Complete Training

This step in the digitization of localities procedure requires the use of a georeferencing calculator and/or GEOLocate, which are online tools that are not intuitive to use at first. Thus, before starting, it might be wise to become familiar with some of the basics of these online tools through a series of helpful online videos made by the iDigBio Georeferencing Working Group. These videos can be viewed from this link: https://vimeo.com/showcase/2163673. Videos to watch from this site include:

- Using Paper Maps: Named Places
    - Overview of the process used to georeference a locality using a paper map and shows some of the basics of how to use the MaNISNet Georeferencing Calculator
- Using GEOLocate: iDigBio GWG Workshop and/or GEOLocate Basics
    - Overview of how to use GEOLocate, the GEOLocate Basics video is a bit fast, while the other one is slower and goes over more examples.
- Batch Processing Using GEOLocate
    - Overview of how to batch process multiple localities in GEOLocate

Below are some recommended videos on the iDigBio Georeferencing Working Group site linked above that might clarify some of the basics of georeferencing:

- Collaboration to Automation
    - Goes over the basics of georeferencing and why we georeference localities in the first place.
- Point-Radius Method and Best Practices
    - Goes over why we use the point-radius method for georeferencing our localities.
- Introduction to GeoLocate Project
    - Goes over what GEOLocate is, how it's used, and some of the successful projects that used GEOLocate
- Geographical Concepts (2 versions, either version is fine)
    - Goes over the basics of what a map projection, datum, and coordinate system are.

Note that the above videos use the MaNISNet Georeferencing Calculator. Unfortunately, the MaNISNet Georeferencing Calculator has been down and unavailable since 2019. A replacement georeferencing calculator has been found from the Department of Computer Science and Applied Electronics (DIEA) at the National Center for Industrial and Technological Research in Antananarivo, Madagascar. The DIEA Georeferencing Calculator works the same way as the MaNISNet Georeferencing Calculator.

Lastly, there are a bunch of resources inside the Georeferencing Resources folder, located here W:\\Section Files\Collections Management\Localities, that go over the basics of georeferencing and why we do it, the best practices of georeferencing, the uses of georeferenced localities in research, and notes and other online resources that may help in the georeferencing process.

Here are the file paths (where to find them) for the various resources that are mentioned below:
- No Data Localities Excel Worksheet
  - W:\\Section Files\Collections Management\Localities
- Georeferenced Localities Excel Worksheet
  - W:\\Section Files\Collections Management\Localities
- Georeferencing Quick Reference Guide
  - W:\\Section Files\Collections Management\Localities\Georeferencing References\Best Practices
- Online Resources for Georeferencing PowerPoint
  - W:\\Section Files\Collections Management\Localities\Georeferencing References
- Vague Localities Excel Worksheet
  - W:\\Section Files\Collections Management\Localities

Step 1: Determine if a Locality is a No Data Locality

Pull all the documents for a locality out of the binder and read them over. Before georeferencing a locality, you need to determine if the locality is a no data locality. No data localities were created to serve two purposes, 1) to assign a locality number to a specimen that has no locality information at all and 2) to assign a locality number to a specimen that just needs to get into the database, regardless of whether it has locality data or not. No data localities are usually marked with the words "No Data" or "ND" somewhere in the locality name or additional information fields. If the words "No Data" or "ND" are not found, then usually you can tell you have a no data locality simply by the total lack of geographical information, such as no country, state, county, or city information, no coordinates, no PLSS information, etc. Note that localities that only have a country, state, or county listed on the form can still be georeferenced.

If you find one of these, then this locality cannot be georeferenced, as there are no data to georeference the locality. Make sure to write this locality down on the No Data Localities Excel Worksheet. Then skip ahead to the filing localities step of the digitization of localities procedure (Step 4_Filing Localities.docx). Otherwise, if your locality is not a no data locality proceed to Step 2 below.

Step 2: Georeferencing Localities

Now begins the fun part of georeferencing a locality. Depending on what kind of data is found on the locality form will determine how you georeference the locality. If the form has a set of geographic coordinates, such as latitude-longitude coordinates (Lat-Long) or Universal Transverse Mercator coordinates (UTM), then follow the procedure under "Option 1: Georeferencing Localities with Geographic Coordinates". If the form does not have a set of geographic coordinates but does have a set of Public Land Survey System (PLSS) information (township, range, section), then follow the procedure under "Option 2: Georeferencing Localities with PLSS Information". If the form does not have a set of geographic coordinates nor any PLSS information but does have some other textural description of the locality (see below for examples), then follow the procedure under "Option 3: Georeferencing Localities with a Locality Description".

Please note that you only have to do one of these options to perform the georeference, not all three. Note that these procedures were patterned off the procedures in the Georeferencing Quick Reference Guide.

Option 1: Georeferencing Localities with Geographic Coordinates
Part A – Determine Original Geographic Coordinate Set

Geographic coordinates come in a variety of types, but the two most common ones you will see are UTM coordinates and Lat-Long coordinates. UTM coordinates are simple to recognize, as they are recorded as a set of meters (e.g. mN and mE). UTM coordinates also come with a zone designation, which tells you which UTM zone the UTM coordinates were collected in. Lat-Long coordinates are also simple to recognize; however, they may come in three different formats, decimal degrees, degrees decimal minutes, and degrees minutes decimal seconds. Degrees are usually notated by the degree symbol (^{o}), minutes are notated by a single quotation mark ('), and seconds are notated by a double quotation mark ("). Here is an example of what the different geographic coordinates will look like:

UTM: Zone 13T, 4576079 mN, 271687 mE
Lat-Long Decimal Degrees: 41.30387^o N, 107.72716^o W
Lat-Long Degrees Decimal Minutes: 41° 18.2322' N, 107° 43.6296' W
Lat-Long Degrees Minutes Decimal Seconds: 41° 18' 13.932" N, 107° 43' 37.7754" W

Note that the UTM zone designation may be written with a cardinal direction at the end to indicate which hemisphere, the northern or southern (e.g. N or S), the coordinate was collected in. Or the UTM zone designation may be written with its latitude band letter at the end (e.g. A-Z). UTM latitude bands are 20° latitude chunks that are lettered from the south pole to the north pole. In this case, latitude band letters A and B represent the south pole region, C-M represent the rest of the southern hemisphere, N-X represent the rest of the northern hemisphere, and Y and Z represent the north pole region. For example, a single coordinate found in Wyoming could look like this:

With Latitude Band Letter: Zone 13T, 4619361 mN, 290161 mE
OR
With Cardinal Direction: Zone 13N, 4619361 mN, 290161 mE

Note that Lat-Long coordinates may be written with either their cardinal direction at the end (e.g. N, S, E, or W) or may have a negative symbol at the front of the coordinate (e.g. -). The negative symbol is used the same way as the cardinal direction in that it indicates which hemisphere the coordinate is in. If the latitude coordinate is negative, then the coordinate is in the southern hemisphere. If the longitude coordinate is negative, then the coordinate in the western hemisphere. For example, a single coordinate found in Wyoming could look like this:

With Cardinal Direction: 44° 57' 51.9948" N, 108° 20' 16.993" W
OR
With Negative Symbol: 44° 57' 51.9948", -108° 20' 16.993"

Along with the geographic coordinates, take note of the datum that the geographic coordinates were taken in. Common ones that you will see include the North American Datum of 1927 (NAD27), the North American Datum of 1983 (NAD83), and the World Geodetic System of 1984 (WGS84).

To georeference a locality with geographic coordinates, it is best to use the original set of geographic coordinates that were taken by the collector at the locality. Unfortunately, some localities have multiple sets of geographic coordinates written on the documents. This causes confusion, as it is sometimes unclear which geographic coordinate set is the original coordinates taken for the locality. If there is more than one set of geographic coordinates on the locality documents, then try one of the following ways to see if the original set can be determined:

- Read over all the documents in the locality, especially any collection tags, to see if the original set of coordinates is mentioned.
- If available, consult the original collector or the field notes of the original collector.
- The set that has the datum circled is usually the original.

Other points to take into consideration when determining the original set of coordinates. Keep in mind that some of these points might be accurate and that you might be looking at a transcription/data entry error:

- There is a total of 60 UTM zones. Thus, if a locality has a zone designation higher than 60, then those coordinates are most likely not the original set.
- Does the UTM zone designation make sense for where this locality is supposedly located at? For example, if the locality is supposedly located in Wyoming and the UTM zone designation for the locality is 26T, which is a zone that does not cover Wyoming, then those coordinates are most likely not the original set.
- Does the cardinal direction or negative sign on the Lat-Long coordinates make sense for where this locality is supposedly located at? For example, if the locality is supposedly located in Wyoming and the Lat-Long coordinates has a latitude with an S at the end and a longitude with a – symbol, which is a place probably somewhere in South America, then those coordinates are most likely not the original set.

If the original set can't be determined, then make the Lat-Long coordinates that are written on the documents the original set. If there are multiple sets of Lat-Long coordinates on the documents, then choose the coordinates that are in decimal degrees. If there are no Lat-Long coordinates, then pick the UTM coordinates as the original set.

It is also sometimes unclear which datum the original set of coordinates were collected in. Furthermore, on some locality documents the datum has been recorded as NAD84, which doesn't exist. If you have picked a set geographic coordinates to use for the georeference but you are unsure of the datum, use the Convert Geographic Units website hosted by Montana State University (http://www.rcn.montana.edu/resources/converter.aspx) to figure out the datum. To use the site:

- First select "WGS 84" from the Select Map Datum drop down list, then:

- o If the coordinates are in Lat-Long decimal degrees format, enter the decimal degrees into the "Decimal Degrees" boxes. Don't forget to include a negative sign (-) in front of the latitude if the locality is in the southern hemisphere AND don't forget to include a negative sign (-) in front of the longitude if the locality is in the western hemisphere.
    - ▪ Click the "Convert Decimal Degrees" button.
    - ▪ View the results on the map to the right.
        - • If the map on the right seems to match the map that is included in the locality documents, then the datum for the coordinates is WGS84.
        - • If the map on the right does not match the map that is included in the locality documents, then the coordinates are in a different datum.
            - o Start the process over by clicking the "Reset Form" button. For this next time, select "NAD 83" from the Select Map Datum drop down list to see if the coordinates are in NAD83 OR select "North American 1927" from the Select Map Datum drop down list to see if the coordinates are in NAD27.
- o If the coordinates are in Lat-Long degrees decimal minutes format, then use the "Degrees, Minutes, Seconds" boxes. Enter the degrees into the first box and the decimal minutes into the second box. Leave the third box blank. In the fourth box, indicate whether this latitude coordinate is in the northern hemisphere (N) or southern hemisphere (S) and indicate whether this longitude coordinate is in the eastern hemisphere (E) or the western hemisphere (W).
    - ▪ Click the "Convert Degrees, Minutes, Seconds" button.
    - ▪ View the results on the map to the right.
        - • If the map on the right seems to match the map that is included in the locality documents, then the datum for the coordinates is WGS84.
        - • If the map on the right does not match the map that is included in the locality documents, then the coordinates are in a different datum.
            - o Start the process over by clicking the "Reset Form" button. For this next time, select "NAD 83" from the Select Map Datum drop down list to see if the coordinates are in NAD83 OR select "North American 1927" from the Select Map Datum drop down list to see if the coordinates are in NAD27.
- o If the coordinates are in Lat-Long degrees minutes decimal seconds format, then use the "Degrees, Minutes, Seconds" boxes. Enter the degrees into the first box, the minutes into the second box, and the decimal seconds into the third box. In the fourth box, indicate whether this latitude coordinate is in the northern

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hemisphere (N) or southern hemisphere (S) and indicate whether this longitude coordinate is in the eastern hemisphere (E) or the western hemisphere (W).

- Click the "Convert Degrees, Minutes, Seconds" button.
- View the results on the map to the right.
  - If the map on the right seems to match the map that is included in the locality documents, then the datum for the coordinates is WGS84.
  - If the map to the right does not match the map that is included in the locality documents, then the coordinates are in a different datum.
    - Start the process over by clicking the "Reset Form" button. For this next time, select "NAD 83" from the Select Map Datum drop down list to see if the coordinates are in NAD83 OR select "North American 1927" from the Select Map Datum drop down list to see if the coordinates are in NAD27.
- If the coordinates are in UTM format, then use the "Standard UTM" boxes. Enter the zone number into the first box. Indicate whether these UTM coordinates were collected in the northern hemisphere (N) or southern hemisphere (S). Enter the easting (mN) and northing (mN) into the last two boxes.
  - Click the "Convert Standard UTM" button.
  - View the results on the map to the right.
    - If the map on the right seems to match the map that is included in the locality documents, then the datum for the coordinates is WGS84.
    - If the map to the right does not match the map that is included in the locality documents, then the coordinates are in a different datum.
      - Start the process over by clicking the "Reset Form" button. For this next time, select "NAD 83" from the Select Map Datum drop down list to see if the coordinates are in NAD83 OR select "North American 1927" from the Select Map Datum drop down list to see if the coordinates are in NAD27.

If, after using the above procedure, you are still unable to determine the datum the original set of coordinates were collected in, then the datum is indeterminate.

Part B – Convert Coordinates into Lat-Long format in WGS84

Once the original set of geographic coordinates has been established, then the next step will be to make sure the coordinates are in a Lat-Long format and are in WGS84. There are essentially two reasons why you must do this. First, the georeferencing calculator used in Part C below does not accept UTM coordinates, but it can accept Lat-Long coordinates in decimal degrees, degrees decimal minutes, or degrees minutes decimal seconds. Second, the

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Paleontology Section has localities all over the World and not just in North America. Thus, in order to accurately map all the localities in a single ArcGIS Pro geodatabase, which will be used in the next step of the digitization of localities procedure (Step 3_Mapping Localities.docx), the datum for the geodatabase has been set to WGS84.

So, what needs to happen depends on the original set of geographic coordinates:

If the Original Set of Geographic Coordinates are in a	Then You Will Need to
Lat-Long Format and in WGS84	Do Nothing. Skip this step and move on to Part C below
Lat-Long Format and not in WGS84	Convert the coordinates into WGS84
Lat-Long Format and datum indeterminate	Do Nothing. Skip this step and move on to Part C below
UTM Format and in WGS84	Convert the coordinates into a Lat-Long format (decimal degrees preferable)
UTM Format and not in WGS84	Convert the coordinates into a Lat-Long format (decimal degrees preferable) and into WGS84
UTM Format and datum indeterminate	Convert the coordinates into a Lat-Long format (decimal degrees preferable)

There are several websites out there that can convert your coordinates into a Lat-Long format and/or WGS84 for you. Try looking for some under the "Tools" menu of www.georeferencing.org. If none of those work, try searching for "convert coordinates from [original format] to Latitude-Longitude" or "convert coordinates from [original datum] to wgs84" on the internet and pick one of the top hits. Make sure to follow the websites instructions carefully so that you get the desired result. Note: for converting those coordinates in UTM format and not in WGS84, it is wise to covert the coordinates into WGS84 first before converting them into a Lat-Long format. This is because most of the Lat-Long format conversion sites assume your UTM coordinates are already in WGS84 when you perform the conversion.

Part C – Using the Georeferencing Calculator

Use the DIEA Georeferencing Calculator (http://41.242.99.131/sigcalc/source/gci2.html) to perform this part. For each of the boxes, set the following parameters:

- Calculation Type: Error only – enter Lat/Long for the actual locality
- Locality Type: Coordinates only (e.g., 27°34'23.4" N, 121°56'42.3" W)
- Coordinate Source:
  - What is selected for this box depends on what is written on or included in the locality documentation OR your personal knowledge of the locality or the collector. These options are listed in order of preference, but only one option may be chosen.
    - Select "GPS" from the list if the locality documents specifically state the coordinates were collected by a GPS unit OR if you know that the coordinates were collected by a GPS.
    - Select "Google Earth/Maps" from the list if the locality has a map document that is a printout/screen capture from Google Earth/Maps.

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- Select "USGS map: 1:24000" from this list if the locality has a map document that is a photocopy of a topographic map. This means that the coordinates were most likely collected off a 7.5 Minute USGS Quad Map, which has a representative fraction scale of 1:24000.
- Select "other map: (representative fraction scale)" from this list if the locality has a map document that is not a photocopy of a topographic map or a printout/screen capture from Google Earth/Maps AND it has a representative fraction scale written on it (e.g. 1:24000, 1:20000, etc.). In this case, make sure to select the correct other map: (representative fraction scale) option, where (representative fraction scale) is the representative fraction scale that is written on the map (e.g. other map: 1:24000, or other map: 1:20000).
- Select "gazetter" from the list if the locality has a map document that is not a photocopy of a topographic map or a printout/screen capture from Google Earth/Maps AND it does not have a representative fraction scale written on it (e.g. 1:24000, 1:20000, etc.).
- Select "locality description" from the list if the locality does not have a map document, and it is impossible to tell how the coordinates were obtained.
- Coordinate System:
  - What is selected for this box will depend on which Lat-Long format the coordinates are in:
    - Select "decimal degrees" from the list if the Lat-Long coordinates or the converted UTM coordinates are in decimal degrees.
    - Select "degrees decimal minutes" from the list if the Lat-Long coordinates of the converted UTM coordinates are in degrees decimal minutes.
    - Select "degrees minutes seconds" from the list if the Lat-Long coordinates of the converted UTM coordinates are in degrees minutes decimal seconds.
- Latitude:
  - Enter the latitude into this (these) box(es)
    - If the "decimal degrees" option was selected for the Coordinate System, then enter the decimal degrees in the box. Don't forget to include a negative sign (-) in front of the decimal degrees if the locality is in the southern hemisphere.
    - If the "degrees decimal minutes" option was selected for the Coordinate System, then the degrees should be entered into the first box and the decimal minutes should be entered into the second box. In the third box, indicate whether this coordinate is in the northern hemisphere (N) or the southern hemisphere (S).
    - If the "degrees minutes seconds" option was selected for the Coordinate System, then the degrees should be entered into the first box, the minutes should be entered into the second box, and the decimal seconds should be entered into the third box. In the fourth box, indicate whether

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this coordinate is in the northern hemisphere (N) or the southern hemisphere (S).

- Longitude:
  - Enter the longitude into this (these) box(es)
    - If the "decimal degrees" option was selected for the Coordinate System, then enter the decimal degrees in the box. Don't forget to include a negative sign (-) in front of the decimal degrees if the locality is in the western hemisphere.
    - If the "degrees decimal minutes" option was selected for the Coordinate System, then the degrees should be entered into the first box and the decimal minutes should be entered into the second box. In the third box, indicate whether this coordinate is in the eastern hemisphere (E) or the western hemisphere (W).
    - If the "degrees minutes seconds" option was selected for the Coordinate System, then the degrees should be entered into the first box, the minutes should be entered into the second box, and the decimal seconds should be entered into the third box. In the fourth box, indicate whether this coordinate is in the eastern hemisphere (E) or the western hemisphere (W).
- Datum:
  - What is selected for this box will depend on a couple of things:
    - Select "(WGS84) World Geodetic System 1984" if the original set of coordinates are in WGS84 AND you didn't have to convert them in Part B above.
    - Select "(WGS84) World Geodetic System 1984" if the original set of coordinates were not in WGS84 AND you did have to convert them in Part B above.
    - Select "datum not recorded" if the datum of the original set of coordinates was indeterminate, as determined in Part A above.
- Coordinate Precision:
  - What is selected for this box will depend on how precise, or how many significant digits, your latitude and longitude coordinates have:
    - If the "decimal degrees" option was selected for the Coordinate System, then
      - Select "nearest degree" from this list if the degree coordinate is a single number with no numbers after the decimal point (e.g. 27°).
      - Select "0.1 degrees" from this list if the degree coordinate has one number after the decimal point (e.g. 27.1°).
      - Select "0.01 degrees" from this list if the degree coordinate has two numbers after the decimal point (e.g. 27.12°).
      - Select "0.001 degrees" from this list if the degree coordinate has three numbers after the decimal point (e.g. 27.123°).
      - Select "0.0001 degrees" from this list if the degree coordinate has four numbers after the decimal point (e.g. 27.1234°).

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- Select "0.00001 degrees" from this list if the degree coordinate has five numbers after the decimal point (e.g. 27.12345^o).
  - If the "degrees decimal minutes" option was selected for the Coordinate System, then
    - Select "nearest minute" from this list if the minute coordinate is a single number with no numbers after the decimal point (e.g. 27° 1').
    - Select "nearest 0.1 minutes" from this list if the minute coordinate has a single number after the decimal point (e.g. 27° 1.2').
    - Select "nearest 0.01 minutes" from this list if the minute coordinate has two numbers after the decimal point (e.g. 27° 1.23').
    - Select "nearest 0.001 minutes" from this list if the minute coordinate has three numbers after the decimal point (e.g. 27° 1.234').
  - If the "degrees minutes seconds" option was selected for the Coordinate System, then
    - Select "nearest second" from this list if the second coordinate is a single number with no numbers after the decimal point (e.g. 27° 1' 2").
    - Select "nearest 0.1 seconds" from this list if the second coordinate has a single number after the decimal point (e.g. 27° 1' 2.3").
    - Select "nearest 0.01 seconds" from this list if the second coordinate has two numbers after the decimal point (e.g. 27° 1' 2.34").
  - Note: if one coordinate is less precise then another, then the less precise coordinate sets the coordinate precision. For example, if the latitude is 27.123^o and the longitude is -108.12345^o, then the latitude will set the coordinate precision at 0.001 degrees, as it is the less precise coordinate.
  - Note: if one or both coordinates have more significant digits then any of the options, then the lowest option should be selected. For example, if a coordinate is 27.123456789^o, then the 0.00001 degrees option should be selected, as that is the lowest option available.
- Measurement Error:
  - What is entered into this box will depend on the coordinate source:
    - If the "GPS" option was selected for the Coordinate Source, then enter the GPS accuracy number into this box. If necessary, convert the GPS accuracy into meters before entering the number into this box. If no GPS accuracy is given
      - AND the original geographic coordinates are in a Lat-Long format, then enter 30 for those localities recorded between now and May 2000 OR 100 for those localities recorded before May 2000.
      - AND the original geographic coordinates are in a UTM format, then enter 1 into this box.
    - For every other option,

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- For Lat-Long coordinates leave the box empty.
- For UTM coordinates enter 1 into this box.
- Distance Units: m

Once all the information has been entered into the georeferencing calculator, click the "Calculate" button near the bottom right side of the page. The results of the georeference will appear in the gray boxes to the left of the "Calculate" button. Move to "Step 3 – Documenting Your Progress" before georeferencing any additional localities.

Option 2: Georeferencing Localities with Public Land Survey System (PLSS) Information
Part A – Verify PLSS Information
PLSS information comes in several pieces, including a township designation, a range designation, a section number, and section quarters. The township designation will be a two-digit number with a cardinal direction at the end to indicate if the township is either north or south (e.g. N or S) of the baseline used for this PLSS grid. The range designation will be a three-digit number with a cardinal direction at the end to indicate if the range is either east or west (e.g. E or W) of the principal meridian used for this PLSS grid. The section number will be a two-digit number and is an indication of which section of the 36 section squares in a township and range set the locality is located in.

Sections are then subdivided into quarters in order to provide a more precise location for the locality within the section. Each section is subdivided by drawing a cross through the middle of the section. Each part of the cross is then labeled as being the northeast (NE), southeast (SE), northwest (NW), or southwest (SW) part (or quarter) of the section. Each of those parts is then subdivided again by drawing a cross through the middle of that part. Here again, each part of the cross is then labeled as being the northeast (NE), southeast (SE), northwest (NW), or southwest (SW) part (or quarter-quarter) of the larger original part (or quarter) of the section. This can go on multiple times, but usually (and what is deemed standard practice) the subdivision of sections into parts (or quarters) only happens three times. The section quarters in PLSS information will be written as a set of cardinal directions (e.g. NE, SE, NW, or SW) separated by backslashes to indicate which quarter, quarter-quarter, or quarter-quarter-quarter of the section the locality is located in. The section quarters set is written so that the smallest quarter (or quarter-quarter-quarter) is written first.

Here is an example of what PLSS Information will look like:

01S, 097W, 06, NE/SE/NW

In the above example,
- "01S" is the township designation and in this case the locality is in the 1st township south of the baseline used for this PLSS grid.
- "097W" is the range designation and in this case the locality is in the 97th range west of the principal meridian used for this PLSS grid.
- "06" is the section number and in this case the locality is in the 6th section of the township 01S and range 097W set.

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- "NE/SE/NW" are the section quarters and in this case the locality is in the NE quarter of the SE quarter of the NW quarter of section 6.

Take note that there are a total of 36 sections for a given township and range set. Thus, if a locality has a section number larger than 36, then the PLSS information may be incorrect and you should consider not using it to georeference the locality. Along the same lines, if the township designation has an east or west cardinal direction and/or the range designation has a north or south cardinal direction, then the PLSS information may be incorrect and a different georeferencing method should be used.

In some cases, you might see the section quarters written as E ½ or SW ½ or only contain one or two quarters instead of three. This is usually not a mistake and an indication that the locality is a larger area rather than a single point. In this example, E ½ means that the locality is in the entire eastern half of that section. Whereas SW ½ indicates the locality is in half of the southwestern quarter of that section, although which half of the southwestern quarter is questionable. Point is, localities with oddly written section quarters can still be georeferenced. Additionally, the order that the section quarters were written on the form may not be the same for each locality. It is standard practice to list the smaller quarter first moving up to the largest quarter. However, some localities may have the largest quarter listed first. Thus, proceed with caution when using the section quarter data for georeferencing.

Part B - Using Earth Point

Once you have verified that the PLSS information can be used for georeferencing, then the next step will be to obtain a gird representation of the PLSS township and range set that can be used in Part C. Use Earth Point's Township and Range – Search By Description website (http://www.earthpoint.us/TownshipsSearchByDescription.aspx) to generate this grid. To use the site:

- Select the state the PLSS information is located in from the State drop down list
- Select "(any)" from the Principal Meridian drop down list
- Select the township designation from the Township drop down list. Make sure you have selected the correct township by checking the cardinal direction (e.g. N or S) that comes after the number.
- Select the range designation from the Range drop down list. Make sure you have selected the correct range by checking the cardinal direction (e.g. E or W) that comes after the number.
- If applicable, select the section number from the Section drop down list.

Once all the information has been entered into Earth Point, click the "Fly To On Google Earth" button. This then downloads a KML file containing the grid for the township and range set entered into Earth Point.

Part C - Using Google Earth

Once the KML file has downloaded, the next step will be to obtain a set of Lat-Long coordinates for the centroid, or center, of the PLSS information and obtain an error

measurement. Both pieces of information will be inserted into the georeferencing calculator used in Part D. To get this information:

- Open the KML file in Google Earth. Here is what you may or may not see on the grid:
    - The orange square is the outline of the entire township and range set. The orange dot is the centroid, or center, of the orange square.
    - The purple square is the outline of the section within that township and range set. The purple dot is the centroid, or center, of the purple square.
    - The green squares are the outlines of the first quarter of the section. The green dots are the centroids, or centers, of those green squares.
- To obtain the needed Lat-Long coordinates will depend on how much data is available on the locality documents and what the grid on the downloaded KML file looks like.
    - If the locality only has township and range data, then click on the orange dot to bring up a pop-up window in Google Earth. In this pop-up, look for "Centroid" under the Calculated Values heading. The numbers written to the right of "Centroid" are Lat-Long coordinates for this point, where the first number is the latitude and the second number is the longitude. Write down these coordinates.
    - If the locality has section data, then click on the purple dot to bring up a pop-up window in Google Earth. In this pop-up, look for "Centroid" under the Calculated Values heading. The numbers written to the right of "Centroid" are Lat-Long coordinates for this point, where the first number is the latitude and the second number is the longitude. Write down these coordinates.
    - If the locality has section quarter data
        - and green dots HAVE BEEN plotted on the grid, then determine which green dot should be clicked. Remember that the green dots represent the first quarter of the section. Thus, if the first quarter of the section is NW, then the NW green dot should be clicked. Once you have clicked on the appropriate green dot, a pop-up window will open in Google Earth. In this pop-up, look for "Centroid" under the Calculated Values heading. The numbers written to the right of "Centroid" are Lat-Long coordinates for this point, where the first number is the latitude and the second number is the longitude. Write down these coordinates.
        - and green dots HAVE NOT been plotted on the grid, then click on the purple dot to bring up a pop-up window in Google Earth. In this pop-up, look for "Centroid" under the Calculated Values heading. The numbers written to the right of "Centroid" are Lat-Long coordinates for this point, where the first number is the latitude and the second number is the longitude. Write down these coordinates.
        - Note: if you are confident you can determine where the center of a quarter section, quarter-quarter section, or quarter-quarter-quarter section is without the use of the green dots OR are able to determine where the center of an oddly written section quarter (e.g. E ½) is, then by all means attempt to obtain a Lat-Long coordinate, as that will provide a more accurate georeference. Otherwise, use the Lat-Long coordinates of the purple dot.

- To obtain the needed error measurement will also depend on how much data is available on the locality documents and what the grid on the downloaded KML file looks like.
    - Click on the "Show Ruler" button (looks like a ruler) near the top of the Google Earth application window to open the Ruler tool.
    - Inside the Ruler tool, make sure you are in the Line tab and change the Map Length units to meters.
    - If the locality only has township and range data, then using the Ruler tool, measure the distance (in meters) between the orange dot and one of the outside corners of the orange square. You may want to zoom in to these points to make sure you are making a precise measurement. Write down this measurement.
    - If the locality has section data, then using the Ruler tool, measure the distance (in meters) between the purple dot and one of the outside corners of the purple square. You may want to zoom in to these points to make sure you are making a precise measurement. Write down this measurement.
    - If the locality has section quarter data
        - and green dots HAVE BEEN plotted on the grid, then using the same green dot used to obtain the Lat-Long coordinates of the centroid use the Ruler tool to measure the distance (in meters) between the green dot and one of the outside corners of the green square. You may want to zoom in to these points to make sure you are making a precise measurement. Write down this measurement.
        - and green dots HAVE NOT been plotted on the grid, then using the Ruler tool measure the distance (in meters) between the purple dot and one of the outside corners of the purple square. You may want to zoom in to these points to make sure you are making a precise measurement. Write down this measurement.
        - Note: if you are confident you can determine where the center of a quarter section, quarter-quarter section, or quarter-quarter-quarter section is without the use of the green dots AND you can determine where the outside corners of that quarter section, quarter-quarter section, or quarter-quarter-quarter section is located, then by all means attempt to obtain an error measurement. Likewise, if you are confident you can determine where the center of an oddly written section quarter (e.g. E ½) is AND you can determine where the outside corners of that oddly written section quarter is located, then by all means attempt to obtain an error measurement. In either case, this error measurement will provide a more accurate georeference. Otherwise, take a measurement from the purple dot.

Part D – Using the Georeferencing Calculator

Use the DIEA Georeferencing Calculator (http://41.242.99.131/sigcalc/source/gci2.html) to perform this part. For each of the boxes, set the following parameters:
- Calculation Type: Error only – enter Lat/Long for the actual locality

- Locality Type: Coordinates only (e.g., 27°34'23.4" N, 121°56'42.3" W)
- Coordinate Source: Google Earth/Maps
- Coordinate System: decimal degrees
- Latitude:
  - Enter the latitude from Google Earth into this box.
- Longitude:
  - Enter the longitude from Google Earth into this box. Don't forget to include the negative sign (-) in front of the decimal degrees.
- Datum: (WGS84) World Geodetic System 1984
- Coordinate Precision:
  - What is selected for this box will depend on how precise, or how many significant digits, your latitude and longitude coordinates have:
    - Select "nearest degree" from this list if the degree coordinate is a single number with no numbers after the decimal point (e.g. 27°).
    - Select "0.1 degrees" from this list if the degree coordinate has one number after the decimal point (e.g. 27.1°).
    - Select "0.01 degrees" from this list if the degree coordinate has two numbers after the decimal point (e.g. 27.12°).
    - Select "0.001 degrees" from this list if the degree coordinate has three numbers after the decimal point (e.g. 27.123°).
    - Select "0.0001 degrees" from this list if the degree coordinate has four numbers after the decimal point (e.g. 27.1234°).
    - Select "0.00001 degrees" from this list if the degree coordinate has five numbers after the decimal point (e.g. 27.12345°).
  - Note: if one coordinate is less precise then another, then the less precise coordinate sets the coordinate precision. For example, if the latitude is 27.123° and the longitude is -108.12345°, then the latitude will set the coordinate precision at 0.001 degrees, as it is the less precise coordinate.
  - Note: if one or both coordinates have more significant digits then any of the options, then the lowest option should be selected. For example, if a coordinate is 27.123456789°, then the 0.00001 degrees option should be selected, as that is the lowest option available.
- Measurement Error:
  - Enter the error measurement (in meters) from Google Earth into this box
- Distance Units: m

Once all the information has been entered into the georeferencing calculator, click the "Calculate" button near the bottom right side of the page. The results of the georeference will appear in the gray boxes to the left of the "Calculate" button. Navigate to the downloads folder on your computer and delete the KML file that was downloaded from Earth Point. Lastly, move to "Step 3 – Documenting Your Progress" before georeferencing any additional localities.

Option 3: Georeferencing Localities with a Locality Description
Part A – Verify and Aggregate Locality Description

A locality description is some sort of textural string of words that is used to describe the location of a locality. A locality description may include several pieces of information, including but not limited to:

- A country, state, or county (e.g. Boulder County, CO)
- A city, town, or village (e.g. Boulder, CO)
- A street address (e.g. 1777 Broadway, Boulder, CO 80302)
- A name of a ranch or farm (e.g. Boulder Valley Ranch)
- A junction, intersection, or crossing (e.g. junction of Broadway and Pearl St.)
- A name of a cave (e.g. Mallory Cave)
- A name of a river, stream, road, or path (e.g. Boulder Creek)
- A mouth or headwaters of a river, confluence of waterways, or a trailhead (e.g. confluence of South Boulder Creek and Boulder Creek)
- Near a named place (e.g. vicinity of Boulder, CO)
- Between two places (e.g. between Longmont and Boulder, Colorado)
- Offset in a particular direction and distance from a named place (e.g. N of Boulder, 5 km outside Longmont, or 50 miles W of Louisville)
- Offset along a path from a named place (e.g. 7.9 mi N Boulder, on US 36)
- Offset in multiple directions and distances from a named place (e.g. 6 km N and 4 km W of Boulder)
- Offset along multiple paths from a named place (e.g. 1.5 mi E CO HWY 119 and 2 mi S CO HWY 157)

You can find locality description information in several places on the locality documents, including the Locality Name, Country, State, County, Land Owner, Map Name, and Additional Information fields. Aggregate as much locality description information as you can from the locality documents. The more detailed you are with the locality description the better the georeference. In other words, don't limit yourself to just one of the bullets above. Include as much information in the locality description as you can.

Unfortunately, there might be instances where a locality description is vague, and you can't quite figure out where the locality is located. This includes dubious localities where the description explicitly states that the location is in question. For example, the locality description states that it is "presumably in central Colorado". This also includes inaccurate localities where the description contains inconsistencies. For example, the locality description states that it is in "Denver, Wyoming". In these cases, do not georeference the locality as the data provided can't be used to figure out where the locality is. Instead, fill out a row for the locality in the Vague Localities Excel Worksheet. Note that it is important that you give a reason in the Reason field of the Vague Localities Excel Worksheet as to what makes this locality too vague to cause the locality to not be georeferenced. Otherwise, no one will understand why you listed it in the worksheet.

Lastly, you may run into localities that:

- Indicate they were collected from areas that overlap multiple times. For example, the locality states that it was collected at the "junction of S. Hampton Cir. and St. Johns Ave.

in Boulder", where S. Hampton Cir. and St. Johns Ave. intersect each other twice. So, which intersection is the locality referring to?
- Were collected from places that are related or have similar names. For example, the locality states that is was collected from "South Boulder". Is the locality referring to the southern part of Boulder the city, South Boulder the creek, or South Boulder the mountain?

If you run into one of these localities, consult the Georeferencing Quick Reference Guide, as it has several suggestions on how to navigate these types of localities. If none of those suggestions work, make sure to include the locality in the Vague Localities Excel Worksheet.

Part B – Using GEOLocate

Once you have verified and aggregated a locality description, then use GEOLocate (https://www.geo-locate.org/) to georeference the locality. To use the site:
- Click on the "Web Application" link at the top of the page.
- Click on the "Standard Client" link in the middle left of the page.
  - This will then load the GEOLocate user interface.
- Click on the "Options" Button.
  - Check or uncheck the various options that you feel will be helpful in georeferencing the locality. Usually leaving the default options is fine, however, some may find the error polygons a bit distracting and will uncheck the "Do Error Polygon" option.
  - Click the Close Button once finished
- Enter the locality description you aggregated in Part A above into the Locality String field.
- Select the country the locality is located in from the Country drop down list
- If applicable, enter the state/province/territory/canton/department/district/prefecture the locality is located in into the State field
- If applicable, enter the county/borough/department/district/division/region/unit the locality is located in into the County field

Once all the information has been entered into GEOLocate, click the "Georeference" button near the bottom left corner of the map. The results of the georeference will appear in the white box to the right of the fields where you entered data. You can also see the results by clicking the Results tab above the Options button. The results will also be mapped onto the map above.

Hopefully, only one dot is plotted in the results. If not, go over all the documents for the locality, especially the map document if there is one, and start deleting dots that are incorrect until you are left with one remaining. Turning on and off some of the base layers and overlays that GEOLocate provides can prove useful in figuring out if a dot is correct. Using the Measure tool, by clicking the button next to "Measure", comes in handy for those localities that are some distance away from a place or some distance along a path, where you can verify the distances using the Measure tool. If none of the results from GEOLocate are correct, feel free to move the

nearest dot to the correct location or click the button next to "Place marker" and insert a dot where the locality should be. In the end, make sure that there is only one dot before moving on.

Update the size of the uncertainty circle, if necessary. The uncertainty circle produced by GEOLocate should encompass all the areas where the locality might be. For instance, if a locality mentions that it was found somewhere along the base of a hill, then the uncertainty circle should encompass the entirety of the base of the hill. Here again, using the various base layers and overlays that GEOLocate provides and the Measure tool may come in handy in figuring out how large the uncertainty circle should be. If the locality is vague or doesn't have enough information for you to determine how large the uncertainty circle should be, then consult the Georeferencing Quick Reference Guide. Figure out what type of locality you have from the column on the left of the Guide and then use the suggestions listed under the Extent heading in the right column to figure out how large the uncertainty circle should be.

There might be cases where GEOLocate is unable to georeference a locality. There are usually two common reasons this occurs. One is that a name of a place is spelled wrong in the locality description. Using Google Maps (https://www.google.com/maps) can usually help in determining the correct spelling of a place. Make sure to not correct any of the locality documentation if you encounter an incorrect spelling. Leave the misspelled word on the locality documents but use the correct spelling in GEOLocate to georeference the locality. The second reason is the name of a place in the locality description is an old name or is a place that no longer exists on modern maps. In this case, you should consult a historical gazetteer or map to figure out where that place is. A useful source is the Geographic Names Information System (https://geonames.usgs.gov/apex/f?p=138:1:0:::::). Other sources can be found on the Online Resources for Georeferencing PowerPoint. Once you have located the old or historical place, then you can try georeferencing in GEOLocate again or move your dot and change the uncertainty radius as appropriate.

Once you believe you have the dot in the right place and the uncertainty circle is correct, move to "Step 3 – Documenting Your Progress" before georeferencing any additional localities.

If GEOLocate is still unable to georeference the locality then write the locality down in the Vague Localities Excel Worksheet. Note that it is important that you give a reason in the Reason field of the Vague Localities Excel Worksheet as to what makes this locality too vague to cause the locality to not be georeferenced. Otherwise, no one will understand why you listed it in the worksheet.

Step 3: Documenting Your Process

As you probably heard several times in the iDigBio Georeferencing Working Group videos, it is imperative that you write down how you arrived at your georeference. You don't have to write a book on what you did, but you should provide clear evidence on how you georeferenced the locality. Open the Georeferenced Localities Excel Worksheet and start a new row for the locality. See the table on the last pages of this document to figure out what to enter into each of the fields. Please note that it is recommended that you perform this step before georeferencing the next locality so that you don't forget what you did and enter the wrong information.

Field Name	Data Format	What to Enter into the Field
Locality_Number		The number for the locality
Locality_Name		The name of the locality
Verbatim_Datum		- If you used geographic coordinates to georeference the locality, - AND you know the original datum of the geographic coordinates (e.g. WGS84, NAD83, NAD27), then enter the original datum into this field. - AND you don't know the original datum of the geographic coordinates, then enter "datum indeterminate" into this field. - If you used GEOLocate or used PLSS information to georeference the locality, leave this field blank.
Verbatim_UTM_Zone		- If you used geographic coordinates to georeference the locality, - AND the original geographic coordinates were in UTMs, then enter the zone designation of those UTM coordinates into this field. - AND the original geographic coordinates were in a Lat-Long format, then leave this field blank. - If you used GEOLocate or used PLSS information to georeference the locality, leave this field blank.
Verbatim_Coordinates_y	Lat-Long coordinate should have degree symbol (°) and hemisphere designation (e.g. N or S). UTM coordinate should have mN written after it.	- If you used geographic coordinates to georeference the locality, then enter the original latitude or mN coordinate of the locality into this field. - If you used GEOLocate or used PLSS information to georeference the locality, leave this field blank.
Verbatim_Coordinates_x	Lat-Long coordinate should have degree symbol (°) and hemisphere designation (e.g. E or W). UTM coordinate should have mE written after it.	- If you used geographic coordinates to georeference the locality, then enter the original longitude or mE coordinate into this field. - If you used GEOLocate or used PLSS information to georeference the locality, leave this field blank.
Township	The township designation should have the cardinal direction (e.g. N or S) and leading 0s for single digit numbers (e.g. 03N, 25S)	- If you used PLSS information to georeference the locality, enter the township designation into this field. - If you used GEOLocate or geographic coordinates to georeference the locality, leave this field blank

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Field Name	Data Format	What to Enter into the Field
Range	The range designation should have the cardinal direction (e.g. E or W) and leading 0s for single digit and double digit numbers (e.g. 003W, 021W 125E)	• If you used PLSS information to georeference the locality, enter the range designation into this field. • If you used GEOLocate or geographic coordinates to georeference the locality, leave this field blank
Section	The section number should have leading 0s for single digit numbers (e.g. 03, 21)	• If you used PLSS information to georeference the locality, if applicable enter the section designation into this field. • If you used GEOLocate or geographic coordinates to georeference the locality, leave this field blank
Quarters	Write exactly how the sections quarters appear on the form	• If you used PLSS information to georeference the locality, if applicable enter the quarter sections into this field. • If you used GEOLocate or geographic coordinates to georeference the locality, leave this field blank
Locality_String		• If you used GEOLocate to georeference the locality, enter the locality description used in GEOLocate into this field. • If you used PLSS information or geographic coordinates to georeference the locality, leave this field blank.
Country	No abbreviations, use entire country name (e.g. United States of America)	The country the locality is found in
State	No abbreviations, use entire state name (e.g. Colorado)	• The state/province/territory/canton/department/district/prefecture the locality is found in. • Leave blank if the locality doesn't have this data.
County		• The county/borough/department/district/division/region/unit the locality is found in. • Leave blank if the locality doesn't have this data.

Datum_georeference		• If you used GEOLocate or used PLSS information to georeference the locality, enter WGS84 into this field.
		• If you used geographic coordinates to georeference the locality
		  ○ AND the original datum was WGS84, then enter WGS84 into this field.
		  ○ AND you had to covert the coordinates into WGS84, then enter WGS84 into this field.
		  ○ AND the original datum was indeterminate, enter "datum not recorded" into this field.

Field Name	Data Format	What to Enter into the Field
Map_Coordinates_lat	Lat-Long coordinate should have degree symbol (°) and hemisphere designation (e.g. N or S).	The latitude coordinate generated via georeferencing.
Map_Coodinates_long	Lat-Long coordinate should have degree symbol (°) and hemisphere designation (e.g. E or W).	The longitude coordinate generated via georeferencing
Uncertainty_meters		The radius, in meters, of the uncertainty circle generated by georeferencing.
Georef_by	First initial and full last name (e.g. J. Van Veldhuizen)	The person who georeferenced the locality
Georef_date	Dates should include leading 0s (e.g. 04/03/2020, 04/13/2020, or 11/13/2020)	The date the locality was georeferenced
Georef_source	Separate multiple entries with a comma. Website URL's are fine.	List all the tools/websites used to perform the georeferencing. This includes, but is not limited to: Montana State University's Convert Geographic Units Website, any Lat-Long format conversion websites, any datum format conversion websites, DIEA Georeferencing Calculator, Earth Point, Google Earth, GEOLocate, Google Maps, Geographic Names Information System, and any historical place look-up website.
Georef_protocol		The protocol used to perform the georeferencing. Always enter "Georeferencing Quick Reference Guide Version 2012-10-02" into this field.
Georef_remarks		One to two sentences on how you used the tools listed in the Georef_source field to get the georeferencing results. See examples below.

Table 1. Field for the Excel Worksheet titled Georeferenced Localities

Examples of Georef_remarks
- Moved GEOLocate point from middle of Darmstadt to Rhein River Valley in the west, increased uncertainty radius to encompass all of Darmstadt
- Used MSU website to covert UTM's into Lat/Long, used tagis website to covert Lat/Long from NAD83 to WGS84; used MSU website to covert Lat/Long to decimal degrees; used DIEA to get error radius