	<Null>	3	250
4	4	Polygon	2010.156126	125112.439612	7	Aeb	Eolian bedform unit	Aeb	<Null>	4	51
5	5	Polygon	5555.788906	493311.231274	5	Nnp2	Nili Planum 2 unit	Nnp	2	5	206
6	6	Polygon	1244.09716	92901.956094	7	Aeb	Eolian bedform unit	Aeb	<Null>	6	51
7	7	Polygon	1143.666312	93963.06701	7	Aeb	Eolian bedform unit	Aeb	<Null>	7	51
8	8	Polygon	597.030134	26294.263348	9	Nrb	Rugged bright unit	Nrb	<Null>	8	203
9	9	Polygon	1656.133897	192649.458915	9	Nrb	Rugged bright unit	Nrb	<Null>	9	203
10	10	Polygon	5586.260601	345973.17361	10	Nue	Upper etched unit	Nue	<Null>	10	74
11	11	Polygon	1358.428046	61066.152133	10	Nue	Upper etched unit	Nue	<Null>	11	74
12	12	Polygon	625.547616	20470.569684	8	su	Smooth unit, undivided	su	<Null>	12	250

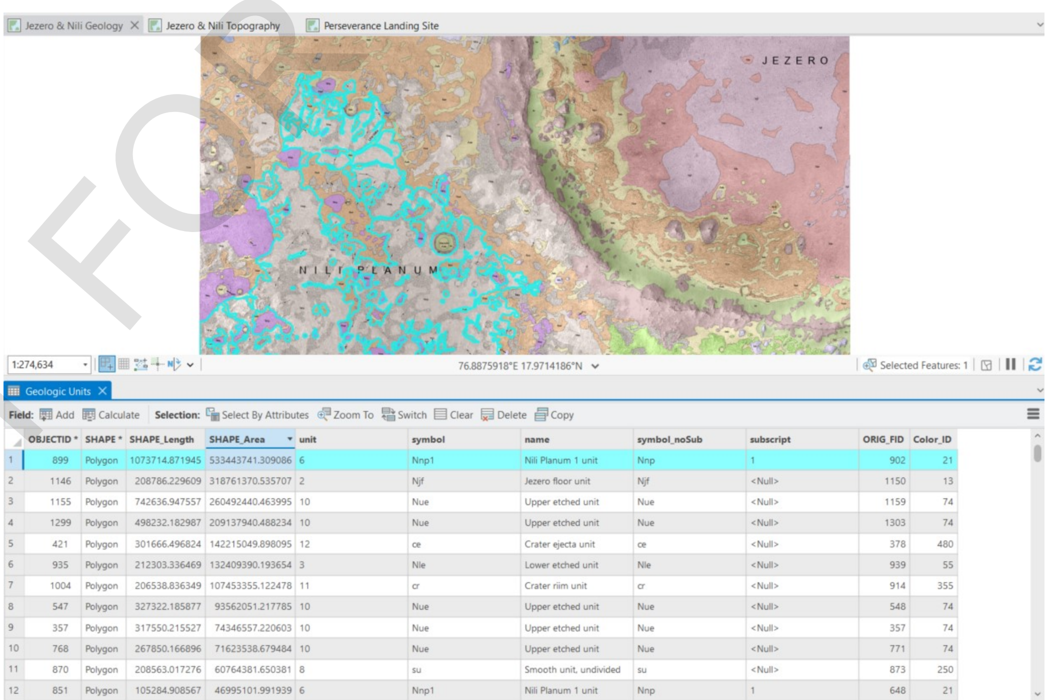
- Right-click on **SHAPE_Area** and select **Sort Descending**.



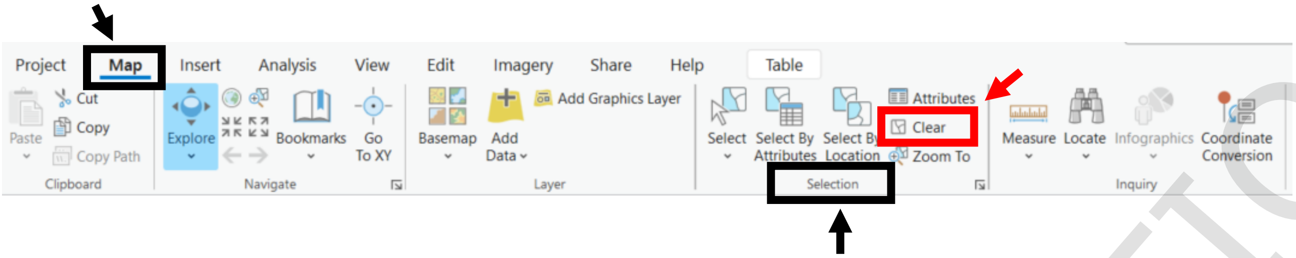
The feature with the largest area is now at the top of the table.

- Click on the **1** at the start of the largest feature's row.

This selects the feature. Both the row in the attribute table and the outline of the feature in the **View** pane are highlighted in cyan.



- Under the **Map** tab, in the **Selection** group, click **Clear** to un-select the feature.



The cyan highlighting is gone.

- Close ArcGIS Pro without saving the Project.

ArcGIS Pro does not use the map document format that ArcMap did, with files ending in .mxd. Therefore, any changes you make to displaying data in Pro, like you have done in this first exercise, will not affect the original map document you imported at the start. However, if you make changes to the source data, you will also see those changes if you open that map document in ArcMap, since it is displaying the same data.

Chapter Summary

Now you have seen some of the basic capabilities of ArcGIS Pro, including setting up a new Project, the structure of Projects, and how to organize and explore data. Files are always found on the right side of the screen in the **Catalog** pane, and layers are always found on the left side of the screen in the **Contents** pane.

You have also seen how the **View** pane can be used to open and explore multiple elements of a Project, and how data frames within map documents in ArcMap are now Maps within a Project in ArcGIS Pro.

Notes:

2

Working with rasters

Exercise 2A: Loading, exploring, and symbolizing rasters

Exercise 2B: Raster analysis

Chapter 2: Working with rasters

Introduction

In this chapter, you will learn the basics of loading, symbolizing, and analyzing raster data. Rasters are analogous to image files. A single-band raster contains an array of pixels, called cells, each with a position and a single value which could represent brightness, elevation, intensity of a quantity, or any other numerical data. A raster could also have multiple bands, each having the same array of cells but with cell values for different quantities, such as different color bands. A raster basemap is usually the starting point for any Map, and is typically an aerial or orbital image, or a mosaic of images. Rasters can be organized into datasets within geodatabases, but can also be stored outside of geodatabases. Since rasters are typically the most demanding of storage space among GIS files, we have put the images provided for this workshop in a single folder, the **Imagery** folder, outside the geodatabases we will be working with. Rasters produced from analyzing these images will be stored within individual geodatabases designated for each exercise.

Objectives

- Load images as rasters in a Map
- Utilize tools on the Map, Analysis, Imagery, and Raster Layer tabs to investigate and display rasters
- Find locations and take measurements of features in a raster
- Symbolize rasters, both continuous and discrete
- Analyze rasters to produce new raster products
- Convert continuous rasters into discrete rasters
- Modify labels in preparation for making Layouts

Terms and Tools

- Basemap
- Cell Size
- Favorites
- Raster
- Symbology
- Geoprocessing Tools: Project, Slope, Reclassify, Raster to Polygon
- Raster Functions: Hillshade, Statistics and Histogram
- Tab Ribbon Buttons: Symbology, DRA, Swipe, Transparency, Go To XY, Measure, Raster Functions, Export Raster, History, Create Chart

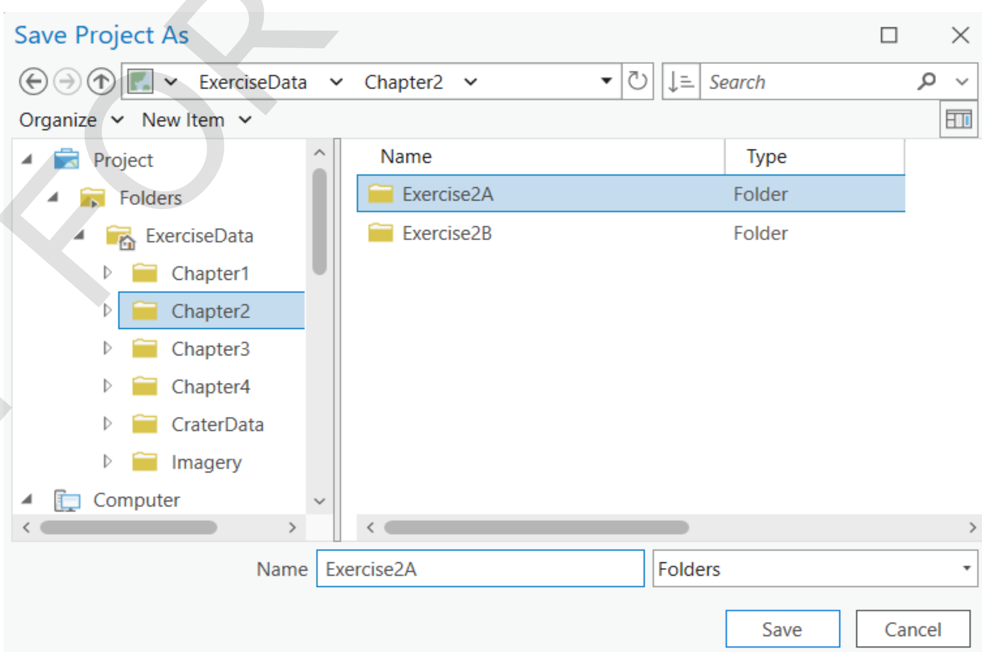
Exercise 2A: Loading, exploring, and symbolizing rasters

Step 1: Set up a new Project

- Start ArcGIS Pro, and select **Start without a template** .
- In the **Catalog** pane, expand **Folders** . You can see that the folder connection you made to **ExcerciseData** in the previous exercise no longer appears.

  Every time you make a new Project, a new **Default** geodatabase and **Untitled** folder are created, both designated as the defaults for the Project. Any folder connection or geodatabase you added to another Project will not be there *unless* you add them to your Favorites, which we will do now.

- Create a folder connection to the **ExerciseData** folder (Hint: right-click on **Folders**).
- As we did in the previous exercise, make this folder the default for the Project and remove the **Untitled** folder from the Project.
- Click the **Save Project** icon in the upper left of the Project window on the Quick Access toolbar.
- Navigate to the **Chapter2** folder (Hint: look in your Project **Folders** for the **ExerciseData** folder). Select the **Exercise2A** folder by clicking on it once. Click **Save**.

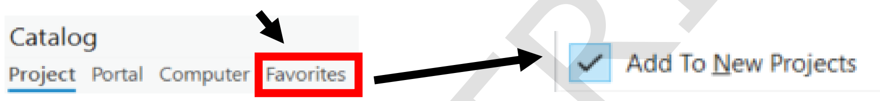


- Outside of ArcGIS, Open **Windows File Explorer** and navigate to the **Exercise2A** folder. You will see that a Project named **Exercise2A** has been created there, along with a few other default items.

- Go back to the ArcGIS Pro window. In the **Catalog** pane, right-click on the **ExerciseData** folder. Notice the option to **Add to Favorites** and **Add To New Projects** . Select **Add to New Projects**.

  Now whenever you start a new Project, a connection to **ExerciseData** will be automatically added, which is very convenient for this workshop.

- Click on **Favorites** at the top of the **Catalog** pane. Right-click on the **ExcerciseData** folder and notice the checked option **Add to New Projects**.



  If you uncheck this option, **ExerciseData** will not be added to your new Projects, but it will still appear in your **Favorites** for easy access to add to a Project. But for this workshop, we will want it added to all new Projects.

  A geodatabase cannot be renamed when it is the default geodatabase. So, we will create a new geodatabase and give it the specific name we want.

- Go back to the **Project** tab at the top of the **Catalog** pane.
- Right-click on **Databases** and select **New File Geodatabase** . Navigate to the **Excercise2A** folder and type **Excercise2A** as the name. Click **Save**.

  This new geodatabase is automatically added to your Project.

- As you did in the previous exercise, make the **Excericse2A** geodatabase the default and delete the **Default** , as you did in the precious exercise.
- Save your Project.

Step 2: Load rasters into a new Map

- In the **Catalog** pane, in the **ExcerciseData** folder, expand the **Imagery** folder. Try to drag -and-drop the **Jezero_HiRISE_CTX_HRCS_Mosaic.tif** raster into the **View** pane. Notice that nothing happens.

  This does not display the raster because there is no Map to load the raster into.

- Right-Click on **Jezero_HiRISE_CTX_HRCS_Mosaic.tif**, go to **Add To New**, and select **Map**. Click **OK** to build pyramids and calculate statistics.

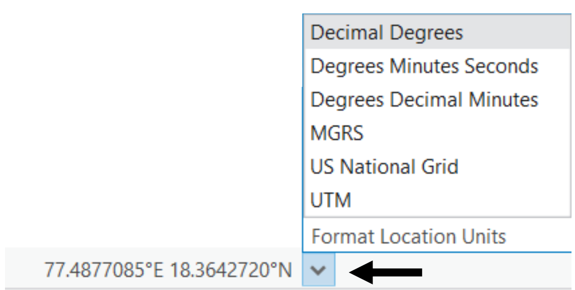
  Pyramids allow for faster display and viewing navigation. They set the display resolution as appropriate to the viewing extent, rather than trying to display the full resolution at all scales, even when the raster cells are much smaller than your screen pixels. Calculating statistics will enable certain options in displaying and analyzing the raster.

- In the **Catalog** pane, expand **Maps** to see the new Map you just created, called **Map**. Right-click on it, select **Rename**, type **Jezero Crater Delta**, and hit **Return**.

  You can also rename a Map by slow-double-clicking on the Map's name, either here in the **Catalog** pane or in the **Contents** pane (on the left side of your Project window). Notice that the Map name can have spaces in it.

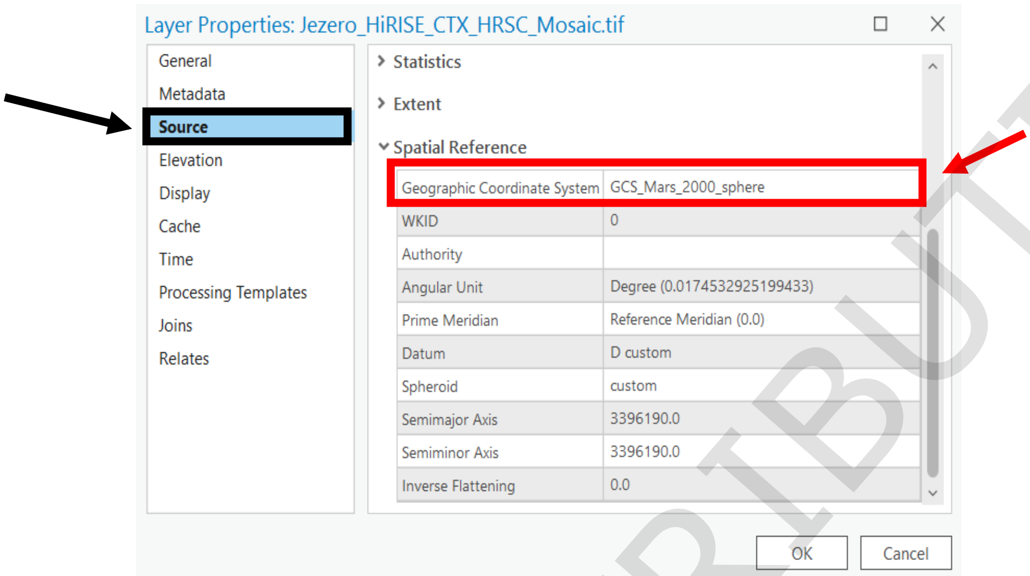
  Notice that the coordinates at the bottom of the **View** pane are in degrees.

- Click on the down arrow to the right of the coordinates to see other display options.



Notice that they are all latitude-longitude coordinates, and no linear units, such as meters. This tells you that the raster is not projected.

- In the **Contents** pane, double-click on the raster layer to open the **Layer Properties** window. Go to **Source** and expand **Spatial Reference**.



Notice that there is only a geographic coordinate system (GCS), and no projected coordinate system (PCS), confirming that this raster is not projected. Step 7 (optional) shows you how to add a projected coordinate system (PCS) to a raster.

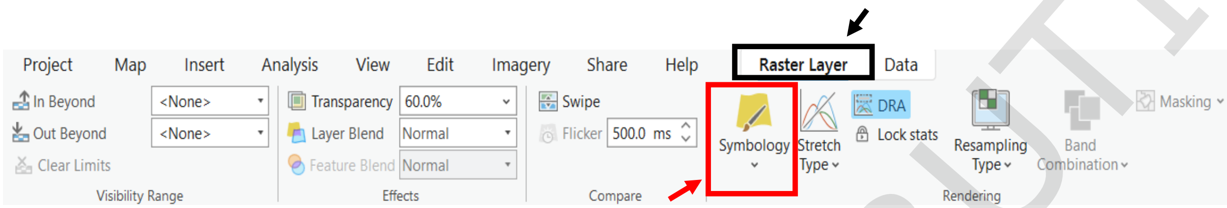
- Click **OK** to close the **Layer Properties** window.
- In the **Contents** pane, click once on the raster layer's name and rename it **Jezero Basemap**, then hit **Return**.
- From the **Imagery** folder in the **Catalog** pane, drag-and-drop the **Jezero_HiRISE_CTX_HRCS_DEM.tif** into the **View** pane. Click **OK** to build pyramids and calculate statistics.

  Drag-and-drop works now that we have a Map open to add the raster to.

- Rename this raster layer **Jezero Elevation**. (Hint: When we refer to a "layer", that's in the **Contents** pane, not the **Catalog** pane.)

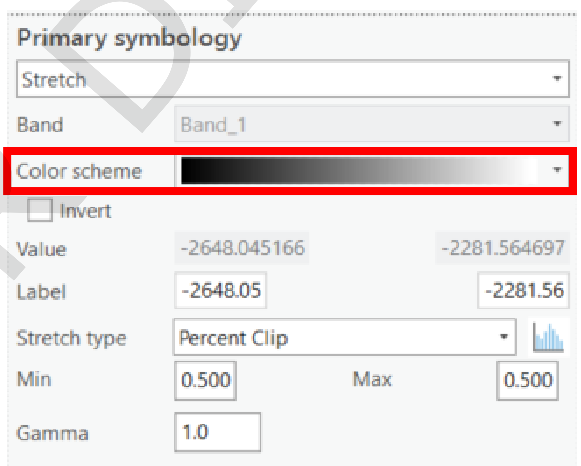
Step 3: Explore raster symbology

- If not already selected, select the **Jezero Elevation** layer by clicking on it once. Note that selected items in the **Contents** and **Catalog** panes are highlighted in blue.
- Click the **Raster Layer** tab at the top of the Project window and then click **Symbology** .



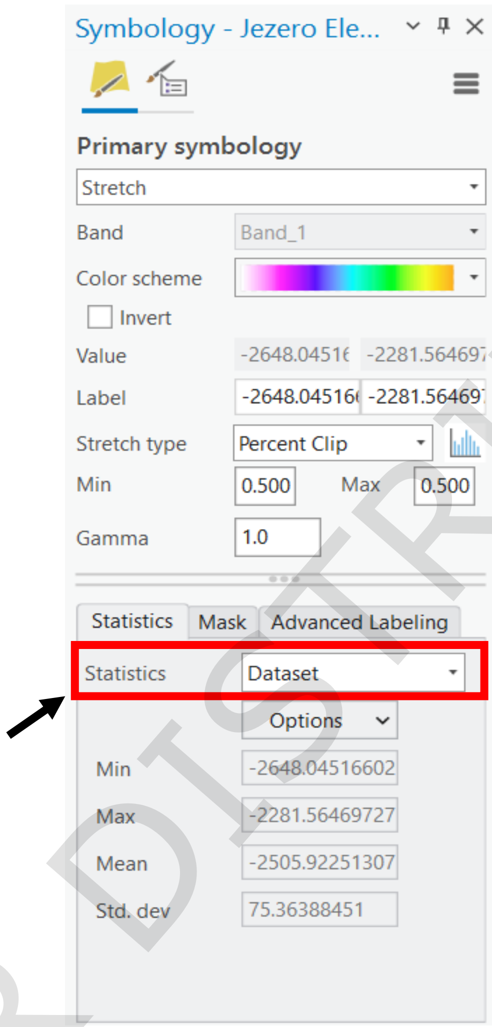
You can also right-click on the layer and click **Symbology**. Instead of opening a separate window like in ArcMap, this opens a **Symbology** pane on the right side of the Project window. Also note that **Symbology** is no longer found in the **Layer Properties** window like it was in ArcMap.

- In the **Symbology** pane, click the arrow for the **Color scheme** drop-down menu to see different color ramps.



- Check the box **Show names.** Scroll down to choose **Temperature** .
- Zoom in to an area that is mostly green until your whole view is green. Then click **Full Extent** on the **Map** tab.

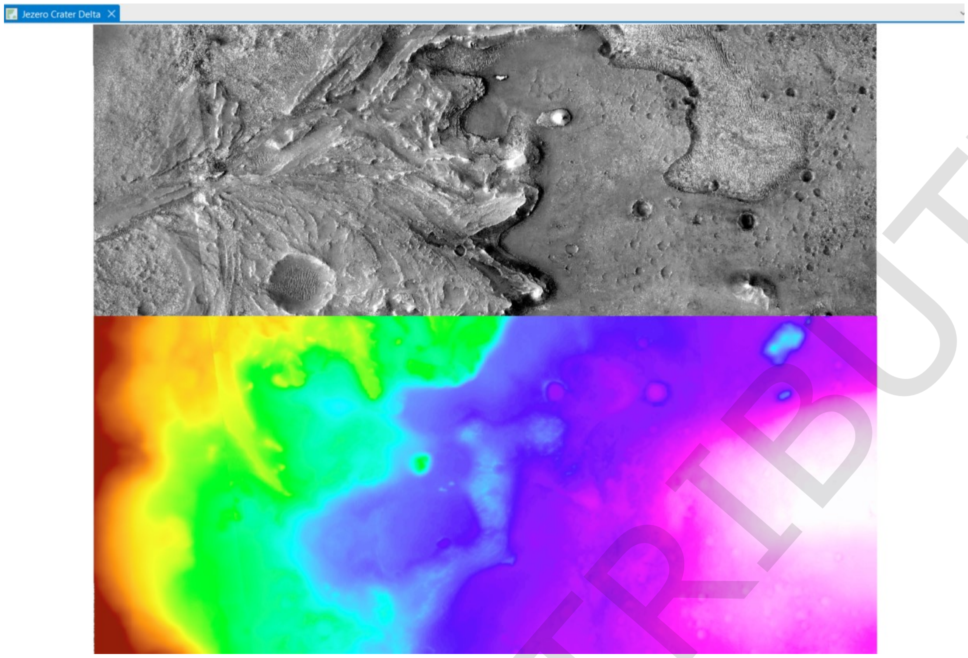
- In the bottom half of the **Symbology** pane, under the **Statistics** tab, change the **Statistics** from **Dataset** to **DRA**, which stands for Dynamic Range Adjustment. Now zoom in again on a mostly green area.



This option will automatically adjust the stretch to the current viewing extent. You can also activate **DRA** on the **Raster Layer** tab.

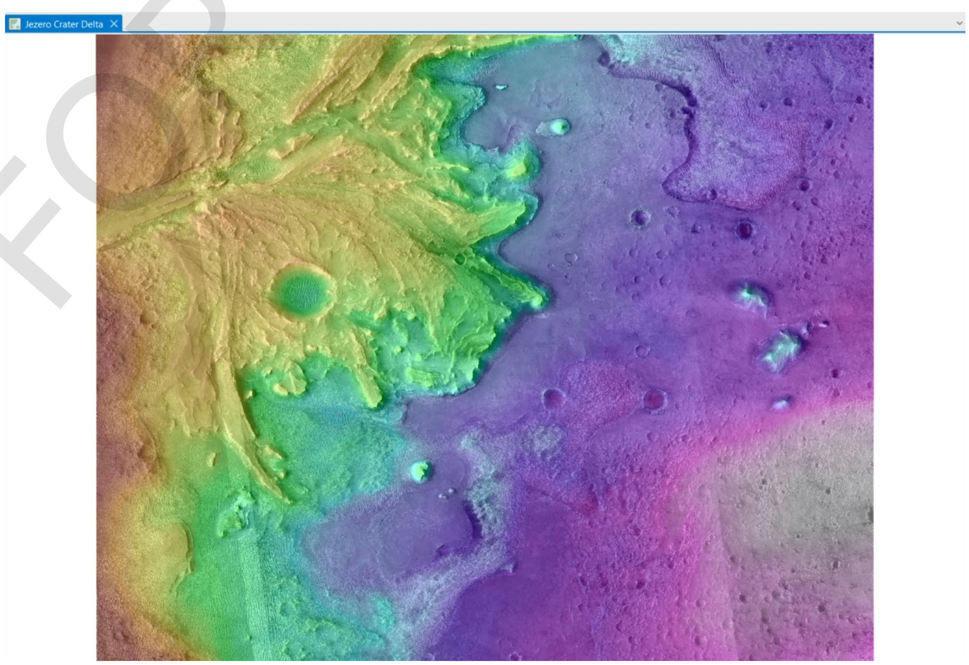
- Go back to **Full Extent** .
- Check that the **Jezero Elevation** layer is selected in the **Contents** pane. On the **Raster Layer** tab, in the **Compare** group click on **Swipe** .

- Click and hold anywhere in the **View** pane and drag the mouse up and down, or left and right, depending on where you clicked in the display.

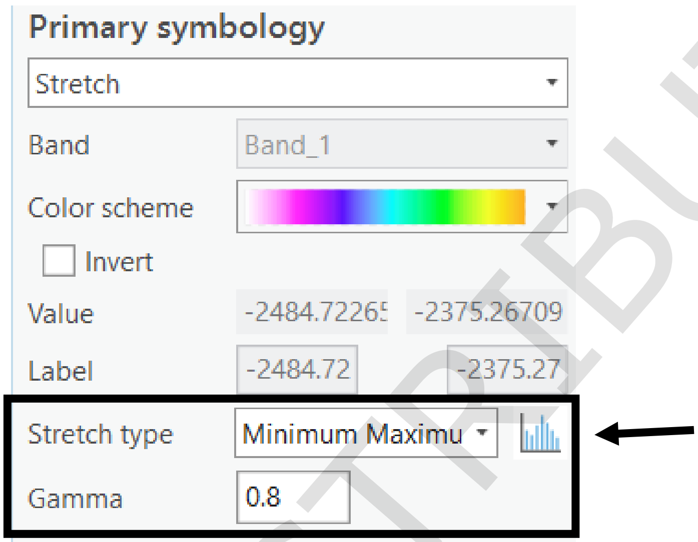


- On the **Raster Layer** tab, in the **Effects** group, set to **Transparency** to *60.0%*. This can be done either by typing *60.0* in the box to the right of **Transparency** and hitting **Return**, or by clicking the arrow for the drop-down menu and dragging the sliding bar until the text box says 60.0% (or something close to it).

  Now the basemap layer can be seen under the elevation layer.



- In the **Contents** pane, uncheck the box next to the **Jezero Elevation** layer to turn it off, and select the **Jezero Basemap** layer.
- In the **Symbology** pane, change the **Stretch type** to **Minimum Maximum**. Change the **Gamma** value to *0.8*.



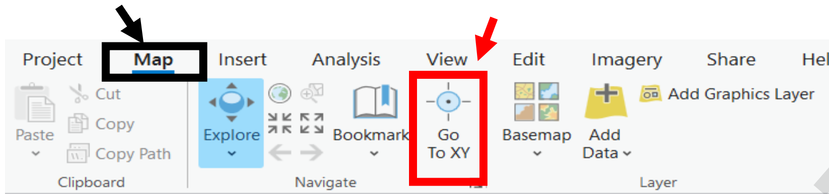
Note how the symbology changes immediately without having to click **Apply** like in ArcMap. Also, having the symbology in a pane, rather than a window on top of the map view like in ArcMap, makes it easier to see the effects of changes as you make them.

You can continue to adjust the stretch options to your liking. You can also adjust the appearance on the **Raster Layer** tab, in the **Enhancement** group, though the brightness and contrast there do not change the stretch properties.

- Save your Project . (Hint: on the Quick Access Toolbar at the top of the window.)

Step 4: Locate positions on a raster

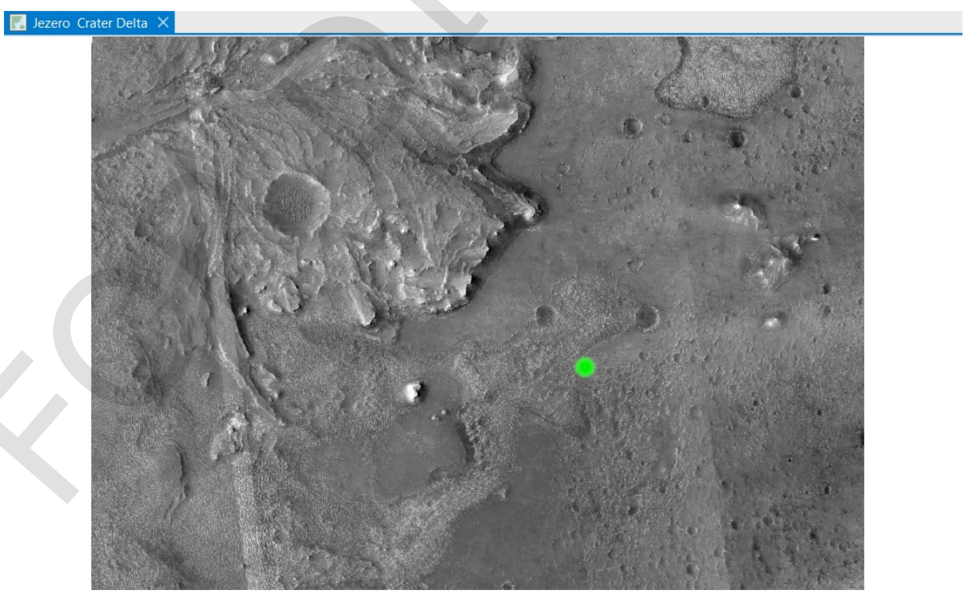
- On the **Map** tab, in the **Navigate** group, click on **Go To XY** .



- In the toolbar that appears at the bottom of the **View** pane, check that the linear units are set to **dd** (decimal degrees).

- Enter **Long:** *77.4509* and **Lat:** *18.4446*, then click **Return**.

The **View** pane pans to center the location and a green circle flashes to show it.



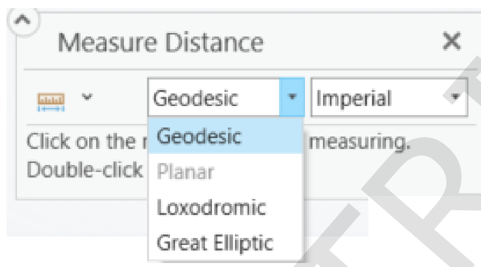
- On the toolbar at the bottom of the **View** pane, click **Flash** to see this location highlighted again. This is the Octavia E. Butler landing site of the Perseverance rover.
- On the **Map** tab, click again on **Go To XY** to close its toolbar.
- Click **Full Extent** .

Step 5: Add a coordinate system to a Map

- On the **Map** tab, in the **Inquiry** group, click on **Measure** .

  The **Measure Distance** toolbar appears by default. You can make other types of measurements, such as area and angles, by clicking on the down-arrow on the **Measure** button on the **Map** tab, or by clicking the down arrow next to the **Measure** icon on the toolbar.

- Click the down-arrow next to **Geodesic** to see the mode options.



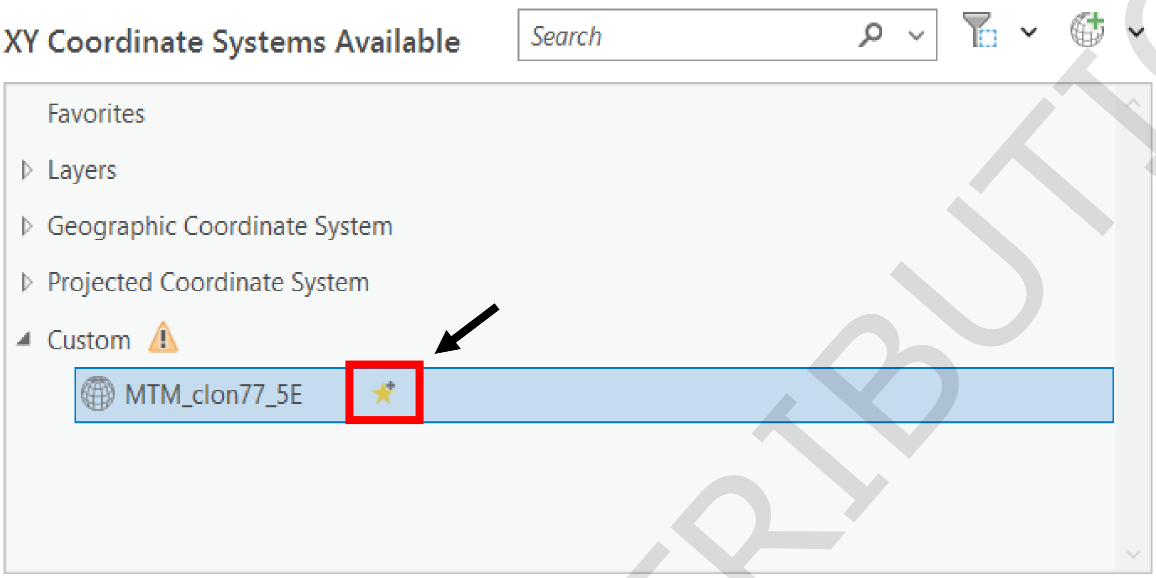
  Notice that **Planar** is greyed out. This is because the raster and therefore the Map we loaded it into, has no projected coordinate system (PCS), as we confirmed in an earlier step.

- Click on the down-arrow again to close the mode options.
- Double-click on the Map name, **Jezero Crater Delta,** in the **Contents** pane to open the **Map Properties** window. Select **Coordinate Systems**.

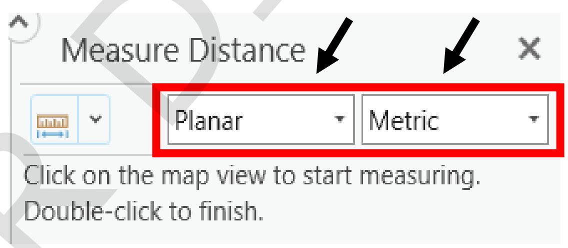
  ArcGIS Pro does have some coordinate systems for the Solar System pre-installed, including GCSs for all round bodies and PCSs for the Moon and Mars, and more are being added with new version releases. But we'd like to use the same projection that the Map you explored in Chapter 1 used.

- Click on **Add Coordinate System** and select **Import Coordinate System** .
- Navigate to the **Imagery** folder and select **NESyrtis_CTX_Basemap.tif**, the basemap that the Map in Chapter 1 used. Click **OK**.

- Under **Custom**, click on the star next to **MTM_clon77_5E** to add it to your favorites. This will make it easy to access this system in the future.

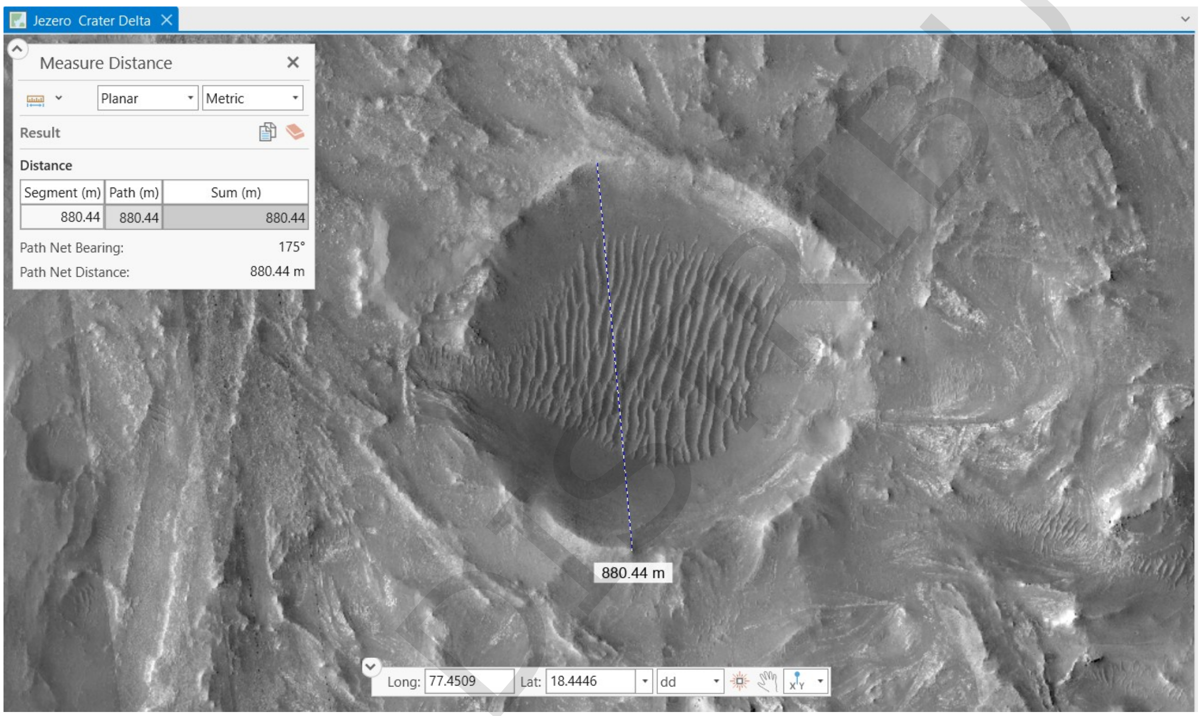


- Click **OK**. In the **Measure Distance** toolbar, the mode automatically switches to Planar. **Units** switches to metric.



Step 6: Measure features on a raster

- Zoom in on the large crater on the delta fan (its center is at roughly 77.379E, 18.483N) by scrolling with your mouse or trackpad with the cursor centered on the crater.
- Click once anywhere on the rim of the crater, move the cursor to the opposite rim, and then double-click. The **Measure Distance** window displays the approximate diameter of the crater, which should be between 870 m and 910 m.



- In the **Measure Distance** window, change the measurement type from **Planar** to **Geodesic**.
- Make the same measurement again.

Planar mode will calculate a Euclidean distance using the projected coordinate system, which assumes the surface is flat. Geodesic takes the curvature of the surface into account. At this Map's scale, the difference is negligible, but at smaller scales (i.e. Maps that show a larger area), it becomes more significant.

- Close the **Measure Distance** window.

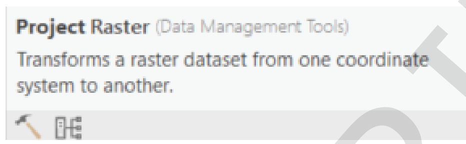
You can save this Project if you'd like, but you do not need to in order to move on.

Optional Steps

Step 7: Project a raster

Although our **Jezero Crater Delta** Map has a PCS, the **Jezero Basemap** source raster does not. You may want to give the raster a projection to use in the future.

- Open the **Geoprocessing** pane by clicking on the tab at the bottom of the right-side pane, or if it does not appear among the tabs, open by clicking **Tools** on the **Analysis** tab.
- Search for *project* and click on **Project Raster (Data Management Tools)**.

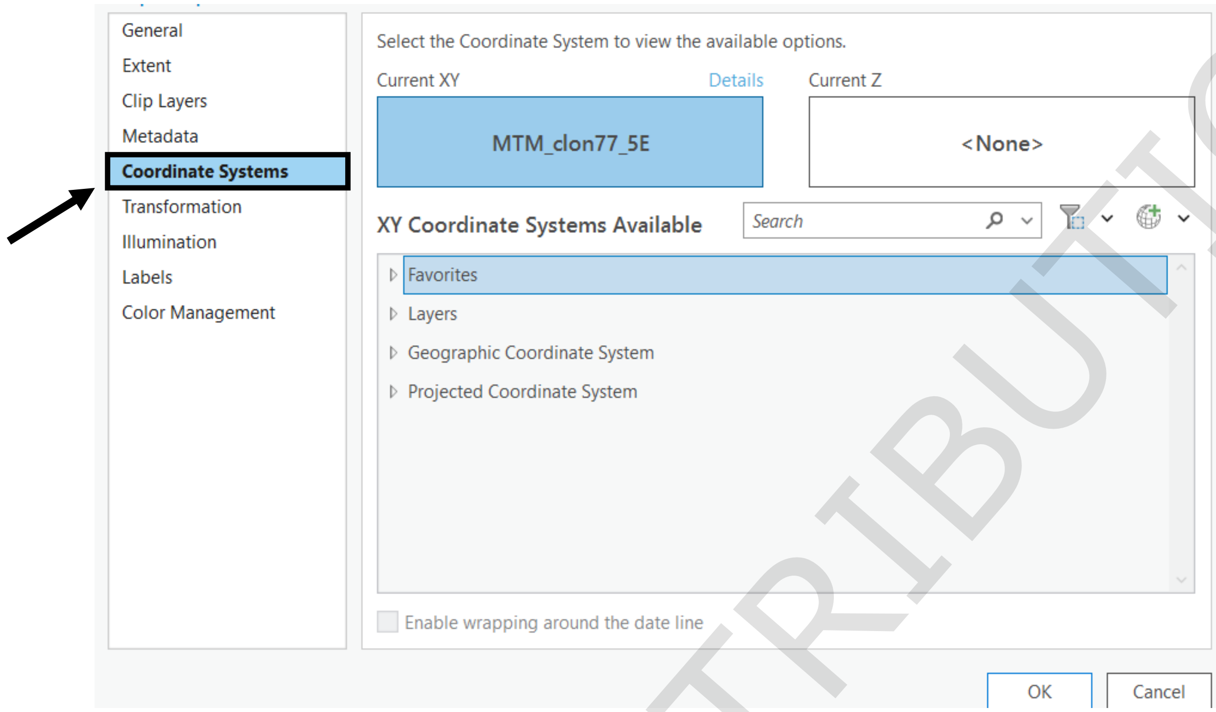


- For **Input Raster**, use the drop-down menu to select **Jezero Basemap**.
- For **Output Coordinate System**, use the drop-down menu to select **Current Map**.
- Change the **Resampling Technique** to **Bilinear interpolation**. Click **Run** .

  Many mappers prefer bilinear interpolation as it produces a more smoothed image.

- Go to the **Catalog** pane, and in the **Exercise2A** geodatabase, right-click on the new raster. From **Add To New** , click **Map** .

- Double-click on **Map** in the **Contents** pane and select **Coordinate Systems**.



The new Map has the PCS we specified, since a Map's coordinate system is set by the first layer added to it.

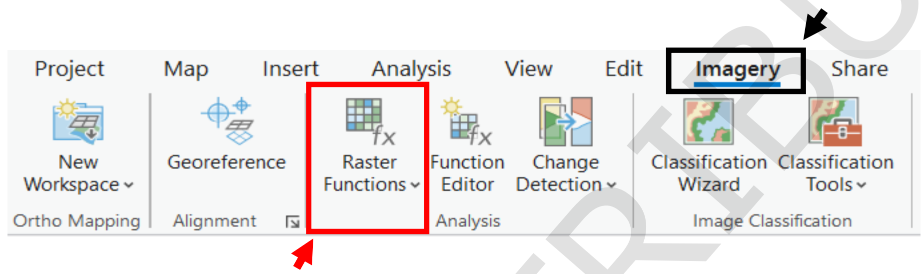
- Click **OK**.
- Close this new Map in the **View** pane and **Remove** the **Jezero_Basemap_ProjectRaster** layer from the **Jezero Crater Delta** Map.

You can save this Project if you'd like to, but you do not need to in order to move on.

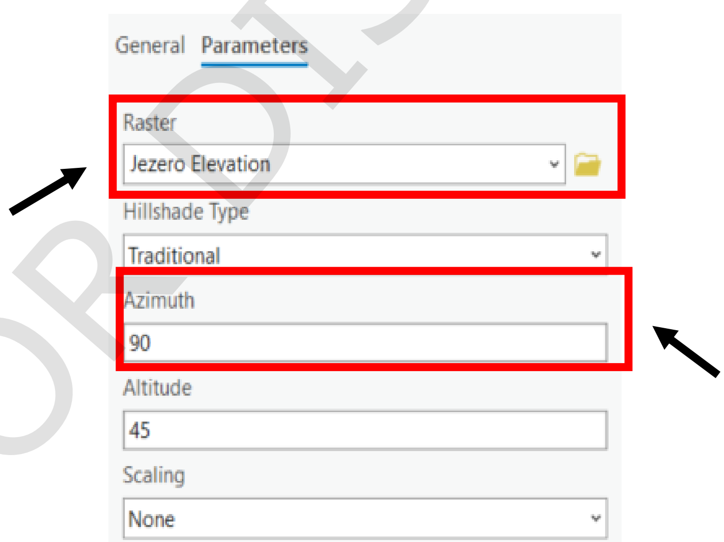
Step 8: Visualize terrain without a basemap

We will now create a simulation of the surface with solar illumination from the east, whereas the basemap has solar illumination from roughly west

- Click on **Full Extent** .
- Turn off the **Jezero Basemap** layer and turn on **Jezero Elevation** layer.
- On the **Imagery** tab, in the **Analysis** group, click on **Raster Functions** . In the **Raster Functions** pane, search for and click on **Hillshade** .



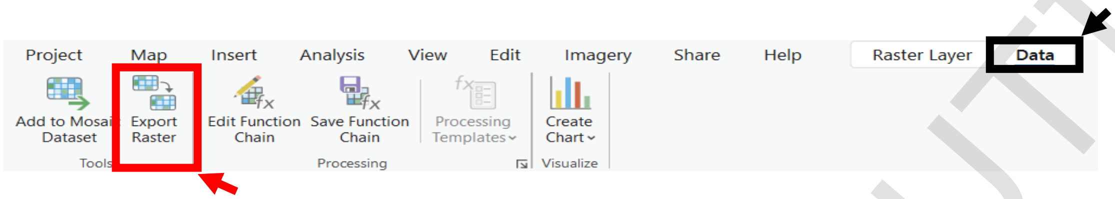
- For **Raster**, use the drop-down menu to select **Jezero Elevation**. Change the **Azimuth** to 90, so that solar illumination will be from the east.



- Click on **Create new layer.**

A new layer appears in the **Contents** pane and the **View** pane. However, no new data has been created, and so this raster does not exist as a .tif file. If you check the **Source** in the **Layer Properties** window for the **Hillside_Jezero Elevation** layer (double-click on the layer), you will see that the source is still the DEM file. This layer is a different way to display the same data as the **Jezero Elevation** layer.

- Use the tabs at the bottoms of the right side pane to switch to the **Symbology** pane. Change **Stretch type** to **Percent Clip** and click Yes to Calculate Statistics. Change **Gamma** to 1.5.
- We will now save this layer as a raster. Check that the **Hillshade_Jezero Elevation** layer is selected. On the **Data** tab, in the **Tools** group, click on **Export Raster** .



- For **Output Raster Dataset**, click the **Browse** button and navigate to the **Imagery** folder. For **Name**, type in **Jezero_Hillshade_90az.tif**. Click **Save**.

  If you do not specify the file extension, you can then select the file format from the **Output Format** drop-down menu.

- For **Coordinate System**, click on the **Spatial Reference** button. Expand **Favorites** and click on **MTM_clon77_5E**. Click **OK**. At the bottom of the **Export Raster** pane, click **Export**.

  A new layer is added whose source data is the raster we just created from the hillshade, not the DEM.

- Go to **Symbology** and set the new layer **Stretch type** to **Percent Clip**.
- Right-click on the **Hillshade_Jezero Elevation** layer and select **Remove** .
- In the **Contents** pane, rename the hillshade layer **Hillshade 90az** and move it to between the **Jezero Elevation** and **Jezero Basemap** layers. Turn the **Jezero Basemap** layer back on and turn off the **Jezero Elevation** layer.
- Check that the **Hillshade 90az** layer is selected, and use the **Swipe** tool to compare the basemap terrain to the hillshade terrain (Hint: it is on the **Raster layer** tab).

  Notice how shadowed regions in one layer are illuminated in the other, and vice-versa.

  You can save this Project if you'd like to, but you do not need to in order to move on.

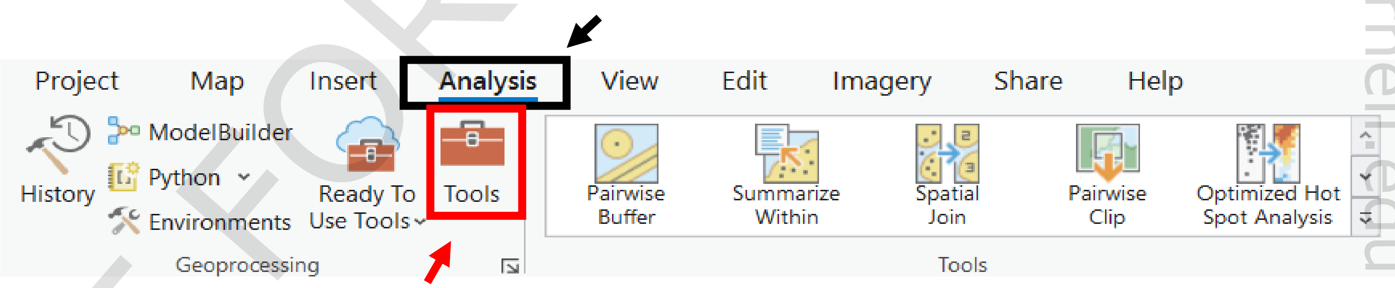
Exercise 2B: Raster analysis

Step 1: Find and use the Slope tool

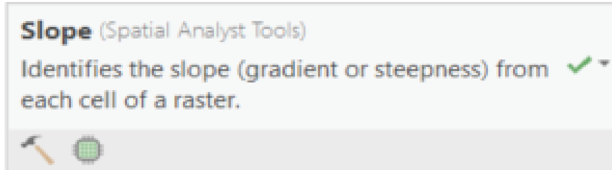
- Open the **Exercise2B** Project in one of these ways (ignore any transformation warnings you get):
  1) If ArcGIS Pro is still open, click on the **Open Project** button at the top left of the Pro window. Navigate to the **Excercise2B** folder, select the **Excercise2B** Project, and click **OK**. You can save the **Exercise2A** Project if you would like to, but you not need to in order to move on.
  2) If ArcGIS Pro is not open, start it and click **Open another project**. Scroll down to **Favorites** and expand it to find the **ExcerciseData** folder and navigate to the **Excercise2B** folder. Select the **Excercise2B** Project and click **OK**.
  3) Open Windows File Explorer. Navigate to the **Excercise2B** folder and double-click on the **Exercise2B** Project file.

You can have more than one Project open at once. To open one Project without closing the other, right-click on the ArcGIS Pro icon in your Windows Taskbar and select **ArcGIS Pro**. You can also go to the Windows Start Menu and in the list of applications, expand the **ArcGIS** folder and single-click on **ArcGIS Pro**.

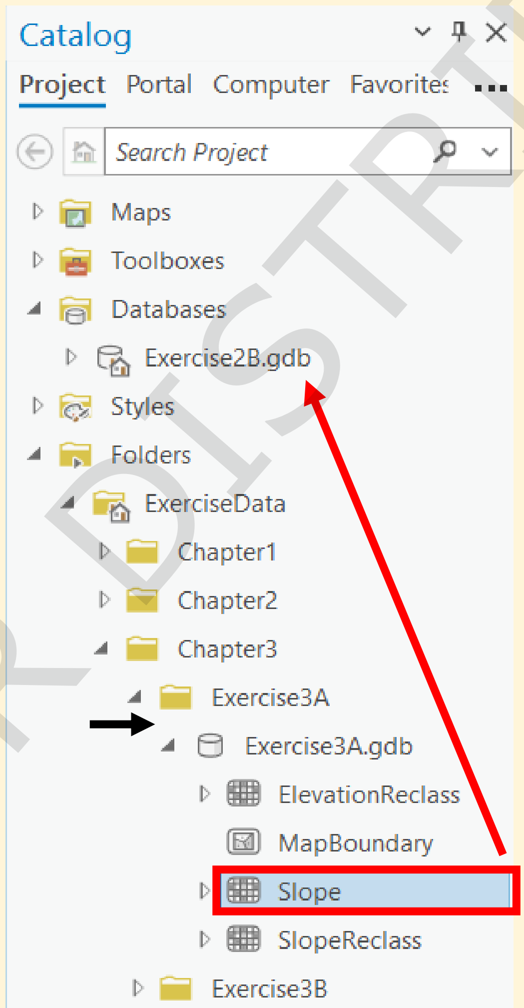
- Go to the **Analysis** tab and click **Tools** to open the **Geoprocessing** pane.



❍ Type *slope* and select the **Slope (Spatial Analyst Tools)**.



☆ **If** you do not have the ***Spatial Analyst Extension***, go to the **Catalog** pane and navigate to the **Exercise 3A** geodatabase. Copy the raster dataset **Slope** and paste it into the **Exercise 2B** geodatabase. Then, skip the next three steps.



❍ From the **Input raster** drop-down menu, select **Jezero Elevation**.

❍ Click on the **Output raster** name. When you do this, the entire pathway name appears. Your curser is at the very end, and there you can use Backspace to change the name of the output file to **Slope**.

- Click **Run**.

  You will see a progress bar at the bottom of the pane showing that the tool is running, and a window will appear in the corner when it is finished. A green checkmark indicates the tool ran successfully. In this case, you will see a warning but it can be ignored.

  If the tool did not run, an "X" in a red circle will appear and clicking on **History** in the **Analysis** tab will open a pane where details of the processes can be viewed, including any errors that occurred.

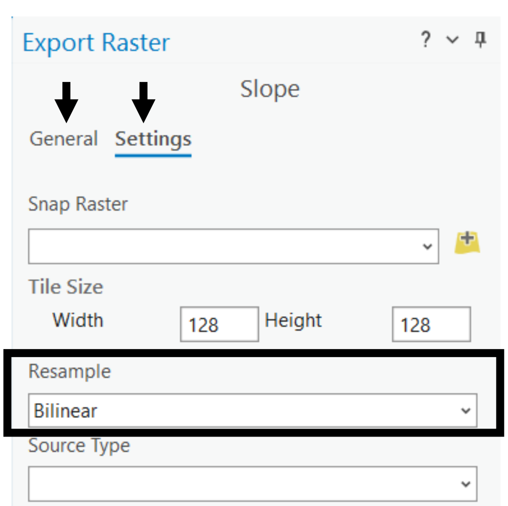
  The new raster is automatically added as a new layer in the Map.

- Make sure the **Slope** layer is selected in the **Contents** pane. Go to the **Symbology** pane. Set **Primary Symbology** to **Stretch**, set the **Color Scheme** to **Slope** (hint: click **Show names**), and make sure the **Stretch type** is set to **Percent Clip**.

Step 2: Export the result

This new raster dataset cannot be accessed outside of ArcGIS Pro because, without having specified a location for the output raster, it was put inside the default geodatabase. The file must be exported to make it available for sharing and use in other programs.

- Make sure the **Slope** layer is selected, and on the **Data** tab click **Export Raster**.
- Click on **Settings** at the top of the **Export Raster** pane. Change **Resample** to **Bilinear**. Click on **General** on top of the pane.



- For **Output Raster Dataset**, click **Browse** and navigate to the **Imagery** folder. Name the file **Jezero_Slope.tif** and then click **Save**.

  If you do not specify the file extension, you can then select the file format from the **Output Format** drop-down menu.

- For **Coordinate System**, use the drop-down menu to select **Jezero Basemap**.

  Unlike in the previous exercise, the **Jezero Basemap** layer is now using the projected raster for its source data. Optional step 7 of the previous exercise shows how to do this. Some tools and functions do not give you the option of selecting the coordinate system of the current Map. Therefore, it is helpful to have at least one layer in your Map use source data that has the same projection as the Map. This allows you to easily assign that projection when using these tools and functions.

- Click **Export**.
- Remove the layer that was just added from the Map in the **Contents** pane.

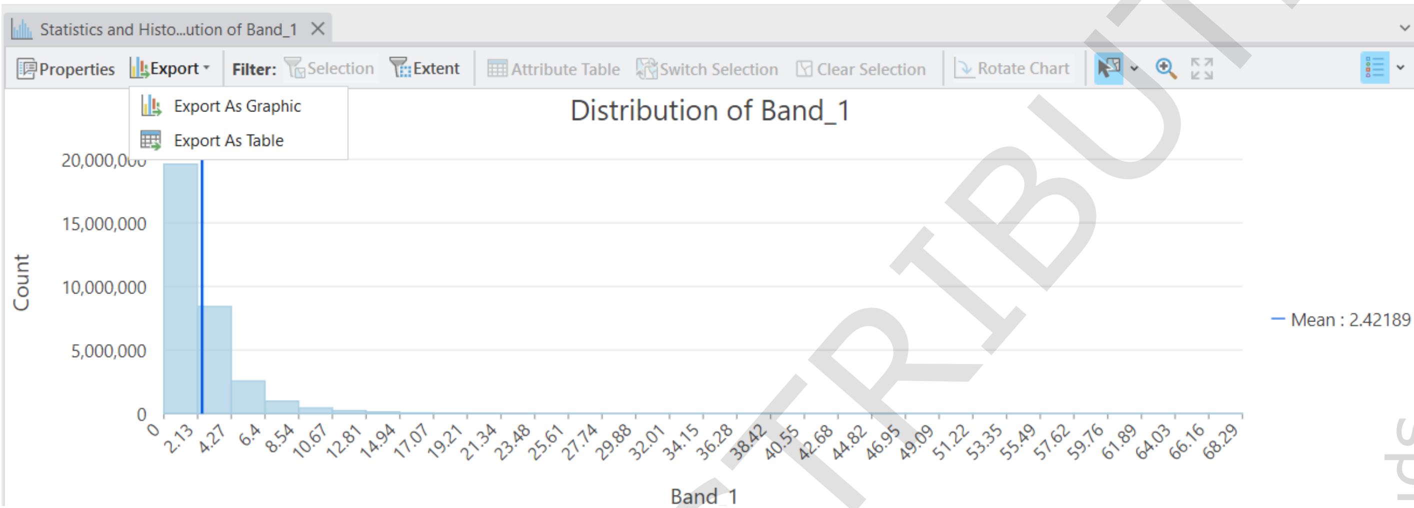
  This image can now be accessed through Windows File Explorer and shared for use in other Maps and programs.

Step 3: Perform statistics on a raster

- Click on the **Raster Functions** tab at the bottom of the right-side pane. If you do not see it there, go to the **Imagery** tab and click on **Raster Functions** .
- In the **Raster Functions** pane, search for *statistics* and select **Statistics and Histogram** . Select **Slope** as the **Raster** from the drop-down menu.
- Click **Create new layer**.
- On the **Data** tab, click **Create Chart** and select **Histogram** .

- In the **Chart Properties** pane on the right, set the **Number** as **Band_1** from the drop-down menu.

  A histogram of cell value appears as a window in the **View** pane. Also, a **Chart** tab has appeared on the top ribbon, and a chart associated with the layer has appeared in the **Contents** pane.

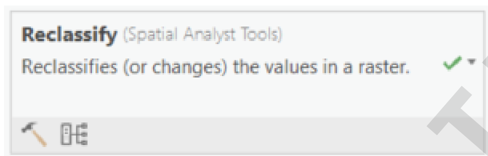


- On the top of the histogram window in the **View** pane, click **Export** to see the options for exporting the data.
- Close the **Chart Properties** pane on the right and the window showing the histogram in the **View** pane. Remove the **Statistics and Histogram_Slope** layer from the Map.

Step 4: Reclassify a raster

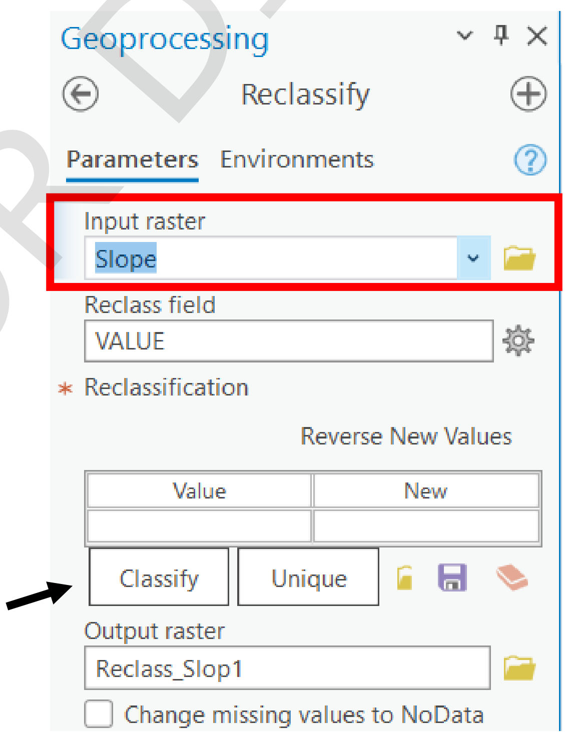
When the **Slope** layer first appeared, the **Symbology** was set to **Classified** and the raster was displayed as discrete. However, the source data was still floating point numbers. To create a discrete-valued raster, we must use a tool.

- Select the **Slope** layer, and go to the **Geoprocessing** pane. If it is still on the **Slope** tool, click the **Back** button ⓔ at the top left of the pane.
- Search for and select **Reclassify (Spatial Analyst Tools)**.

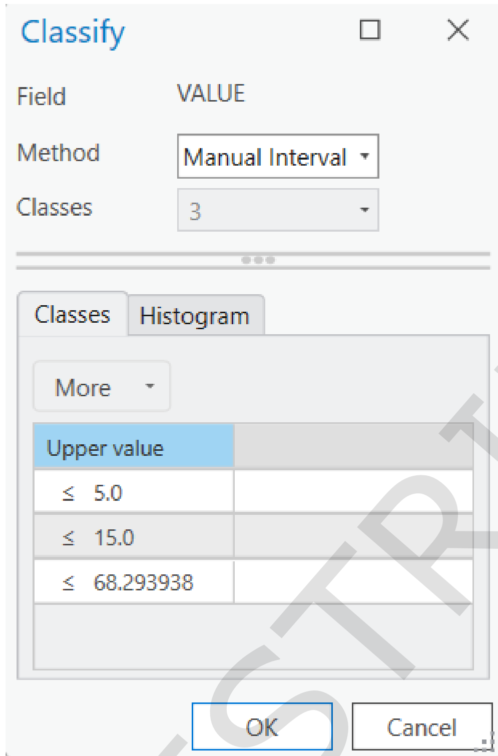


☆ **If** you do not have the ***Spatial Analyst Extension***, go to the **Catalog** pane and navigate to the **Exercise 3A** geodatabase. Copy the raster dataset **SlopeReclass** and paste it into the **Exercise 2B** geodatabase. Then, skip the next four steps.

- Select **Slope** as the **Input raster** and below **Reclassification**, click **Classify**.



- First, set **Classes** to 3, and then set **Method** to **Manual Interval**. In the **Upper Value** column, set the first number to *5*, the second number to *15*, and leave the third as it is. Click **OK**.



You can also edit the table directly on the **Reclassify** pane by typing in **Start** and **End** columns and adding new rows and/or deleting unnecessary ones.

- For the **Output raster**, name the file **SlopeReclass.** Click **Run**.
- Open the attribute table of the **SlopeReclass** layer. (Hint: Ctrl-double-click on the layer, or select the layer and do Ctrl-T)

Notice the cells now have only three different values (1, 2, or 3) instead of the floating point values they had in the **Slope** layer ranging 0 to 68.2939.

	OBJECTID *	Value	Count
1	1	1	32531407
2	2	2	21979
3	3	3	5977
	Click to add new row.		

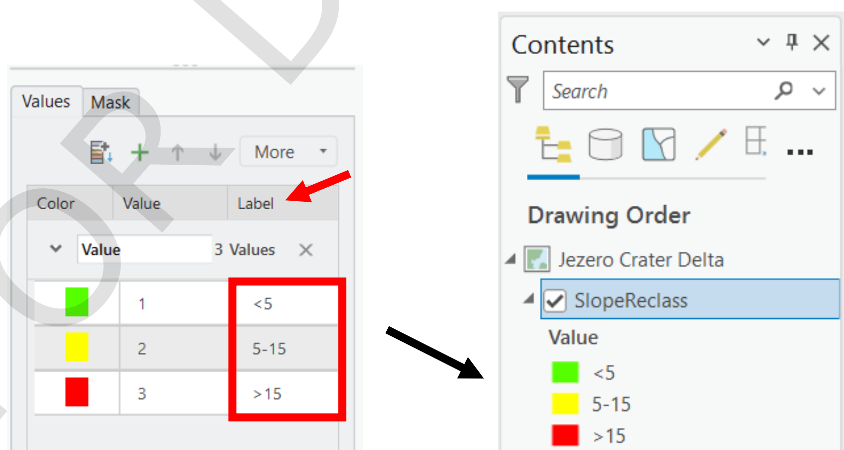
- Close the attribute table.

Step 5: Symbolize a discrete raster

We will now assign colors to the classified rasters pixel values 1, 2, 3.

- Select the **SlopeReclass** layer and go to the **Symbology** pane.
- In the bottom portion of the **Symbology** pane, on the **Values** tab, click on the first colored box in the **Color** column.

- Select **Medium Apple** (row 3, column 7, hovering the mouse pointer over a color reveals its name). Set the color in the next row to **Solar Yellow** (row 3, column 5). Set the color for the last column to **Mars Red** (row 3, column 2).
- In the **Label** column, change the first value to *<5*, the second value to *5-15*, and the third value to *>15.*



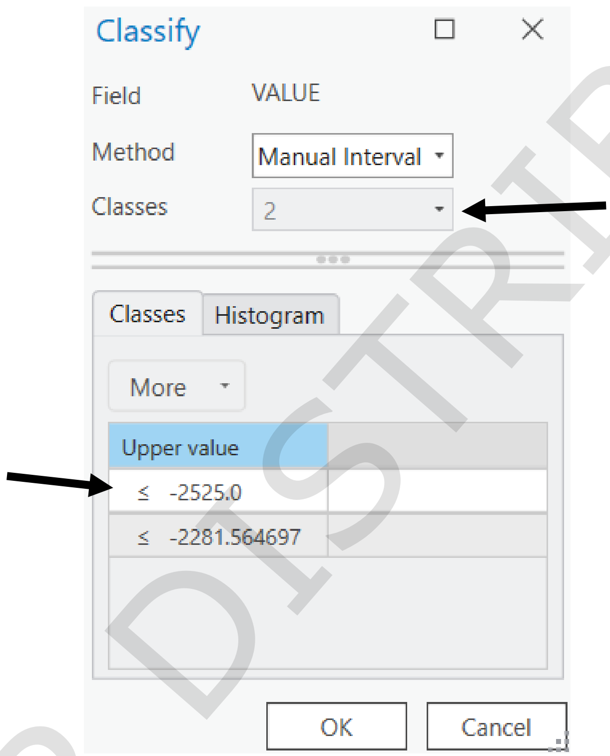
Notice that changing the labels changes what is displayed in the **Contents** pane. It will not change the actual data values, which are 1, 2, or 3. Labels and how things appear in the **Contents** pane will later carry over to elements in Layouts, such as legends.

You can save the Project if you'd like to, but you do not need to in order to move on.

Optional Steps

Step 6: Reclassify the elevation raster

❍ If you have the ***Spatial Analyst Extension***, repeat steps 4 and 5 to reclassify the DEM raster used by the **Jezero Elevation** layer into two classes, with the boundary between the classes as –2525 m. (Hint: You'll need to change the **Method** to something other than **Manual Interval** to change the number of classes.)



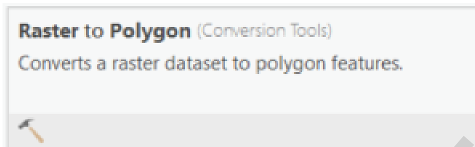
❍ Symbolize the low elevations with green and the high elevations with red, and change the labels to indicate the range of elevations represented by each of the pixel values. Turn off the **Slope** and **Jezero Elevation** layers and make both reclassified layers transparent, setting the **Slope Reclass** layer to 25% and the **Elevation Reclass** layer to 75%.

In this view, bright green regions are both low elevation and low slope, whereas bright red regions are both high elevation and high slope. Adjustments like this to display properties can help you do quick by-eye analysis before deciding what tool analysis you would like to do next.

Step 7: Create a map boundary layer

It is often useful to have a layer that outlines your Map extent. There is no specific tool for this in ArcGIS, but here is a quick way to do it.

- Reclassify the **Jezero Basemap** raster, setting the number of classes to 1. (It doesn't matter what **Method** you use.) Name the **Output Raster** **MapExtent**.
- In the **Geoprocessing** pane, find and open **Raster to Polygon (Conversion Tools)**.



- For **Input Raster**, select **MapExtent**. Name the **Output polygon features** **MapBoundary**. Click Run .
- Remove the **MapExtent** layer from the Map.
- Go to **Symbology** for the **MapBoundary** layer and click on the colored box next to **Symbol**. Click **Properties** at the top of the pane. From the **Color** menu, select **No color**. Click **Apply**.

  You now have a layer with a polygon that exactly outlines your Map extent.

  You can save this Project if you'd like to, but you do not need to in order to move on.

Chapter Summary

In this exercise you have learned how to create a new Project, and some of the basics of working with rasters. You have also been introduced to using Geoprocessing Tools and Raster Functions to analyze rasters, and how to export the results. You have seen how to change the appearance of Map layers in the Contents Pane, which does not affect anything about the source data displayed in the Catalog pane, and is only saved within the Project document. In addition to making your Map easier to interpret, these changes will carry over to presenting your Map in a Layout, making your finished product easy to read and understand.

Notes:

3

Working with vector data

Exercise 3A: Creating and sketching features

Exercise 3B: Editing and finalizing features

Exercise 3C: Importing shapefiles and using selection

Chapter 3: Working with vector data

Introduction

In this chapter you will learn the basics of creating, editing, and analyzing vector data, geometric shapes that contain spatial reference data. These objects may be points, lines, or polygons. In ArcGIS, vector data is stored in files called feature classes, which cannot be used with other GIS platforms. Vector data that can be used in all platforms is stored in files called shapefiles. Shapefiles can be imported into ArcGIS as feature classes, and feature classes can be exported as shapefiles. Unlike rasters, in which each cell can only store one numerical value, feature classes contain geometric information for each feature, such as length and area, and can also store other values that can be numerical, text, images, or hyperlinks. Creating feature classes to represent objects in rasters, such as craters, valleys, ridges, or geologic regions, allows for even more extensive analysis of these objects since so much information can be stored without needing to create a new file, as with rasters. We will learn how to create and edit feature classes and how to use and manipulate existing vector data.

Objectives

- Create a new feature class
- Sketch and edit features
- View attribute tables
- Symbolize features
- Use selection methods
- Create new features from existing features
- Create and calculate new attributes
- Import a shapefile
- Analyze features

Terms and Tools

- Feature Class
- Field
- Selection
- Shapefile
- Sketching
- Snapping
- Streaming
- Construction Tools
- Geoprocessing Tools: Feature to Polygon, Project, Clip, Average Nearest Neighbor, Pairwise Buffer
- Tab Ribbon Buttons: Create, Clear, Delete, Discard, Save, Modify, Edit Vertices, Reshape, Select by Attributes

Exercise 3A: Creating and sketching features

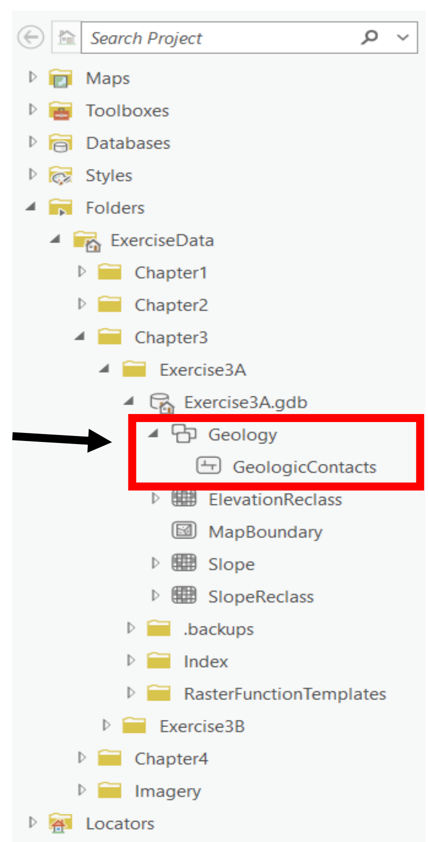
Step 1: Create a new feature class

- Open the **Exercise3A** Project, found in the **Exercise3A** folder, within the **Chapter3** folder.
- In the **Catalog** pane, right-click on the **Excercise3A** geodatabase and from **New**, select **Feature Dataset**. Name it **Geology** and set the **Coordinate System** to **Current Map**. Click **Run**.
- Go back to the **Catalog** pane and expand the **Exercise3A** geodatabase to see the new **Geology** feature dataset. Right-click on it, and from **New** select **Feature Class**.
- Name the feature class **GeologicContacts**, give it the **Alias Geologic Contacts**, and set the **Feature Class Type** to **Line**. Click **Finish**.

  Once a geometry type is set for a feature class, it cannot be changed through any editing methods. Feature Datasets can contain feature classes with different geometry types, and can therefore be useful for organizing your data.

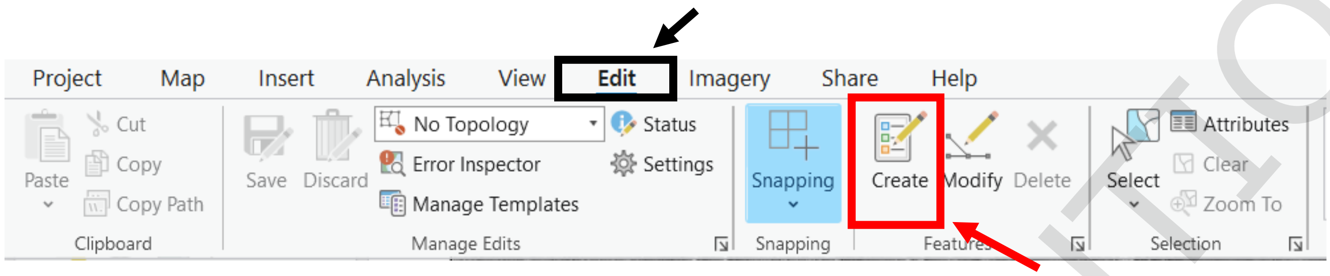
- Go back to the **Catalog** pane and expand the **Geology** featuredataset to see the newly created **GeologicContacts** feature class.

  Notice how the feature class is automatically added as a layer in the Map with the alias name. It is turned on but no features are visible, because the feature class has no data.



Step 2: Prepare for sketching

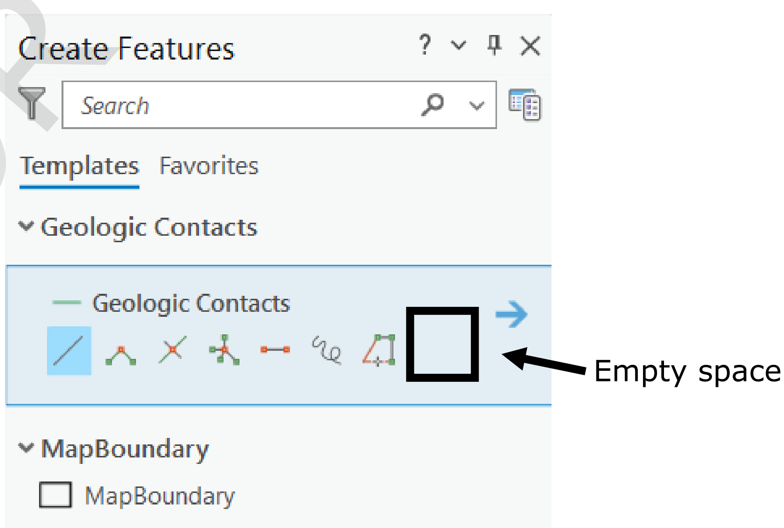
❍ On the **Edit** tab, in the **Features** group, click on **Create** .



❍ In the **Create Features** pane, click on **Geological Contacts** to select it. A set of tools appears underneath it.

A preferred sketch method for many planetary mappers is streaming. It best simulates the act of sketching by hand. This works well for creating features that are not primarily made of straight lines. However, manual dexterity varies from person to person, and we will explore a different method later.

❍ If you do not see the **Stream** tool, right-click anywhere in the empty space next to the tool icons and click **Properties**. Go to **Tools**, scroll down and check the square box for the **Stream Line Tool**. Clicking the circle will make this your default tool. Click **OK**. The **Stream** tool now appears under **Geologic Contacts**.



❍ Click on **Stream** to select it as our **Sketch** tool.

- Right-click anywhere in the **View** pane and select **Streaming Options** . You can also access it by typing **O** on the keyboard. Set the **Stream tolerance** to *35 m*. Click **OK**.

  The stream tolerance influences approximately how often a vertex will be added as you sketch. Spacing will be larger than your tolerance if a portion of the sketch is close to a straight line.

- Look at the map scale in the bottom left of the **View** pane. Multiply it by 4, and change the scale to roughly that value. Example: If my scale is 1:41,915 at **Full Extent**, then I would change my scale to 1:10,000. You can do this by typing *1:10000* in the scale box, or click the arrow to see a list of common map scales to choose from.

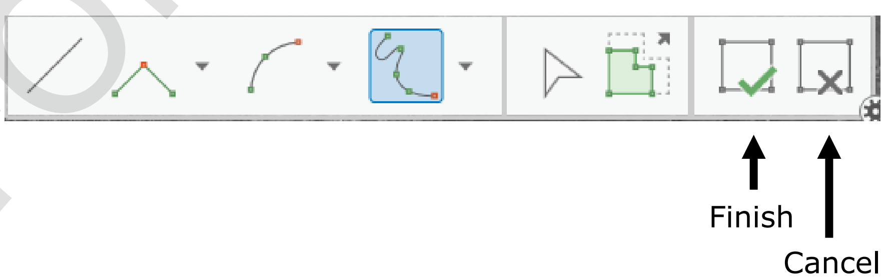
  This is the recommended way to determine the scale you will sketch at to ensure that curved lines will look smooth at the scale you want to publish. When beginning a mapping project, you should experiment with the stream tolerance so that lines look roughly smooth at the scale you are sketching, but you can still easily see individual vertices.

Step 3: Sketch geologic contacts

You will now sketch features on your Map. This is not a geology lesson, no prior knowledge of geology is needed, and this is just for practice drawing. Look for natural boundaries between different terrains and landforms, and sketch along those boundaries. If you want some guidance, you can refer back to the figure on page 5 that shows a geologic map. The contacts are the boundaries between the different-colored regions. You do not need to draw the same contacts as this map, and in the interest of time we recommend your sketching be much less detailed than this. Aim for creating 3-5 different regions on your Map.

- On the construction toolbar on the bottom of the **View** pane, ensure that **Streaming** is selected. If it is not, click the down-arrow and select it.

- **Pan** to what appears to be a geologic boundary where you'd like to sketch a contact. Do not zoom since we want to maintain sketching at the scale we set in the previous step.
- Click once anywhere along that boundary and trace it by moving your mouse. Don't try to draw perfectly, edits can always be made later. Sketch for a little while (no need to complete the boundary, you can stop anywhere), and then double-click to finish sketching. When you finish, you will briefly see the feature as green vertices along a dashed line, and then it switches to a line highlighted in cyan (which means it is selected).
- On the **Edit** tab, in the **Selection** group, click **Clear** to unselect the feature you just sketched.
- In the **Contents** pane, click on the line symbol below the **Geologic Contacts** layer name. Click **Properties** at the top of the **Symbology** pane and adjust the **Color** and **Line width** to your liking in order to see your features clearly, but don't choose something close to cyan, as this color is used for noting selected features. You will need to click **Apply** after each change to see the results in the **View** pane.
- Read through the following tips, and practice them a bit before you start sketching your boundaries. Your goal is to create closed regions, so your contacts should all connect with each other or the edge of the Map Boundary. However, set a timer for yourself when you begin sketching your contacts (after practicing for a bit) and don't spend more than 15 minutes sketching. You do not need to finish in order to move on.
  - **Deleting features**: Clicking **Delete** on the **Edit** tab will permanently delete all selected (cyan highlighted) features. Clicking **Discard** on the **Edit** tab will permanently delete any features you've sketched since you started sketching or since your last **Save**. Clicking **Cancel** on the construction toolbar at the bottom of the **View** pane will permanently delete a feature you are in the middle of sketching.



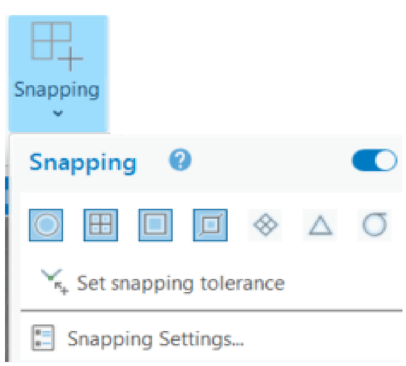
  - **Saving features**: Features are not saved when you finish a sketch by double-clicking on the Map or clicking **Finish** on the construction toolbar. You must click **Save** on the **Edit** tab. However, once you **Save**, you can no longer **Undo** any previous edits. Saving a Project does not save edits to features, unless you have set that as a Project option. (Options are found by clicking on the **Project** tab). If you try to close a Project, you will get a warning message if there are unsaved edits.

- **Undo**: Clicking **Undo** on the Quick Access Toolbar, or *Ctrl*-Z, will remove the last feature you finished. If you are in the process of sketching, it will not affect that feature but will undo the previous action. You can restore that action by clicking **Redo** on the Quick Access Toolbar, or *Ctrl-Y*, unless you have clicked **Save** or **Discard** after your last **Undo**.

- **Panning while sketching**: If you are sketching and nearing the edge of your viewing extent, you can hold down *C* on the keyboard to pause sketching and instantly switch to the **Explore** tool (your cursor will turn into the hand symbol for this tool), which lets you pan with the mouse. Holding down *C* to temporarily access the **Explore** tool works regardless of what you are doing in ArcGIS. Begin by clicking once to pause sketching. Then hold down *C* and click and drag to pan. Release *C* and move the cursor close to where you left off. Click once to continue sketching the feature.

- **Continuing a feature**: If you finished a feature and then want to add to it, click **Modify** on the **Edit** tab. In the **Modify Features** pane, under **Reshape**, select **Continue Feature** . Click on the feature you want to continue sketching. The red vertex shows where you finished sketching. If you want to continue sketching at the other end, right-click on the feature and select **Reverse Direction** . Position your mouse close to the red vertex and click once to start sketching again. Note that you may have to set the tool back to **Streaming** on the construction toolbar, as it usually defaults to the **Line** tool even if you have set **Streaming** as your default tool.

- **Snapping**: Snapping will help you connect features to other features by jumping your cursor to an element of another feature, such as a vertex or edge, when you get within a certain distance of it. This can be very helpful if you don't want to have gaps and overlaps in your sketching, but it can also make things difficult if you're trying to sketch close to another feature but don't want to actually connect to it. Click on the down arrow below the **Snapping** button on the **Edit** tab to see a toggle for turning it on and off, options for various types of snapping that can be individually turned on and off, and **Snapping Settings** where you can adjust how close you need to be to a feature for it to snap to it. You can also hold down the space bar to temporarily suspend snapping while you are sketching.



Alternative Method: Sketching without using streaming

Some people prefer sketching using the **Line** tool, which some call the “clicky-clicky method.” With this tool selected, you can click once to start sketching, and then click once to place vertices as you move your mouse. Between clicks, straight lines are sketched. Double-clicking finishes the sketch. All the above tips also work with this method.

- ❍ Now set your 15-minute timer, and begin sketching your contacts! Don’t forget to **Save** often.
- ❍ When you’re finished sketching, click **Save** on the **Edit** tab and **Save** your Project.

Exercise 3B: Editing and finalizing features

Step 1: Edit features

- Open the **Exercise3B** Project. In the **Catalog** pane, navigate to the **Geology** feature dataset in the **Exercise3A** geodatabase (Hint: look for it in **Folders**). Right click on your **GeologicContacts** feature class and select **Copy**. Navigate to the **Exercise3B** geodatabase, right-click on the **Geology** feature dataset, and select **Paste**.
- Click the **Explore** tool on the **Map** tab, then pan and zoom to examine your geologic contacts features. Locate places you'd like to edit, such as a contact that needs to be adjusted to better align with the terrain, or an intersection of contacts that is messy or incomplete.
- Choose one of these locations to start with. Pan to it and zoom to your sketching map scale (4 times your full extent scale).
- Read through the following tips, try each of them out (you can Undo changes while you're practicing), and then edit your contacts. Remember to adjust and turn on/off snapping if needed. Clicking **Finish** commits your changes to the feature but you still need to click **Save** to commit the changes to the data file. Set a timer for yourself when you begin making your edits (after practicing for a bit), and don't spend more than 10 minutes editing. You do not need to finish in order to move on.
    - **Moving Vertices**: Click the **Edit Vertices** button on the **Edit** tab. Click on the feature you'd like to edit to select it. This opens the **Edit Vertices** toolbar at the bottom of the **View** pane. You can now click and drag a vertex. You can also use the **Lasso** tool on the toolbar to select multiple vertices and drag them all at once.
    - **Adding Vertices**: On the **Edit Vertices** toolbar, click **Add** . Click anywhere on the feature to place a new vertex.
    - **Deleting Vertices**: On the **Edit Vertices** toolbar, click **Delete** . Click on a vertex to delete it. To delete multiple vertices at once, click and drag to lasso the vertices. When you release your mouse click, the vertices will be deleted.
    - There is also a button on the **Edit Vertices** toolbar for **Continue Feature** , which you probably used in the previous step.

- **Redrawing Segments**: Click on **Reshape** on the **Edit** tab. Select **Streaming** or **Line** on the toolbar at the bottom of the **View** pane, depending on which sketching method you prefer. Click once on the feature where you want to start redrawing. Sketch the new segment until you connect with the feature again. Double-click to finish redrawing.

❍ While making edits, remember to click **Save** on the **Edit** tab.

If this was an actual mapping project, then once you completed your geologic contacts, you would use the geoprocessing tool **Union** to combine them with a line feature class version of your Map boundary to create closed shapes along the edge of your Map.

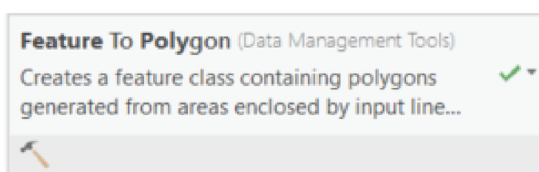
Step 2: Build polygons of geologic regions

Now you will use a sample of a completed geologic contacts line feature class to create a geologic units polygon feature class.

❍ In the **Catalog** pane, go to the **JezeroNili** geodatabase in the **Chapter1** folder and expand it. **Copy** the **GeoContacts_Complete** feature class and **Paste** it into the **Geology** feature dataset in the **Exercise3B** geodatabase.

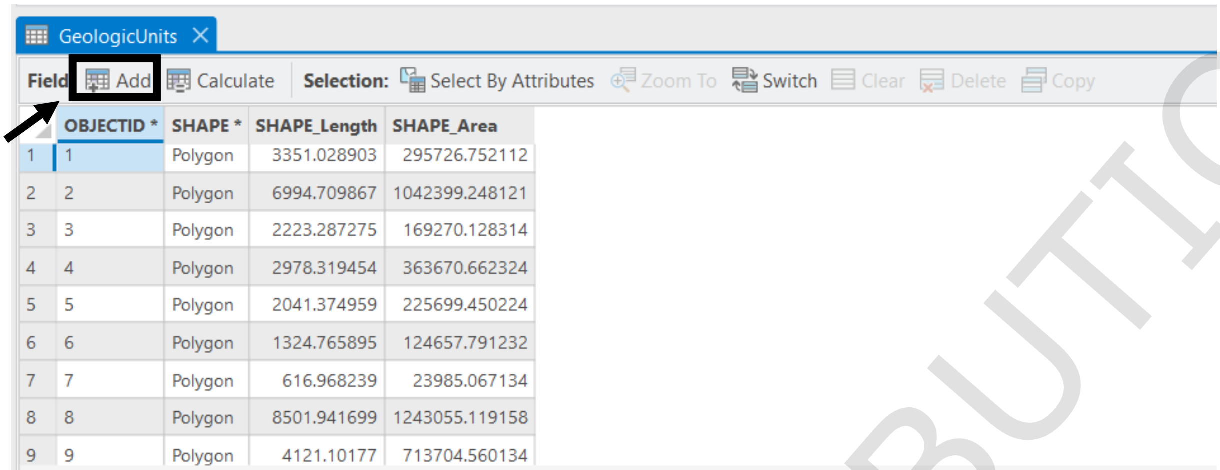
❍ Add the **GeoContacts_Complete** feature class to the Map by dragging and dropping it into the **View** pane. Turn off your **Geologic Contacts** layer and click **Full Extent**.

❍ Open the **Feature To Polygon (Data Management Tools)** geoprocessing tool. For **Input Features**, use the drop-down menu to select **GeoContacts_Complete**. Name the **Output Feature Class** **GeologicUnits**. Click **Run**.

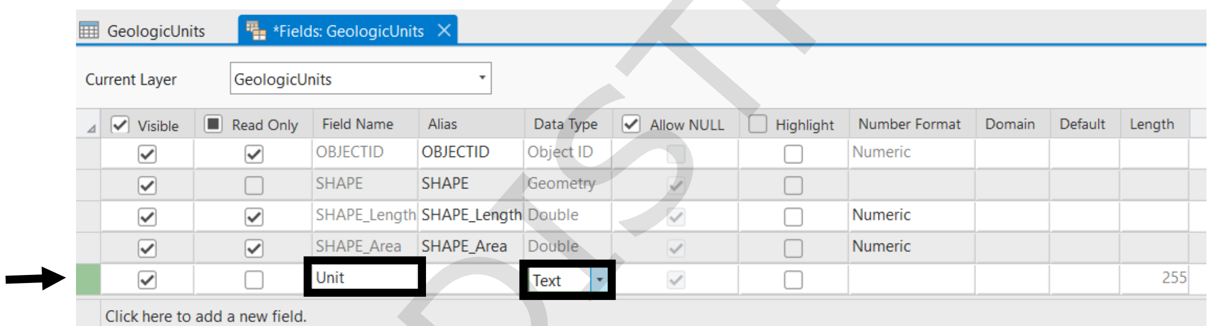


Now we must create an attribute to uniquely identify each unit for symbology and labeling.

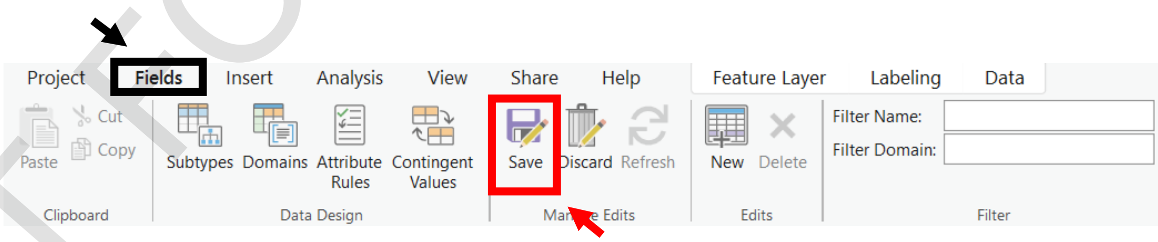
❍ Open the attribute table for the **GeologicUnits** layer. Click **Add** .



❍ Name the new field **Unit** and set the **Data Type** to **Text**.

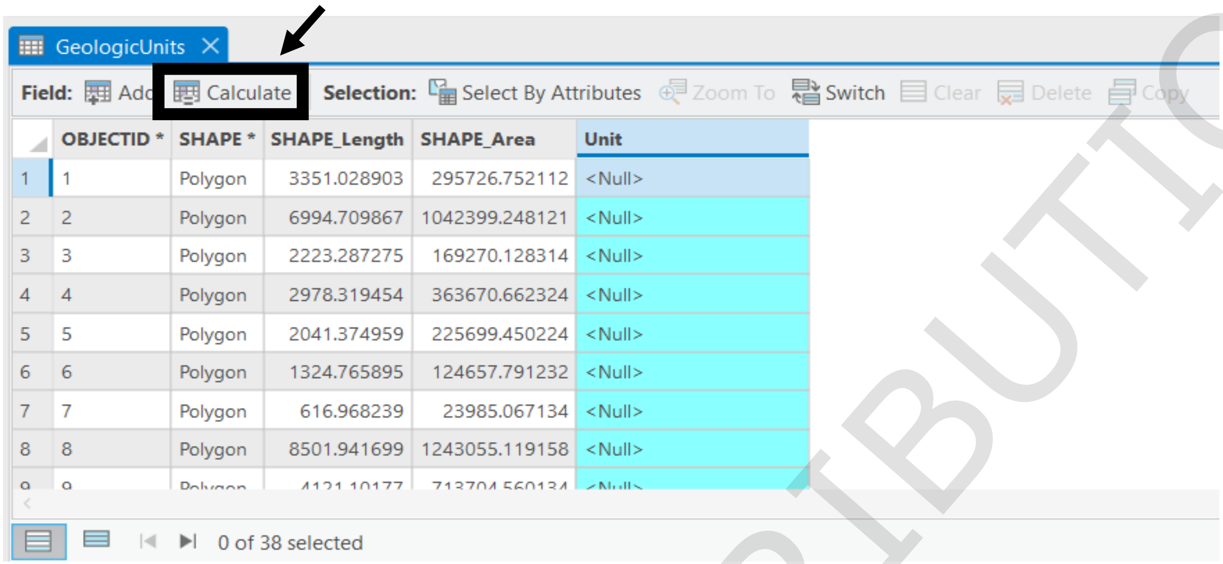


❍ Click **Save** on the **Fields** tab and close the **Fields** window by clicking on the **X** on its tab in the **View** pane.

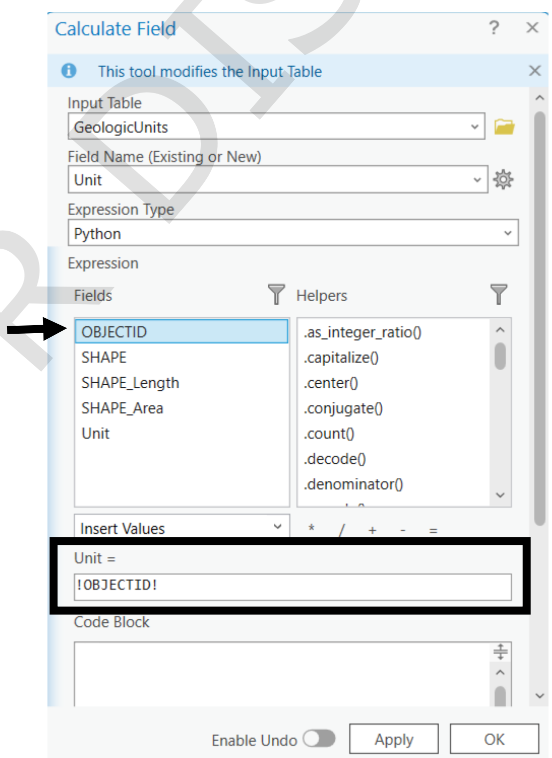


You would normally now type the names of each unit into the attribute table, but for brevity we will quickly give them unique identifiers.

- In the attribute table, click on **Unit** and click **Calculate** on the **Field** toolbar on the top of the attribute table.



- Click on the text box under **Unit =** and double-click **OBJECTID** in the **Fields** box above. Click **OK**.



Now there is a column in the attribute table with numerical placeholders for where you would later type in descriptive names of different geologic units.

- Close the attribute table and go to the **GeologicUnits** layer's **Symbology**. For **Primary symbology** select **Unique Values**. For **Field 1**, select **Unit**.

  This exercise has led you through the basic process of creating geologic units, or any polygon feature class. Although your end goal is a polygon feature class, you should not start by creating a polygon feature class. Trying to sketch adjacent polygons is difficult. It will produce topology problems (overlaps or gaps) and are extremely difficult to edit since to change one polygon you also have to change all of its adjacent polygons. The procedure we just led you though eliminates these issues by drawing single lines for the boundaries and then building the polygons based on these. You should never edit the polygons you create through this process. If after you've made them you want to edit something, go back to the line feature class and edit the boundaries, then re-build the polygons.

  There is a wonderful product provided by the USGS called the PGM Toolbox. It streamlines this process of creating geologic maps. It will check your contacts feature class for topology errors (gaps, overlaps, etc.), guide you through fixing them, and then build the polygons. It also has all the standard symbologies used in geologic maps built into it. You can download the PGM toolbox here: https://doi.org/10.5066/P91ZHZGH.

  You can save this Project if you'd like to, but you do not need to in order to move on.

Exercise 3C: Importing shapefiles and using selection

Step 1: Import a shapefile as a feature class

- Open the **Exercise3C** Project.
- In the **Catalog** pane, locate the **CraterData** folder in the **ExcerciseData** folder and expand it to find the **Jezero_CraterDatabase.shp** shapefile.

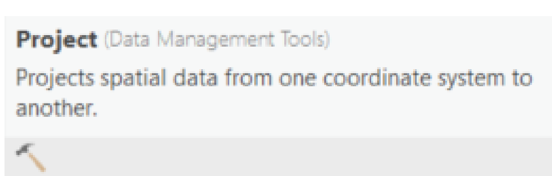
  Since this is a shapefile (not ArcGIS specific) it cannot be simply copied and pasted into a geodatabase. It will need to be converted into a feature class. You can still add shapefiles to the Map, but feature classes offer more attribute capabilities. Also, some ArcGIS processing and analysis functions cannot be used on shapefiles.

- Right-click on the **Excercise3C** geodatabase and from **Import** select **Feature Class(es)**.
- For **Input Features**, browse to the **CraterData** folder and select the shapefile. Click **OK**. Click **Run**.
- Go to the **Catalog** pane, find the **Jezero_CraterDatabase** feature class in the **Excercise3C** geodatabase. If you do not see it there, right-click on the geodatabase and select **Refresh**. Add it to the Map.

Step 2: Project the new feature class

ArcGIS has projected the new layer "on the fly" based on the coordinate system of the Map, but the **Jezero_CraterDatabase** feature class has no projection of its own. To perform spatial analysis we need to project it.

- Go to the **Geoprocessing** pane and open the **Project (Data Management Tools)** tool.



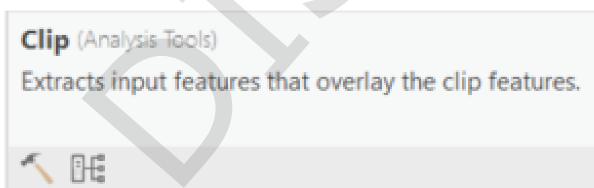
- For **Input Dataset or Feature Class**, choose **Jezero_CraterDatabase**. For **Output Dataset or Feature Class**, leave it as the default name. For the **Output Coordinate System**, use the drop-down menu to select **Current Map [Jezero Crater Delta]**. Click **Run**.
- Right-click on the **Jezero_CraterDatabase** layer in the **Contents** pane and select **Remove**.

Step 3: Clip the feature class to the Map extent

- Right-click on the **Jezero_CraterDatabas_Project** layer in the **Contents** pane and select **Zoom To Layer** .

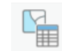
  The **Jezero_CraterDatabas_Project** feature class covers a larger area than our Map. So we will delete data outside of our Map's extent.

- Find and open the **Clip (Analysis Tools)** geoprocessing tool. For **Input Features or Dataset**, select **Jezero_CraterDatabas_Project**. For **Clip Features**, select **Map Boundary**. Name the **Output Features or Dataset** **CraterCenters**. Click **Run**.



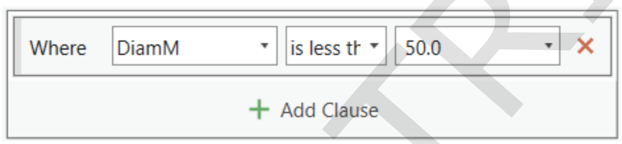
- Remove the **Jezero_CraterDatabas_Project** layer from the Map. Go to **Full Extent** .
- For the **CraterCenters** layer's **Symbology**, click on the point symbol (either in the **Contents** or **Symbology** panes) and click on **Properties** at the top of the **Symbology** pane. Change the **Color** to **Ginger Pink** (row 3, column 12), the **Outline color** to **Arctic White** (row 1, column 1), decrease the **Outline width** to 0.5 and increase the **Size** to 6. Click **Apply**.

Step 4: Select features by attribute values to highlight smaller craters

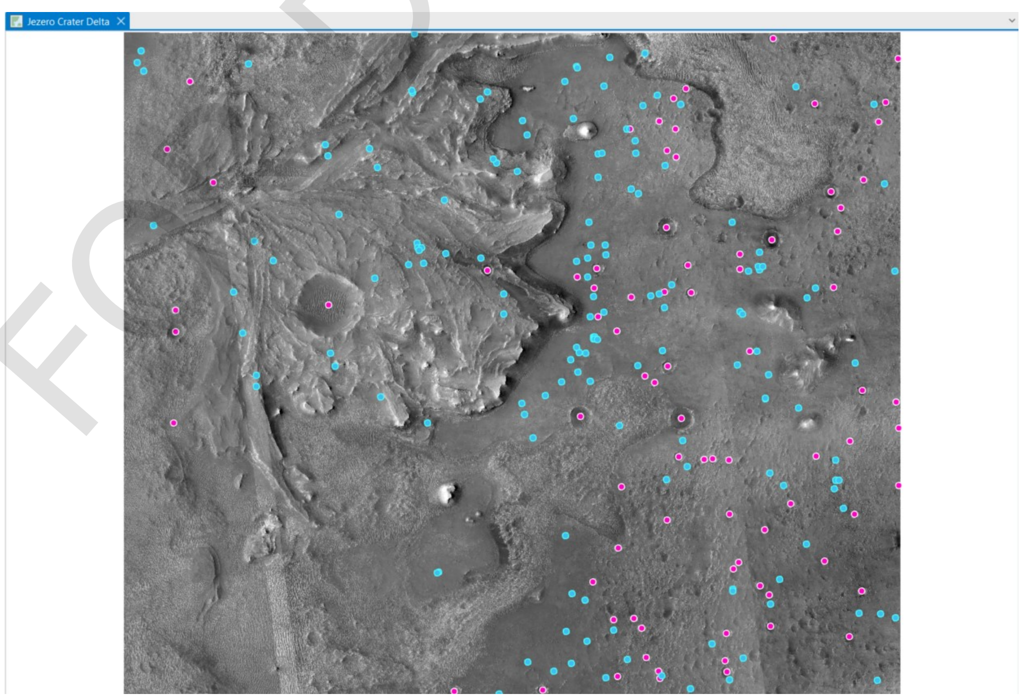
- On the **Map** tab, in the **Selection** group, click **Select by Attributes**  .
- For **Input Rows** select **CraterCenters**. For **Selection Type**, keep the default **New Selection**, but open the drop down menu to see the other choices.

  We want to select only the craters with diameters smaller than 50 m.

- For **Where**, use the drop-down menu to select the **DiamM** field. In the box that appears to the right that says **is equal**, use the drop-down menu to select **is less than**. In that last box, type *50.0*.

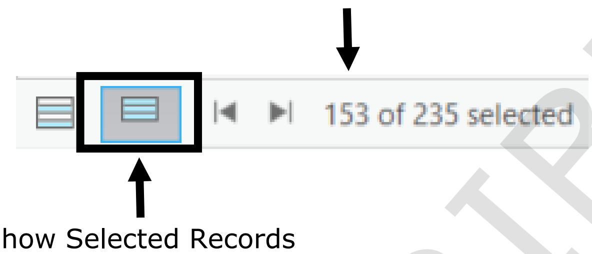


- Click **Apply** to see the selected craters highlighted in cyan in the **View** pane. You may have to move the **Select By Attributes** window out of the way. Click **OK**.



Step 5: View selected features in the attribute table

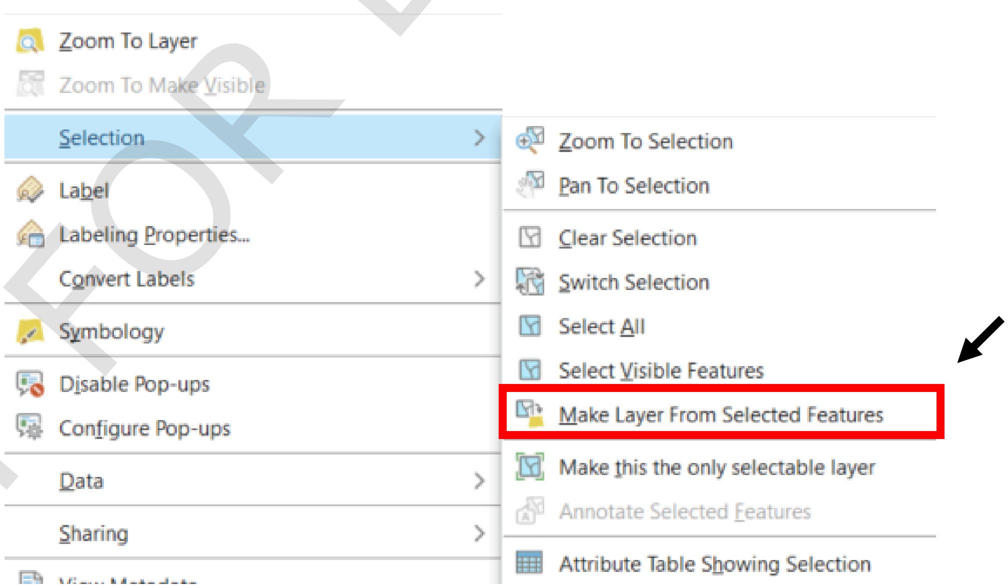
- Open the attribute table for the **CraterCenters** layer. You should see a few rows highlighted in cyan.
- At the bottom of the attribute window, click **Show Selected Records**. Scroll down to see that only selected features are shown in the table now. At the bottom of the window, notice how 153 craters have been selected from a total of 235.



- Close the attribute window.

Step 6: Create a new layer from selected features

- Right-click on the **CraterCenters** layer, and from **Selection** click **Make Layer From Selected Features**. A new layer appears just above the original layer.



- On the **Map** tab, in the **Selection** group, click **Clear** .

  Clear is another button you will likely use a lot, so you may want to add it to your **Quick Access Toolbar** at the top of your Pro window. (Hint: Right-click on the **Clear** button.)

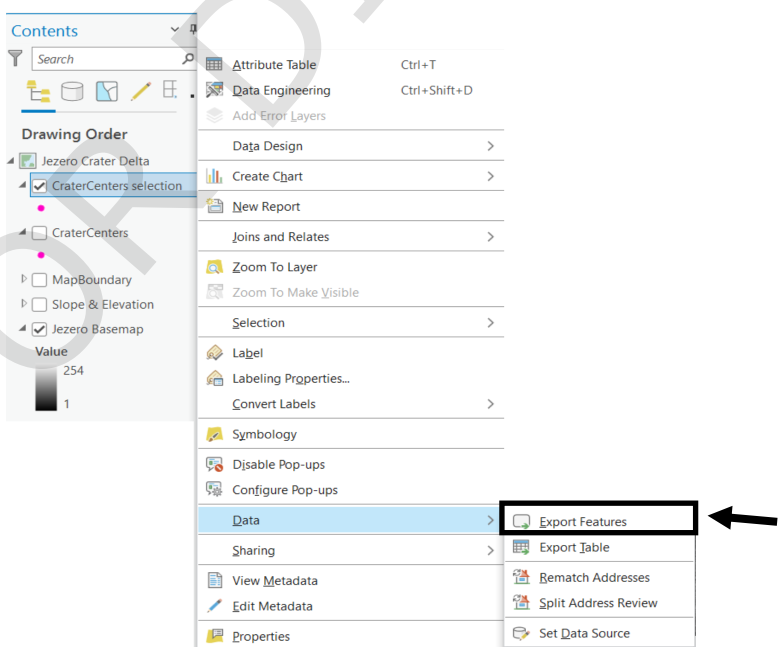
- Turn off the **CraterCenters** layer.

  The new layer only displays craters less than 50 m in diameter. However, if you open its **Layer Properties** window and check the **Source**, it is still getting its data from the **CraterCenters** feature class, which has all the craters in it.

Step 7: Create a new feature class from a selection layer

Look in the **Catalog** pane and notice that **CraterCenters selection** does not appear as a new feature class in the **Exercise3C** geodatabase. It is only a layer in the Map and a way to display the **CraterCenters** features. It will be saved as a part of your Project, but does not exist as a file you can share with others.

- Right-click on the **CraterCenters selection** layer and from **Data** select **Export Features** .



  Note that if there are currently selected features in the layer, only the selected ones will be exported.

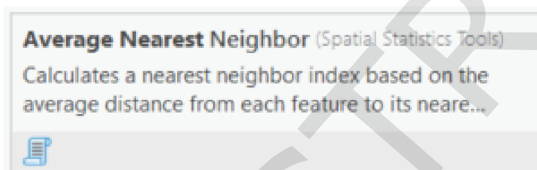
- Name the **Output Feature Class** **CraterCenters_small**. Click **OK**.

  Notice in the **Catalog** pane there is now a new feature class named **CraterCenters_small**.

- Go to **Symbology** for the **CraterCenters_small** layer. Change the color to **Electron Gold** (row 3, column 4) and decrease **Size** to 4. Click **Apply**.
- Remove the **CraterCenters selection** layer from the Map and turn the **CraterCenters** layer back on.

Step 8: Analyze crater size distribution

- Open the **Average Nearest Neighbor (Spatial Statistics Tools)** geoprocessing tool.



- For **Input Feature Class**, select **CraterCenters**. Check the box next to **Generate Report**, and then click **Run**.
- In the details window that appears to the right, click the link for **Report File**.

  An html file opens showing the results of the analysis. It has been saved to the folder you are currently working in. It will not show up in the **Catalog** pane, but you can go to Windows File Explorer to see it in the **Exercise3C** folder.

- Close the browser window with the analysis results in it.

  You can save this Project if you'd like to, but you do not need to in order to move on.

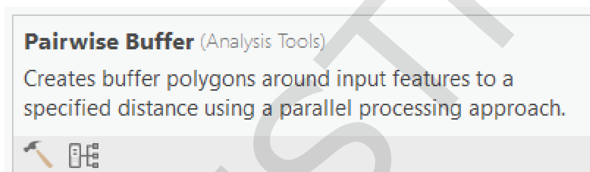
Optional Steps

Step 9: Calculate circumference and area for the crater points

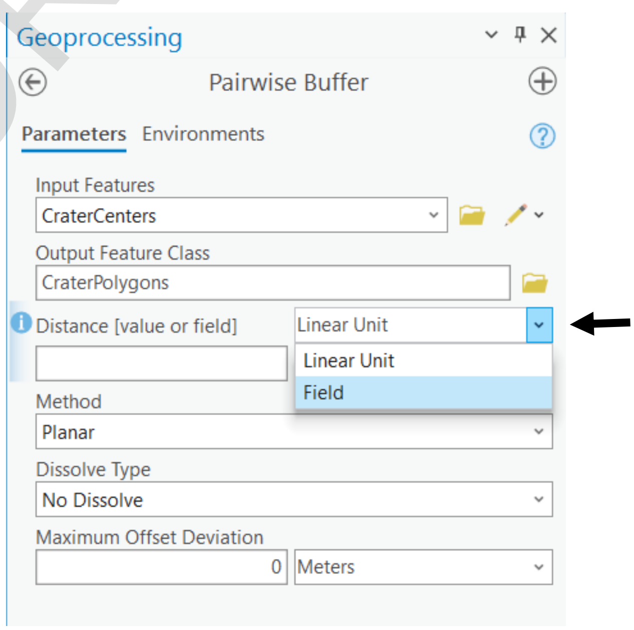
- Open the attribute table of the **CraterCenters** layer.
- As in the demo, create a new field titled *AreaM2* and calculate the area of the craters using the diameter. You can find the code for π in the **Helpers** box. Scroll down to find **math.pi** and double-click on it to add it to your expression.
- Close the attribute table.

Step 10: Buffer the crater points to create approximate polygon features

- Open the **Pairwise Buffer (Analysis Tools)** geoprocessing tool.

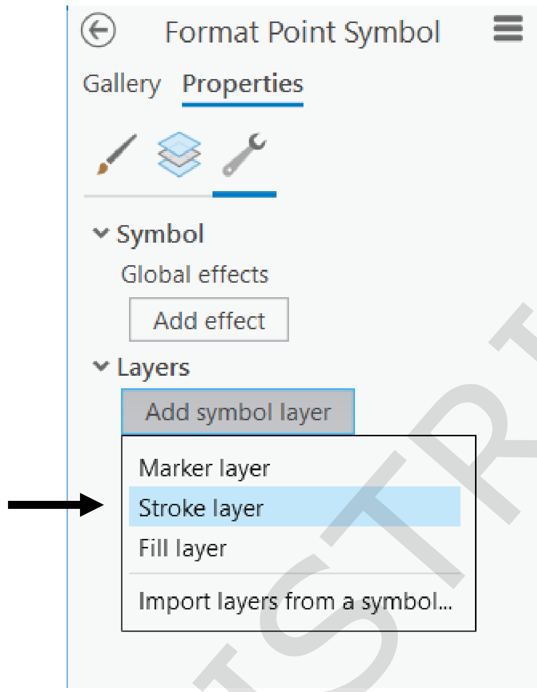


- For **Input Features** choose **CraterCenters**. For **Output Feature Class**, name the file **CraterPolygons**.
- For **Distance [value or field]**, use the drop-down menu to the right to select **Field**. From the drop-down menu below that, select **Radius (meters)**. Click **Run**.



- Turn off the **CraterCenters** and **CraterCenters_small** layers. Symbolize the new polygon layer with no fill color and a Medium Apple (row 3, column 7) outline with width 1.5.

★ If **Outline color** is greyed out, click on **Structure** Click **Add symbol layer** and select **Stroke layer**. Then, click on **Symbol** to go back to Appearance.



- Pan and zoom to explore these circular approximations of the craters. Use the **Swipe** tool to compare the features to the basemap.
- Open the attribute table for the **CraterPolygons** layer to compare the **Shape_Area** values to the **AreaM2** values. The values should match.

You can save this Project if you'd like to, but you do not need to in order to move on.

Chapter Summary

In this chapter you have learned the basics of creating, editing, symbolizing, and analyzing vector data. Our end product is a variety of feature classes representing geologic features in and around the Jezero Crater delta that can now be used for further analysis. You have also seen how attribute tables show you geometric and ancillary information of vector data and how to manipulate those tables.

If you were doing initial investigations for potential research, existing vector data is a good place to start. However, if you are ready to perform your own analysis for a research project, you should consider making your own data from scratch using the methods in this chapter. It is time-consuming, but it will ensure that the aspects of the data most important to your research are included, and you will be using spatial references that are possibly more up-to-date than those in pre-existing datasets. Though many processes in ArcGIS can be automated for performing large numbers of repeated operations, either through Model Builder or writing a Python script, things like sketching features generally needs to be done by hand. If you've invested a lot of time into a dataset, you should consider sharing it with others in your research group or even in an online forum like ArcGIS Online, so that others can use your data for their initial investigations and as guidance for doing their own research.

Notes:

4

Criteria analysis

Exercise 4A: Converting rasters to vector data

Exercise 4B: Using overlay to find landing site areas

Chapter 4: Criteria analysis

Introduction

In this chapter you will learn how to prepare data for analysis that involves finding candidate objects, locations, or regions that meet certain criteria through a process of selection and combination. You will be using analysis techniques on vector data, including proximity and overlay analysis, to determine potential touchdown locations for the Mars2020 Perseverance rover. The criteria we will use could have hypothetically been programmed into the self-guided landing system, and then our map could have helped refine those criteria by predicting where the rover would touchdown under those requirements. Our criteria are that the rover must land in an area that:

1) Is below −2525 m in elevation, to ensure the rover lands on the crater floor;
2) Has slopes that are less than 5 degrees, to minimize stresses due to some wheels touching down before others;
3) Be within the determined landing ellipse, which is centered roughly on the ideal touchdown location and ensures we land within a certain distance from the delta;
4) Be able to contain a 25-m-radius error circle to account for the margin of error in the self-guided landing system;

Objectives

- Convert raster data into vector data
- Perform overlay analysis using Union and Intersect
- Perform proximity analysis using Buffer
- Manage polygon features

Terms and Tools

- Dissolve
- Overlay
- Geoprocessing Tools: Union, Pairwise Buffer, Intersect

Exercise 4A: Converting Rasters to Vector Data

Step 1: Convert a discrete raster into a polygon feature class

- Open the **Exercise4A** Project.
- Create a new **Feature Dataset** in the **Exercise4A** geodatabase, name it **LandingSiteAnalysis**, and set the coordinate system to the current Map.
- Open **Raster to Polygon (Conversion Tools).**

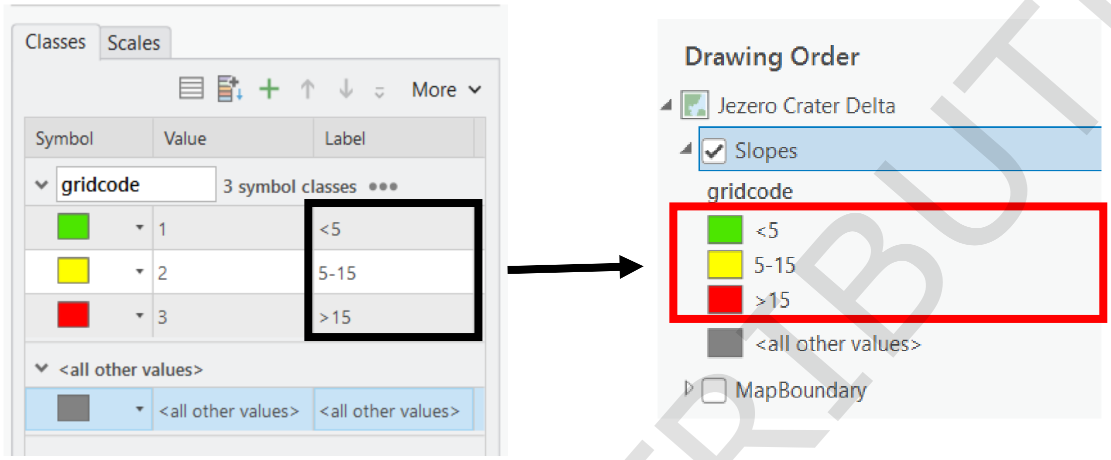
- For **Input Raster**, select **SlopeReclass** (it's inside the **Slope & Elevation** layer group). For **Output polygon features**, browse to the **LandingSiteAnalysis** feature dataset and name the feature class **Slopes**, and click **Save**. Click **Run**.
- In the **Contents** pane, turn off the **Slope & Elevation Rasters** layer group and collapse it by clicking the arrow to the left.

Step 2: Symbolize the polygon feature class

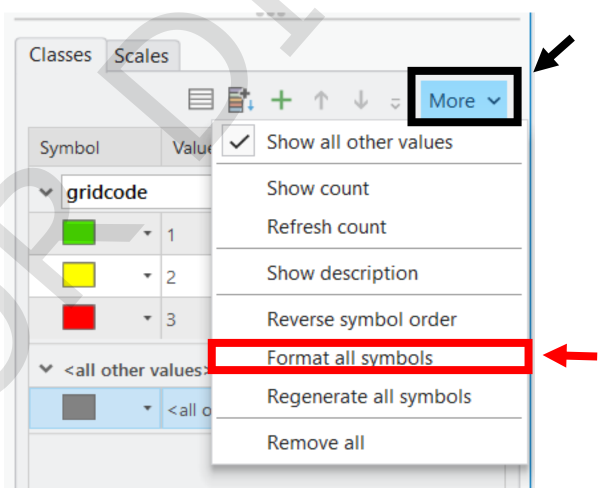
- Open the **Symbology** pane for the **Slopes** layer.
- From the drop-down menu under **Primary symbology**, select **Unique Values** . For **Field 1**, select **gridcode**.
- Change the color of the classes to bright green, yellow, and red, similar to the reclassified raster. (Hint: Click on the colored rectangles under the **Classes** tab. The colors do not have to be exactly the same ones that you used before.)

Now we will change the labels for each class to match those of the **SlopeReclass** layer.

- On the **Classes** tab in the **Symbology** pane, in the **Label** column, double click on each value to change it. Look in the **Contents** pane at the **SlopeReclass** layer, within the **Slope & Elevation** layer group, to see the labels.



- Click on **More** in the upper right corner of the **Classes** tab and select **Format all symbols**. Set the **Outline color** to **No color**. Click the back arrow at the top left corner of the **Symbology** pane.



- Click on **More** again, and uncheck **Show all other values**. The **Raster to Polygon** tool automatically adds symbology to values other than those in the original raster. This is where any raster cells that have no data would be accounted for. No such cells exist in our raster, so this symbology is unnecessary.
- Set the transparency of the **Slopes** layer to 50%.

Optional: Convert the elevation raster

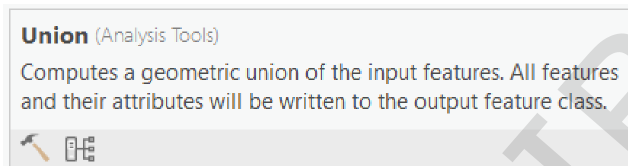
- Repeat the previous steps for the elevation raster, name the output feature class **Elevation**, symbolize it (colors and labels), and set the transparency to 75%.

You can save this Project if you'd like to, but you do not need to in order to move on.

Exercise 4B: Using overlay to find landing site areas

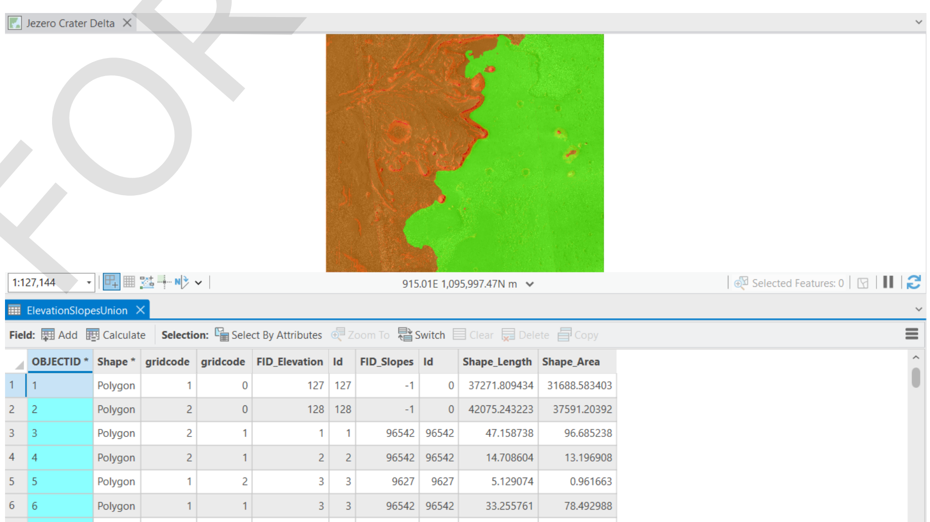
Step 1: Merge feature classes using Union

- Open the **Exercise4B** Project.
- Open **Union (Analysis Tools)**.



- For **Input Features**, first select **Elevation**, and then select **Slopes**. For **Output Feature Class**, name the feature class **ElevationSlopesUnion**. Click **Run**.
- Open the attribute table for the **ElevationSlopesUnion** layer.

There are now more polygons than in either of the original feature classes, subdivided by their combination of attributes from both layers. There are six different combinations of attributes from the input features (3 possible attributes for slope and 2 for elevation), and each different region of overlap has become its own polygon. We now want to symbolize the layer to see these six different attribute combinations.



	OBJECTID *	Shape *	gridcode	gridcode	FID_Elevation	Id	FID_Slopes	Id	Shape_Length	Shape_Area
1	1	Polygon	1	0	127	127	-1	0	37271.809434	31688.583403
2	2	Polygon	2	0	128	128	-1	0	42075.243223	37591.20392
3	3	Polygon	2	1	1	1	96542	96542	47.158738	96.685238
4	4	Polygon	2	1	2	2	96542	96542	14.708604	13.196908
5	5	Polygon	1	2	3	3	9627	9627	5.129074	0.961663
6	6	Polygon	1	1	3	3	96542	96542	33.255761	78.492988
7	7	Polygon	2	2	4	4	2291	2291	13.869781	6.242123

- Set the transparency of the new layer to 0%.

- In the **Symbology** pane, check that **Primary Symbology** is set to **Unique Values** and **Field 1** is set to gridcode (make these changes if necessary).

  The first gridcode value is coming from **Elevation** attribute. The second gridcode value is coming from the **Slope** attribute, since that is the order in which you entered them in the **Union** tool. That is why you are not seeing all the polygons with six different colors in the **View** pane.

- Underneath **Field 1**, click on **Add field**. Open the drop-down menu for **Field 2**.

  You don't see another **gridcode** option listed because the alias for both is gridcode. If you hover the mouse over the name of the second gridcode column in the attribute table, you'll see that the actual name of the field is **gridcode_1**. We need to change the alias to be a unique name.

- On the **Table** tab, in the **Field** group, click on **Fields** to open the field editing window in the **View** pane. The name of this window on its tab is **Fields**: **ElevationSlopesUnion**.
- In the **Field Name** column, find **gridcode** and change its **Alias** to **Elevation**. In the **Field Name** column, find **gridcode_1** and change its **Alias** to **Slope**. Click **Save** (top ribbon, on the **Fields** tab in the **Manage Edits** group) and close the field editing window.
- Go back to the **Symbology** pane. For **Field 2**, select **Slope**, which now appears on the drop -down menu.

  Now there are six colors symbolizing the different combinations of elevation and slope classifications.

  Note: If you see more than six colors, it is likely because one or both gridcode values has an additional "0" value that was added in the **Union**, which is an artifact of the edges along the map extent not lining up perfectly. You can find and delete these few polygons in the attribute table if you like, though it is not necessary for this exercise. If you do delete these polygons, go back to the **Symbology** pane and click on **More** in the **Classes** tab. Select **Refresh count**. If this does not work, switch **Primary Symbology** to **Single Symbol**, then back to **Unique Values**. Redefine the fields again.

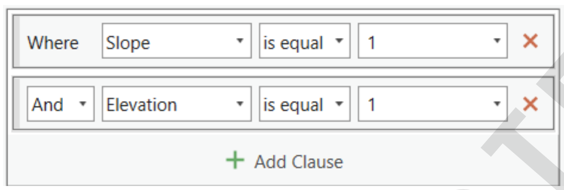
- Close the attribute table.

Step 2: Select potential landing areas

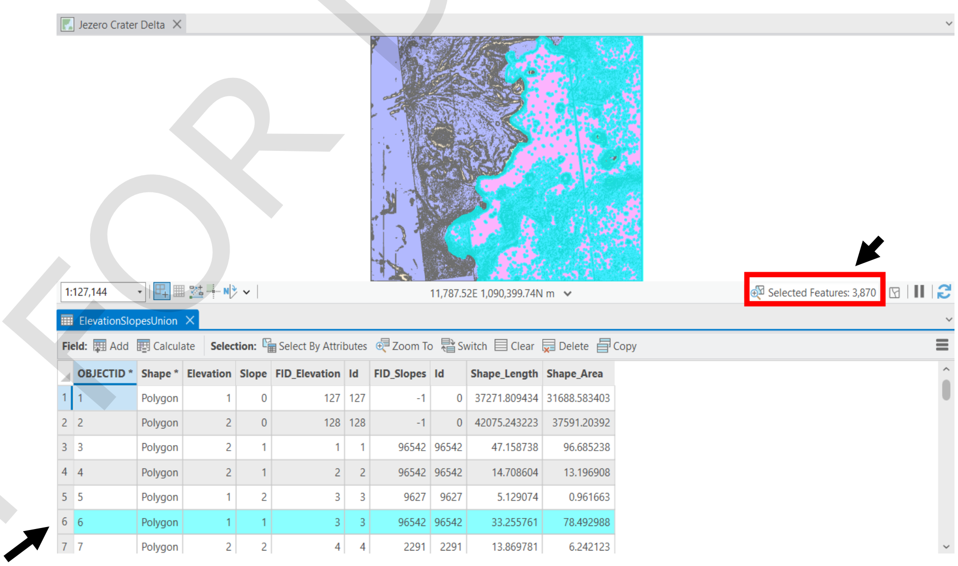
- On the **Map** tab, click on **Select By Attributes** .

  We want to select the lowest classes for both elevation and slope, which in both cases corresponds to gridcode values of 1.

- Select **ElevationSlopesUnion** layer and build the following query: Slope is equal to 1 and Elevation is equal to 1.



- Click **OK**.
- Open the attribute table for the **ElevationSlopesUnion** layer to see which polygons are selected, and how many have been selected (it should be 3,870 out of 97,004). If you do not see any selected polygons, you can scroll down a bit. If you still don't see any, you can try either reordering the table so that both **Slope** and **Elevation** are sorted by ascending (Hint: right click on the Field name), or click **Show selected records** at the bottom of the table.



You should also see the selected regions highlighted in the **View** pane.

- Close the attribute table.

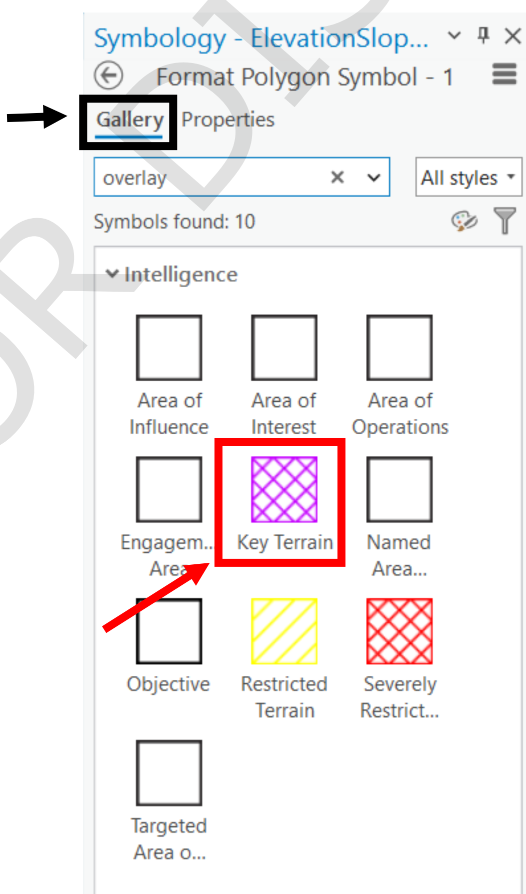
Step 3: Create a feature class from the layer selection

We want to create a new feature class with only these selected features.

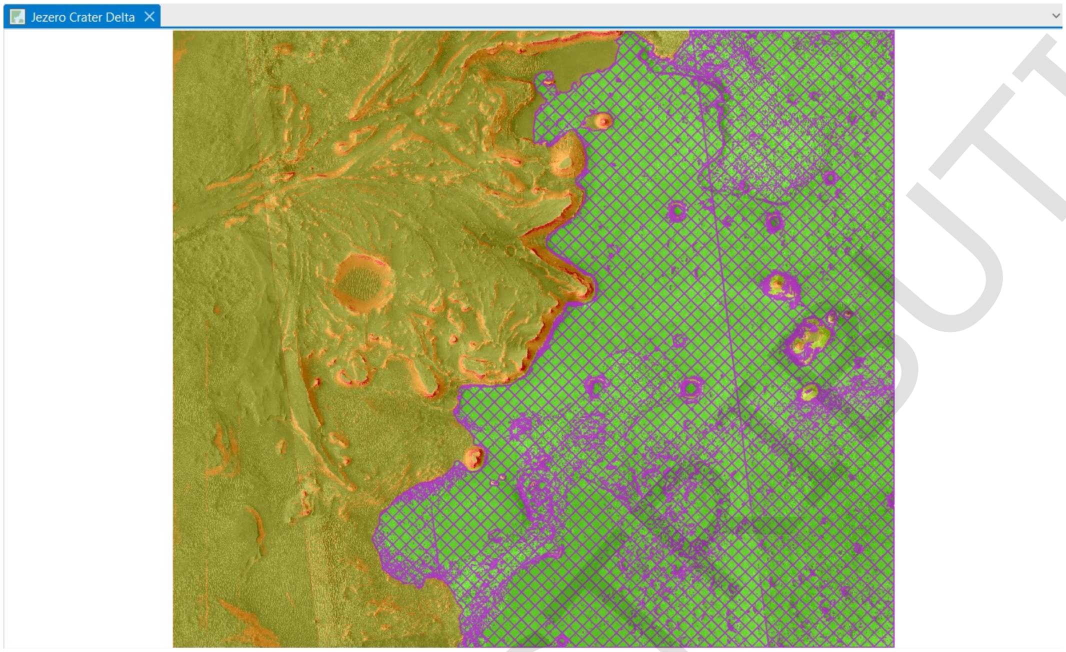
- Right click on the **ElevationSlopesUnion** layer, and from **Data** choose **Export Features** .
- For **Output Feature Class**, name the file **ElevationSlopeSafe**.
- Click on the **Environments** tab at the top of the **Export Features** window. Set the **Output Coordinate System** as **Current Map [Jezero Crater Delta]** and click **OK** to see the new layer appear.
- Clear the selection and turn off the **ElevationSlopesUnion** layer.

Step 4: Symbolize and explore the results

- Go to the **Symbology** pane for the **ElevationSlopeSafe** layer. On the **Classes** tab, click on the colored box under the **Symbol** column.
- On the **Gallery** tab, type *overlay* in the search box and hit return, and click to select **Key Terrain**.



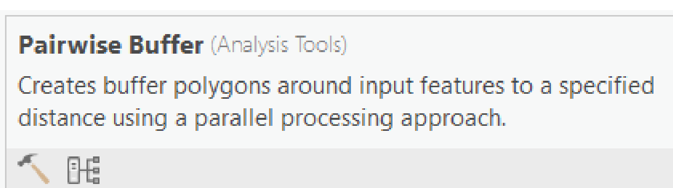
- Set the layer's transparency to 50% on the **Feature Layer** tab.
- Explore and zoom around to notice how the **ElevationSlopeSafe** features overlap the greenest areas where both the elevation and slopes are low.



Step 5: Buffer the safety region to account for navigation errors

The landing system is programmed to avoid landing anywhere within 25 m of an area that does not meet the safety requirements we have established in the previous steps. We will apply a negative buffer to eliminate these areas. We don't need this resulting region to be covered by multiple feature classes, so we will also use this tool to combine all the polygons into one.

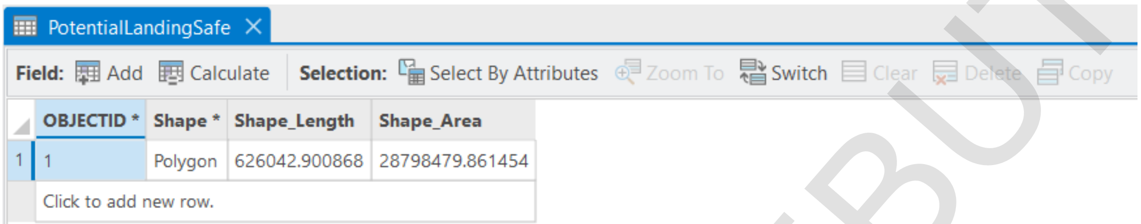
- Turn off the **Slopes** and **Elevation** layers.
- In the **Geoprocessing** pane, find and open **Pairwise Buffer (Analysis Tools)**.



- For **Input Features**, choose **ElevationSlopeSafe**. For **Output Feature Class**, name the file **PotentialLandingSafe**. For **Distance**, ensure that **Linear Unit** is selected.

- Select **Meters** below **Linear Unit** and enter *–25* in the box to the left of that.
- Set **Dissolve Type** to **Dissolve all output features into a single feature**. Click **Run**.
- Open the attribute table for **PotentialLandingSafe**.

Notice there is now only 1 feature.



- Close the attribute table. With the **PotentialLandingSafe** layer selected in the **Contents** pane, **Zoom in** and use **Swipe** on the **Feature Layer** tab to compare the buffered layer to the **ElevationSlopeSafe** layer. Turn off the **ElevationSlopeSafe** layer.
- Symbolize the **PotentialLandingSafe** layer as you like or leave it as is.

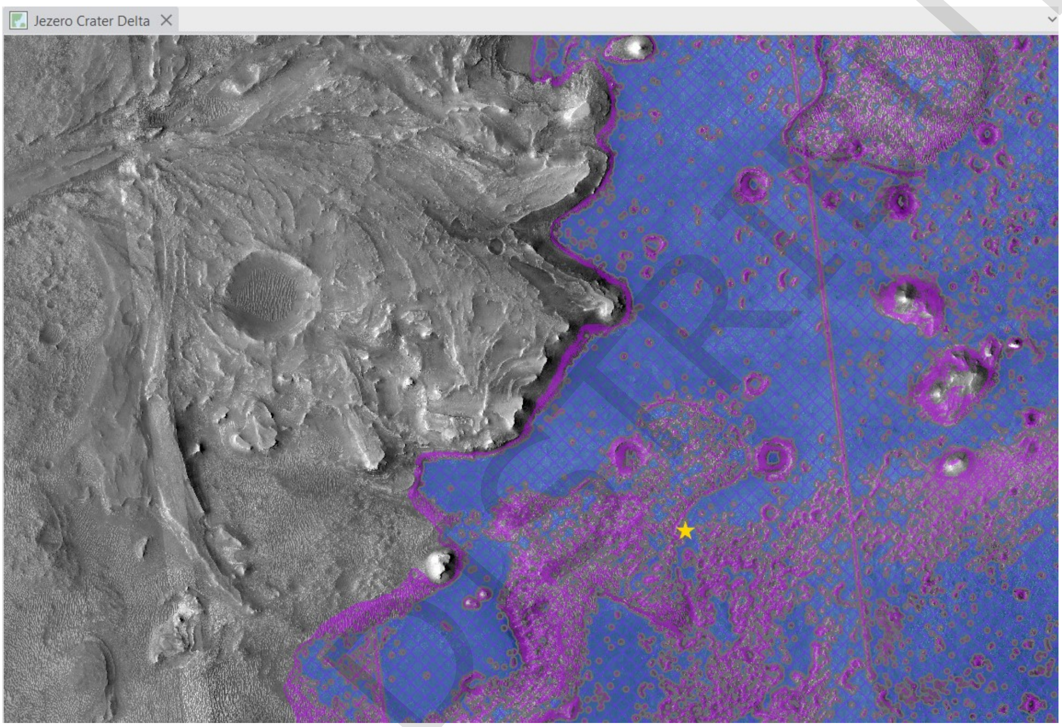
Step 6: Eliminate areas outside of the landing ellipse

- In the **Catalog** pane, navigate to the **JezeroNili** geodatabase in the **Chapter1** folder, and in the **MappingData** dataset find the **LandingEllipse** feature class. Drag and drop it into the **View** pane to add it to the Map.
- In the **Geoprocessing** pane, find and open **Intersect (Analysis Tools).** Select the **LandingEllipse** and **PotentialLandingSafe** layers for **Input Features**. Name the **Output Feature Class PotentialLandingAreas**. Click **Run**. Turn off the **LandingEllipse** and **PotentialLandingSafe** layers.
- Symbolize the new layer as you like.

Step 7: Compare to the actual landing site

- In the same dataset as the **LandingEllipse** feature class, find the **LandingSite** feature class and add it to the Map. This is the actual touchdown site of the Perseverance rover.

  Does the Octavia E. Butler Landing Site fall within the region you derived in the workshop? (Hint: symbolize the **LandingSite** point to make it easier to see.) How do you think the data you produced in this workshop could have been used in mission planning prior to landing?



Chapter Summary

In this chapter you learned how to combine raster and vector data to perform analysis based on specific criteria. You converted rasters into feature classes so that you could use vector analysis tools. It is also possible to convert vectors into rasters and use raster analysis tools, though this usually only works well with two-dimensional vectors like polygon feature classes. Raster Calculator is a general overlay tool that is used to combine data from multiple rasters. It is best to carefully plan out the steps you will take to perform your analysis ahead of time, since there are usually multiple ways to obtain the same results and you must decide which is most efficient for your purposes. For instance, we could have created new layers through selection for each of the elevation and slope layers that would only contain the lowest ranges, and then used the Intersect tool to create polygons that fit both requirements. Instead, we first used Union and then a single selection from the resulting layer, which for this exercise was quicker and easier.

For an analysis process that you plan on repeating, the Model Builder function can be used to create a pipeline of tools and outputs to essentially create a new tool that you design. This model can then be saved as a single tool. If you are working with only rasters, you can use the **Processing Templates** tool on the **Data** tab to create a single function out of a series of functions.

Notes:

Appendix

Common File Types

Main Components of the ArcGIS Pro Window

Ribbons

Glossary

Common File Types

Feature Class:

- Similar to shapefile, but with additional files for use in ArcGIS
- Can ONLY be used within an ArcGIS geodatabase, can be exported as a shapefile, can be exported as a shapefile

Feature Dataset:

- Contains multiple feature classes related by content, must have the same coordinate system

Geodatabase: *gdb (default geodatabase:)

- ArcGIS file structure for storing, organizing, and sharing data with other ArcGIS users

Image Files: *tif

- Common: TIFF (regular or GeoTIFF), JPEG, JPG2, PNG, BMP, GIF, etc.
- Dataset specific: SAR, SRTM, DEM, DOQ, LAS, many more

Layer: *.lyrx

- Stores information for how to display a particular data source or dataset
- Does NOT store any source data

Map Document: *.mapx

- Stores information for how to display all data in a map
- Does NOT store any source data

Project: *.aprx

- Stores information for how to display and organize all ArcGIS data, including Maps, Local and Global Scenes, Tables, and links to Folders and Geodatabases
- Does NOT store any source data

Packages: *.lpkx , *.mpkx , *.ppkx

- The tools for creating Packages are located on the Share tab
- Stores both display instructions and source data
- Good for sharing with other ArcGIS users who do not have access to your geodatabase

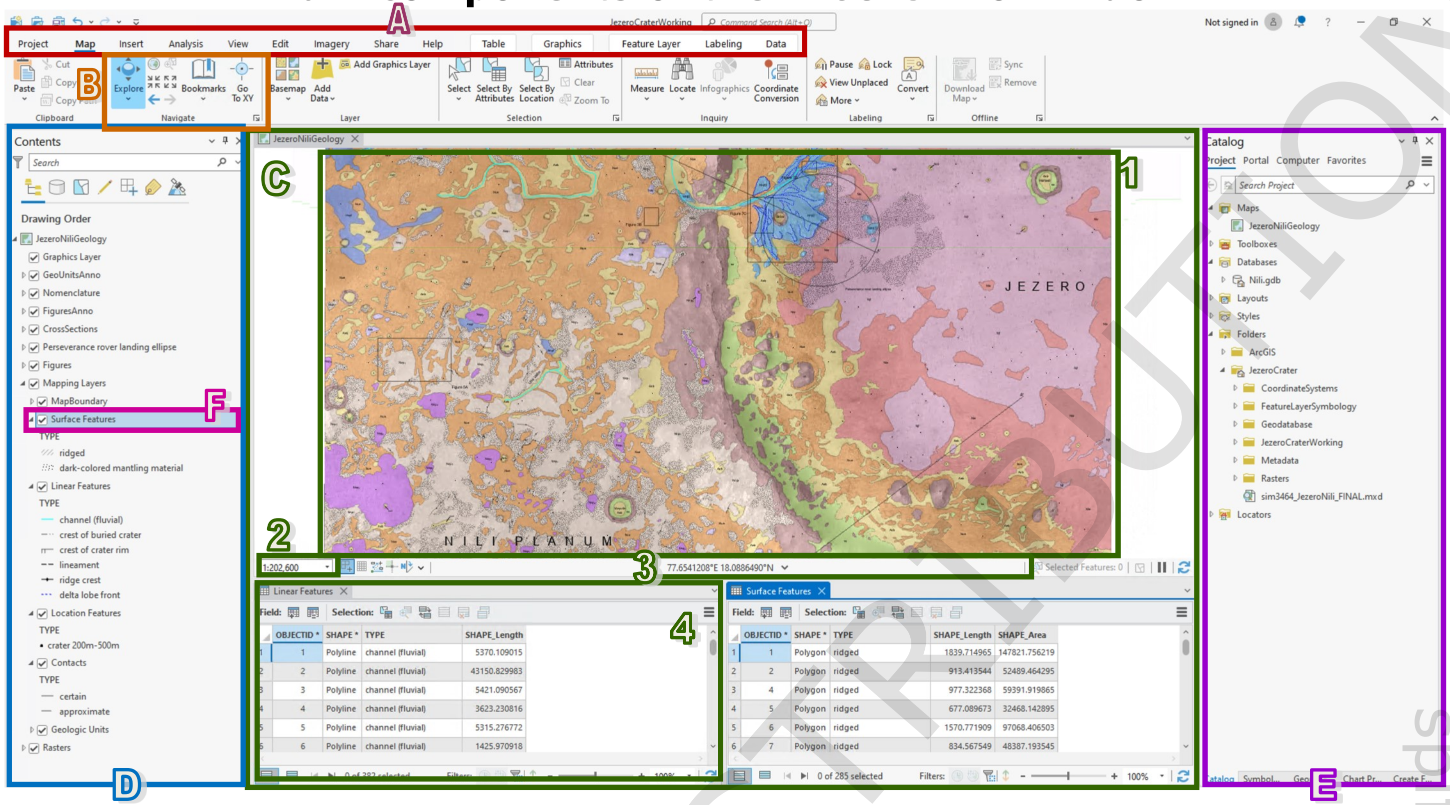
Shapefile: *.shp

- Stores spatial and geometric data for features
- Used by most GIS software , can be used in ArcGIS but not within a geodatabase, can be imported as a feature class or exported from a feature class

Table:

- Tabular data, can be imported from other formats like MS Excel and then added to the attribute table of a feature class, or can be exported from the attribute table data of a feature class

Main components of the ArcGIS Pro window



A. **Adaptive Tabs** that change depending on what type of data you are viewing or have selected.

B **Tab Ribbon** and **Tool Groups** appear with relevant tools for each of the tabs. There are no longer toolbars that need to be opened individually.

C The **View Pane** is the main workspace where you can view elements of your project, such as Maps, Tables, Local and Global Scenes, and Layouts.

1. A Map displayed within the **View Pane**.

2. This shows the map scale. You can change it from the drop-down menu next to it or by typing the scale you want.

3. This shows the position of the cursor in the coordinates of the map. You can change the units shown here by clicking on the drop-down menu to its right and selecting your desired units.

4. An **Attribute Table** displayed within the **View Pane** that shows data associated with a Map layer.

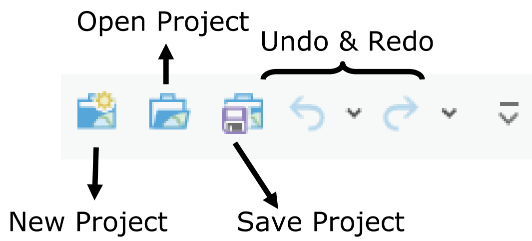
D The **Contents Pane** contains a list of all the layers in the Map.

E The **Catalog Pane** is where you manage, organize, and access your geographical data and Project elements.

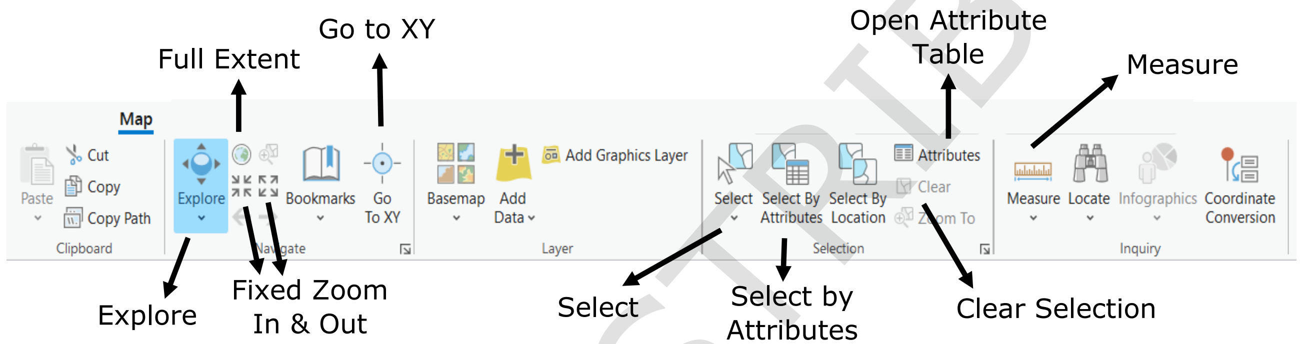
F A **layer** is a displayed set of geographic features with the same type of geometry (point, line, polygon) or a raster (image).

Ribbons

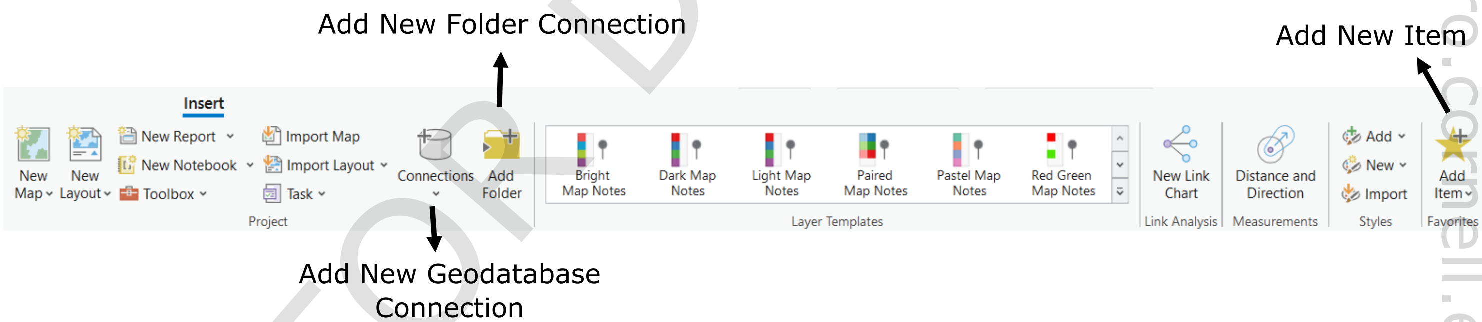
- *Quick Access Toolbar (can add any buttons to customize)*



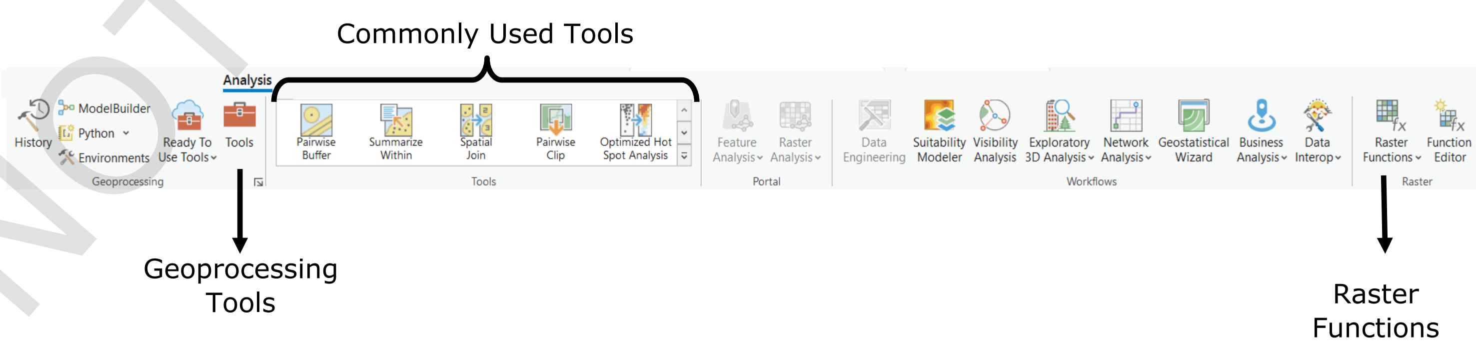
- *Map Ribbon*



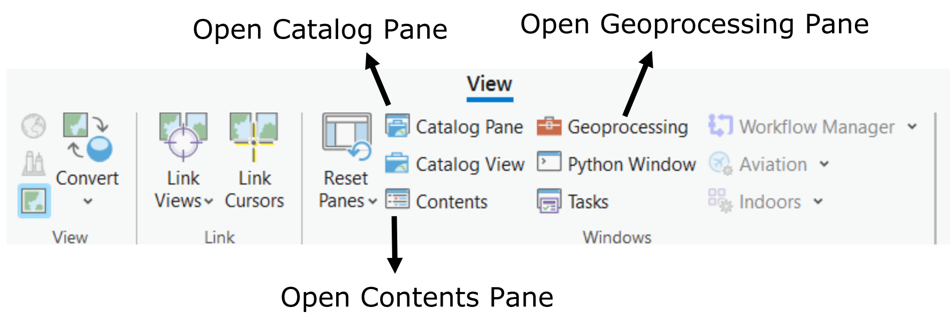
- *Insert Ribbon*



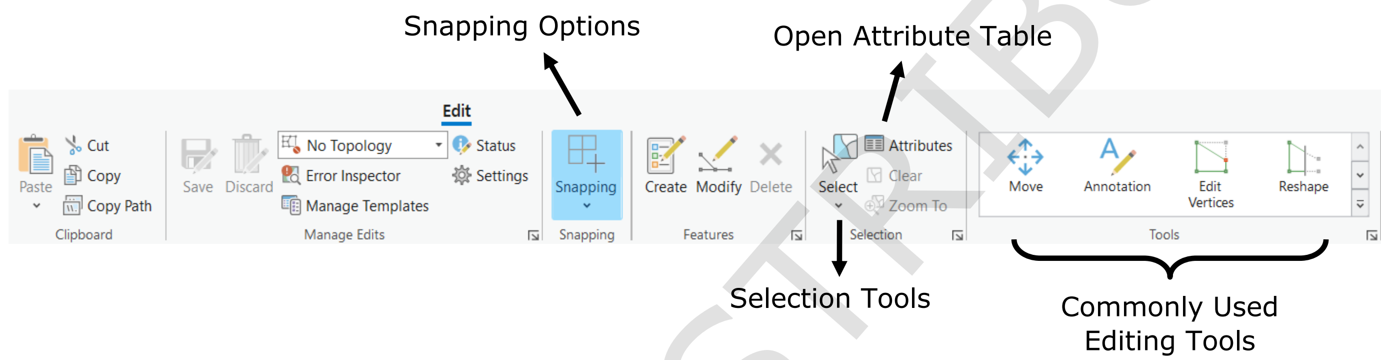
- *Analysis Ribbon*



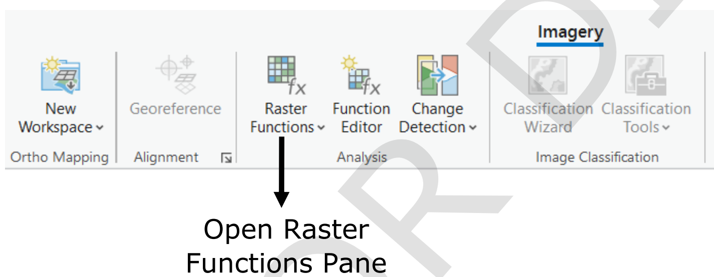
- *View Ribbon*



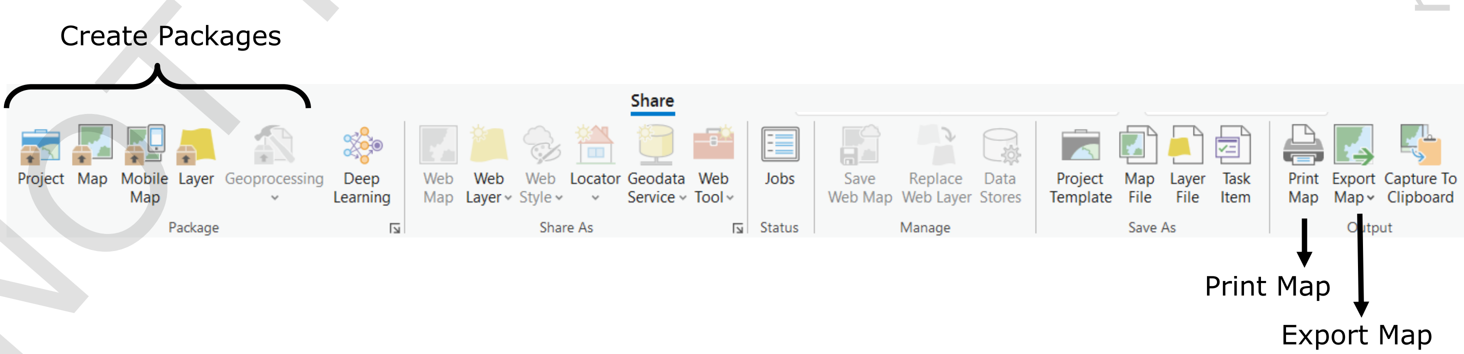
- *Edit Ribbon*



- *Imagery Ribbon*



- *Share Ribbon*



Glossary

Attribute Table: A table that displays non-spatial information about features in a feature class, such as feature ID numbers, length, and area. More columns, called fields, can be added to associate additional data with features. Some rasters can also have attribute tables that display frequency values for each cell value, but the Statistics and Histogram raster function must be performed in order to create this table.

Average Nearest Neighbor: A geoprocessing tool that calculates the nearest neighbor index from the average distance between each feature and its next neighboring feature.

Basemap: A raster depicting background reference information on top of which other layers, either from rasters or feature classes, are placed.

Bookmark: This saves the zoom and position of a Map's current display in the View pane to easily return to it later.

Buffer: A geoprocessing tool for creating a zone around a feature a specified distance from the edge of the feature. The output is a polygon feature class. If the distance is negative, it creates a smaller zone within each feature.

Cell Size: The spatial resolution of a raster, i.e. the physical size of a pixel on the surface being viewed.

Construction Tools: These specify the method by which the user will sketch or edit a feature.

Dissolve: An option on some geoprocessing tools to merge the output polygons into fewer polygons or a single polygon.

Favorites: Coordinate systems, geodatabases, toolboxes, and folder connections can be designated as favorites to make them easier to locate for future Projects. There is also an option to automatically add these components to all new Projects. Favorites are specific to your ArcGIS license and will not show up when a different user logs into ArcGIS on that same computer.

Feature: An individual point, line, or polygon, or a specific group of lines or polygons. Each feature will have one row in the attribute table of a feature class.

Feature Class: A vector data file used specifically by ArcGIS to store features and attributes associated with them. A feature class has a defined geometry (point, line, or polygon) that cannot be changed, and only features with that geometry can be in that feature class. They are analogous to shapefiles used throughout GIS platforms, but with added features for use with ArcGIS tools and capable of holding more ancillary data for features than shapefiles. Shapefiles can be imported as feature classes, and feature classes can be exported as shapefiles. However, the export process will delete any ancillary data not supported in shapefiles.

Feature Dataset: A collection of feature classes stored together that share the same coordinate systems, extent area, and theme. Unlike individual feature classes, feature datasets do not have a set geometry and can contain point, line, and polygon feature classes. Different geometries can be stored in the dame dataset.

Field: A column in an attribute table which associates a value for a property, or other type of information such as a word, thumbnail image, or hyperlink, for the features in a feature class.

Folder Connection: Any folder can be added to the Folders of a Project to make it easier to access the data being used for that Project. These are viewable in the Catalog pane. Folder connections can be added to your Favorites or designated to be added to all new Projects.

Geodatabase: An ArcGIS specific database that contains a file structure for organizing data such as feature classes, rasters, charts, and tables. They can only be viewed within ArcGIS, as their schema and file types are not recognized by other data viewers such as Windows File Explorer or Mac Finder.

Hillshade: A raster function that uses elevation data to simulate the terrain with shadows generated for a light source specified in the function parameters.

Intersect: A geoprocessing tool for creating a new feature class from two or more existing polygon feature classes, which creates polygon features based on the areas where features in the existing feature classes overlap and eliminates portions of features that do not overlap. Attributes from all input features are included in the attribute table of the output feature class.

Layer: An element of a Map that displays data from a feature class or raster. It contains information on how to graphically display the data (see **Symbology**) and which data from the source to display (see **Selection** and **Query**). Layers appear in the Contents pane and can be copied and pasted into other Maps. They can be saved as individual Layer files that can be added to Maps in other Projects, but cannot be opened in ArcMap. Layer files do not contain any of the source data they display (see **Package**).

Layout: An element of a Project that is used to create a final publishable map product, displaying one or more Maps and graphical elements such as north arrows, scale bars, and legends. Layouts are listed in the Catalog pane and can be opened, viewed, and edited in the View pane. Layouts can be exported in formats such as pdf and image files.

Map: An element of a Project used for viewing, organizing, editing, and analyzing data visually. Maps contain layers, each displaying spatial data. They are listed in the Catalog pane and can be opened, viewed, and edited in the View pane. Maps can be saved in individual files that can be added to other Projects, but cannot be opened in ArcMap. Map files do not contain any of the source data they display (see **Package**).

Overlay: A set of geoprocessing tools, such as Intersect and Union, that create new feature classes from the overlapping and combining of existing features.

Package: A file that contains information on how data are displayed and organized, as well as all the source data. Layers, Maps, and Projects can all be saved as packages.

Project: A file that contains all information on how data are displayed and organized. Elements of Projects include Maps, Layouts, tables, charts, geodatabases, folder connections, favorites, toolboxes, and processing logs. Projects do not contain any of the source data that is being displayed and organized (see **Package**).

Query: An expression used to specify a subset of features that meet given criteria. Queries are used in Select By Attributes (see **Selection**). They are also used in Display Filters, which are part of Symbology, and in Definition Query, which is found on the Data tab. Display Filters will only show the defined subset of features in the Layer, but all features will be processed when the Layer is analyzed. Definition Queries will restrict the data accessed by the Layer so that only the defined subset will be processed in analysis.

Quick Access Toolbar: The buttons along the top left of the ArcGIS Pro window. In addition to the default buttons, any other buttons can be added by right-clicking on a button on a tab and selecting Add to Quick Access Toolbar.

Raster: An array of cells (pixels in image files), each possessing a numerical value and a spatial coordinate. Image files of all common types, as well as some planetary data specific formats, can be loaded into a Map. If an image lacks any coordinate system, spatial data can be added through georeferencing (identifying matching features) to existing rasters covering the same geographic area.

Selection: A subset of features in a feature class isolated for display, organization, or analysis. They are highlighted in cyan in the Map and in the feature class' attribute table. Selections can be created using a query, with Select By Attributes, based on a spatial relationship to other features with Select By Location, or by hand using the Select tool on the Map tab.

Sketching: This describes the process of creating and editing new features by hand using construction tools in Create Features or Modify Features on the Edit tab.

Snapping: An optional setting for editing found on the Edit tab that allows for exact matching of a vertex's position to an existing part of a feature, such as a vertex or edge, when the mouse is moved to within a specified distance, or tolerance, of the object. Different types of snapping can be turned on or off, and the tolerance can be adjusted. Snapping can also be turned completely off, or temporarily suspended by holding down the space bar.

Streaming: A construction tool for sketching lines and polygons that automatically adds vertices as the cursor is moved. Setting the stream tolerance to a specific distance will control how frequently vertices are added, though they may be added less frequently if the cursor is moving in a roughly straight line.

Symbology: This controls how the data are displayed in a Map, such as color, icon size, line width, and stretch properties. It is accessed in a pane on the right side of the ArcGIS Pro window. Symbology information is stored in Projects, Maps, and Layers.