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Workflow for Marking and Exporting Lithic Scar Orientations Using Geomagic Wrap and Rhino

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Zhi Ye: This protocol manuscript was written by Zhi Ye;

Sam Lin: This method was developed by Sam Lin, who provided the methodological framework for applying orientation analysis to the study of flake scar organization. He also contributed to the revision of this manuscript;

Ben Marwick: This protocol manuscript was revised by Ben Marwick



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Protocol status: Working

We use this protocol and it's working

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Abstract

Understanding the organization of flake scars on core is crucial for interpreting core reduction strategies. Here, we present a protocol for recording and extracting flake scar orientations from 3D scanned models of cores. Using Geomagic Wrap and Rhino 8, the method involves scar vector annotation, generation of a best-fit plane, spatial alignment and standardization of scar vectors, and the export of vector coordinate data. The resulting set of scar vector coordinates is ready for orientation analysis in R. Developed by Sam Lin et al., this protocol enables reproducible and objective analysis of scar orientations across archaeological lithic assemblages.

Guidelines

To ensure clarity and consistency throughout the protocol, the following typographical conventions are used:

- (1) **Software features and tools** are written in **bold**, e.g. **Feature**;
- (2) <Keyboard keys> are enclosed in <angle brackets>, e.g. or <Ctrl>;
- (3) Software operations and workflows are indicated using arrow notation, e.g. Features > Plane > Best Fit;
- (4) Commands typed into the keyboard or command line are written in [square brackets], e.g. [what].

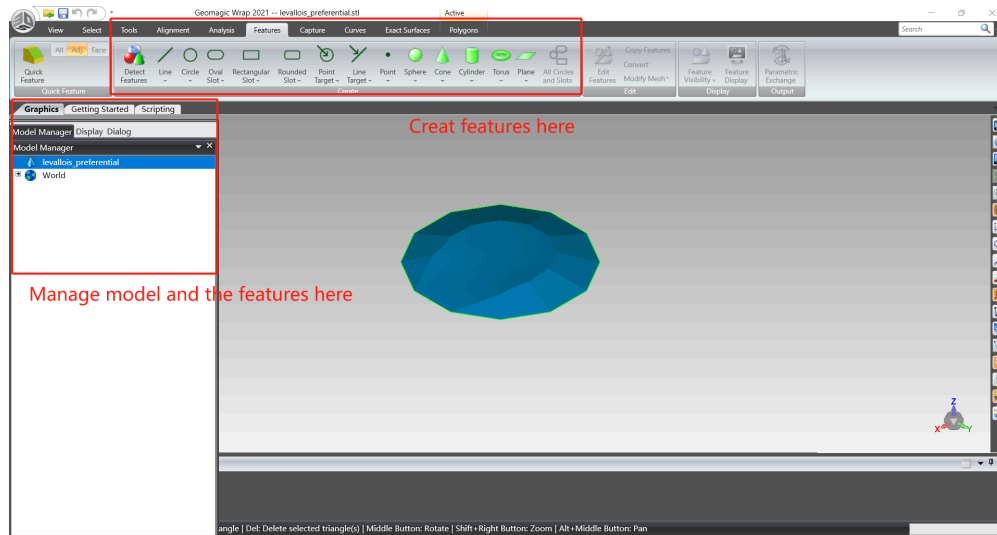
Acquire 3D Scan of cores

- 1 Digitize the core using a 3D laser scanner
Use a structured-light or laser scanner (e.g., Artec Spider, etc.)
- 2 Post-process the raw scan
Use the scanner's native software (e.g., Artec Studio, etc.) or compatible 3D processing tools
 - 2.1 In Artec Studio, the post-process usually includes:
 - Erasing Tool-to remove unnecessary geometry
 - Global Registration-to align all scan frames into a coherent point cloud
 - Fusion-to merge the frames into a single mesh
 - Optional: Small Object Filter or Outlier Removal and Hole Filling
- 3 Export the 3D model
Save the final mesh as an STL (.stl) or OBJ (.obj) file

Mark Scar Orientations in Geomagic Wrap

- 4 Open the model in Geomagic Wrap
 - 4.1 Open Geomagic Wrap
 - 4.2 Select: **File > Open**, and load your .stl file
 - Set units as needed (e.g., centimeters)
 - Optional: Run Mesh Doctor to repair the mesh
 - 4.3 After loading your .stl file, the interface will appear as shown below. For demonstration purposes, we used a standardized core model (Lin et al.,2024) here

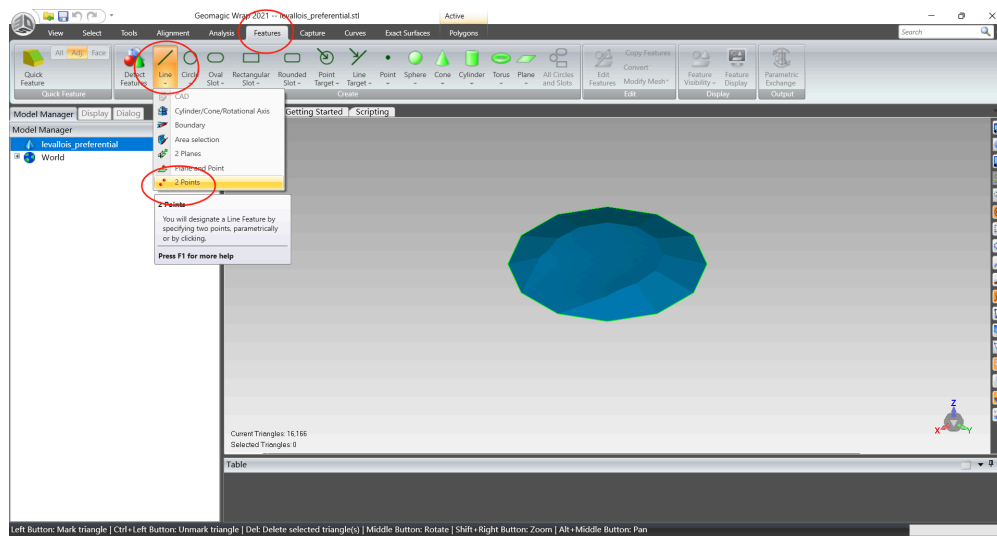




Snapshot of configured workspace, with labelled positions of the basic tools and functions which will be needed in the following steps

5 Annotate line features on the core

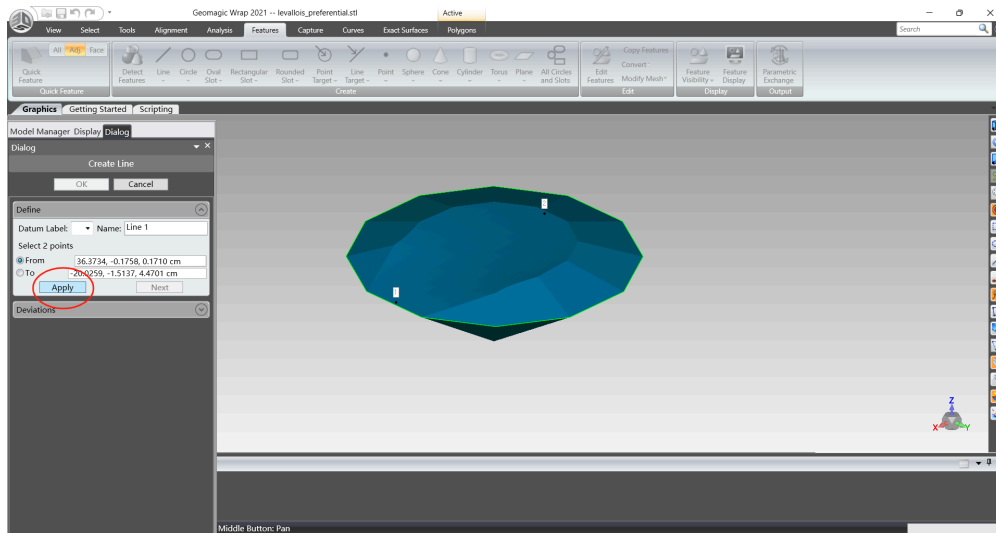
5.1 Select: **Features > Line > 2 Points**



Snapshot of step 5.1

5.2 Click on the model to mark: flake scar origin and flake scar termination

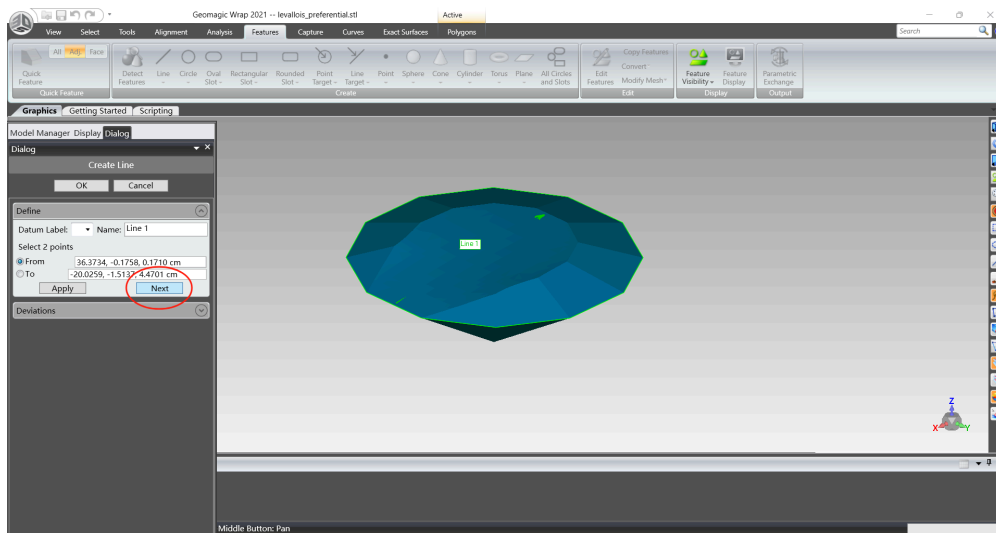
- For incomplete scars lacking identifiable origins, terminations, or both, first determine the flaking axis. Then, mark the proximal-most and distal-most points along this axis



Snapshot of step 5.2-5.3

5.3 Click **Apply** to save the current line

5.4 Click **Next** to begin annotating the next flake scar

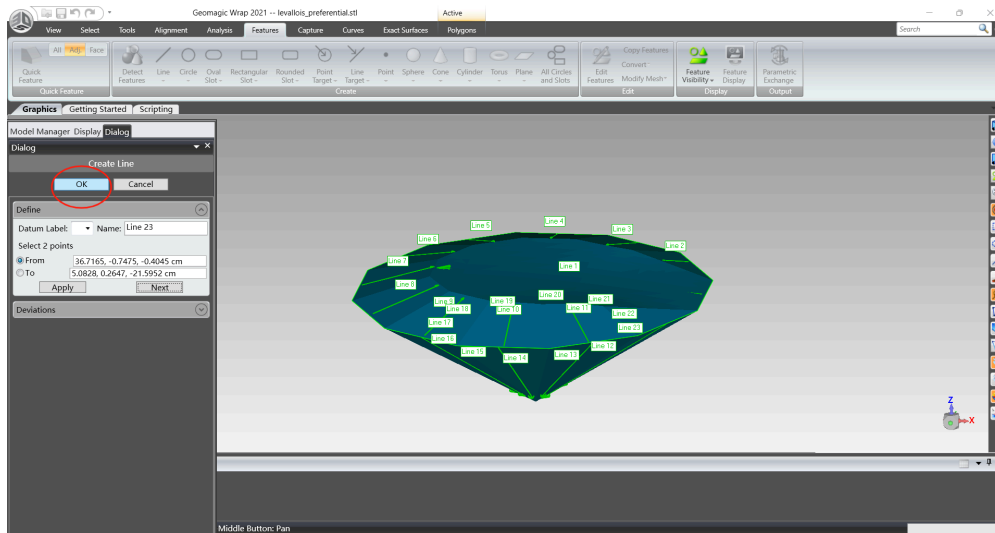


Snapshot of step 5.4

5.5 Repeat the steps: Mark points → **Apply** → **Next**, until all flake scar vectors are completed
Tips:

- Rotate: Hold scroll wheel and drag
- Zoom: Use scroll wheel

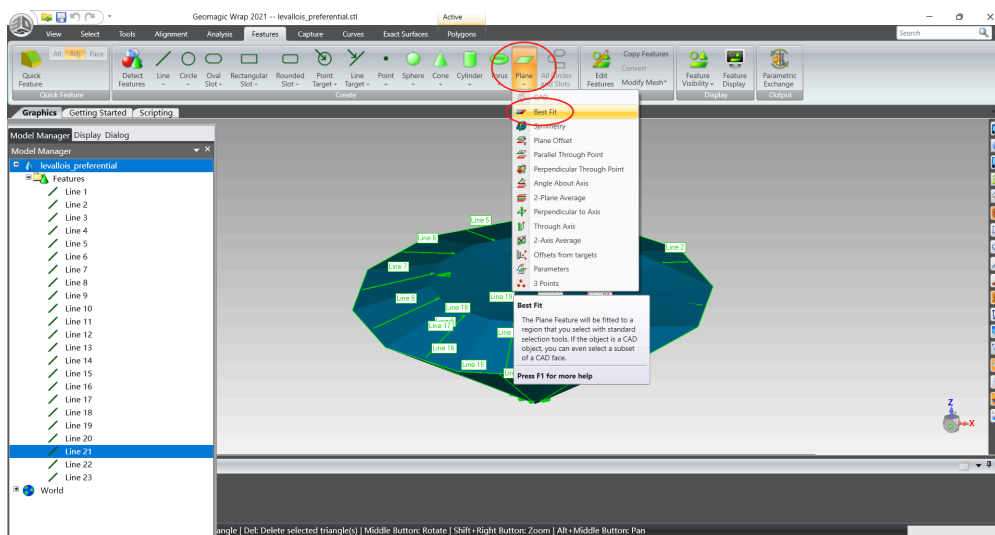
5.6 Click **OK** to save line features



Snapshot of step 5.6

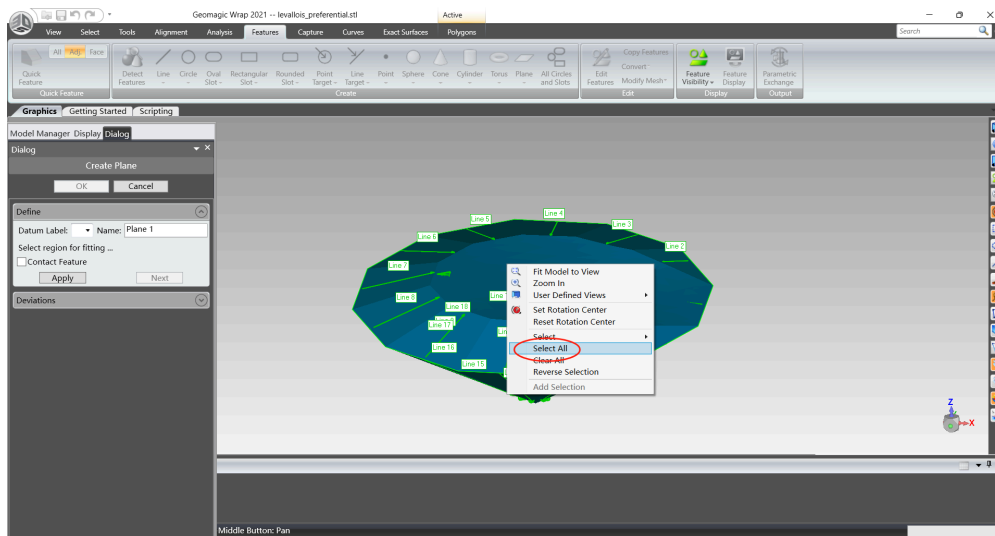
6 Create best-fit plane

6.1 Select: **Features > Plane > Best Fit**



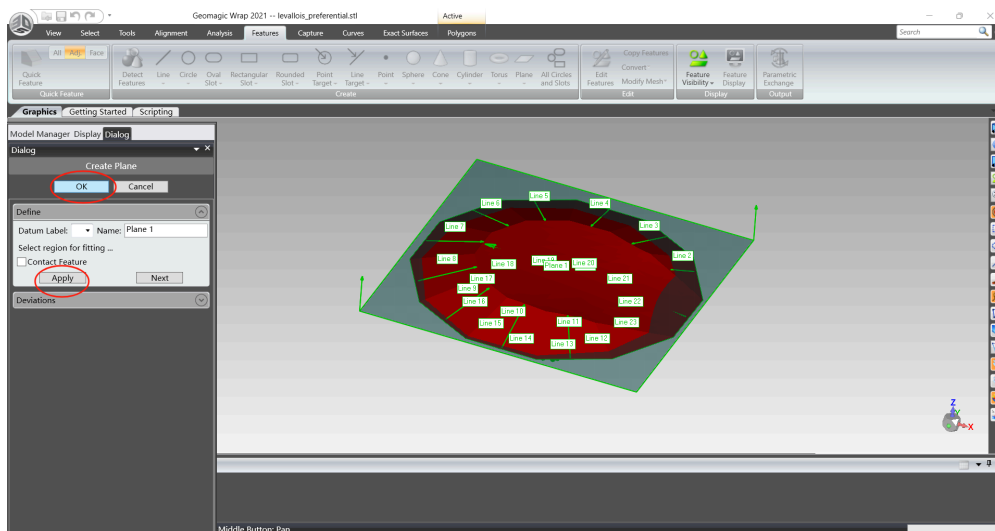
Snapshot of step 6.1

- 6.2 <Right-click> on the model and choose: **Select All**
- After selecting **Select All**, the model will turn red to indicate that it is fully selected



Snapshot of step 6.2

- 6.3 In the **Graphic-Dialog**, click **Apply**, then click **OK**

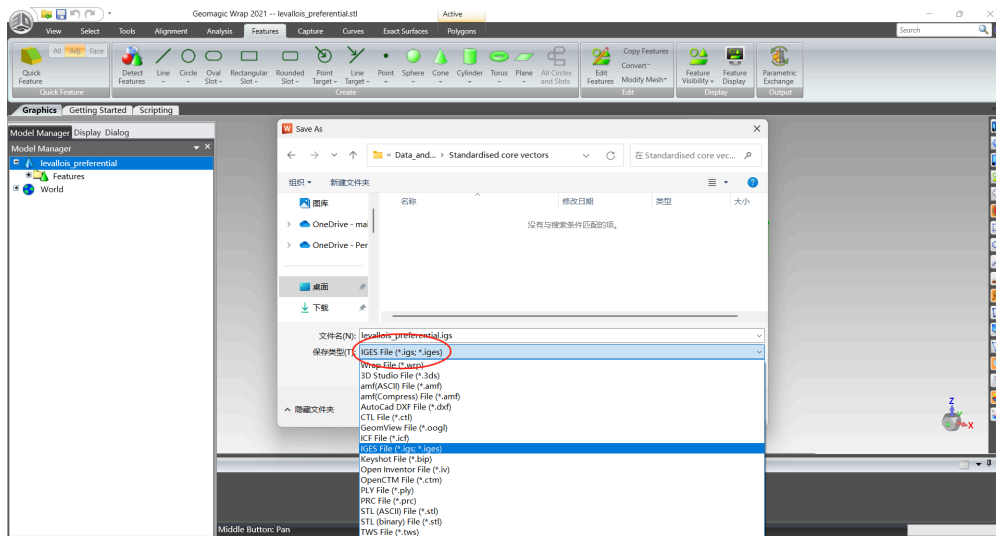


Snapshot of step 6.3

7 Export the annotated model

7.1 Select: **File > Save As**

7.2 Choose a location to save the work and set format to .igs



Snapshot of step 7.2

Align Line Features in Rhino

8 Import the model in Rhino

8.1 Open Rhino 8

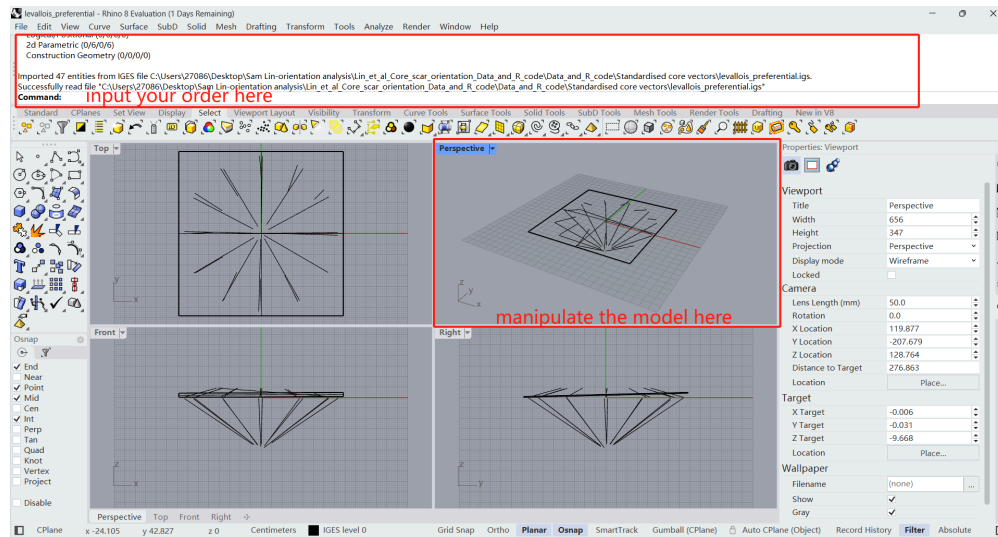
8.2 Select: **File > Open**, and load your .igs file

- The Rhino interface displays four viewports. You can enlarge a preferred view (e.g., **Perspective**) and right-click to rotate the model

8.3 After loading your .igs file, the interface will appear as shown below

- Commands can be entered via buttons or directly in the **Command** dialog — the latter is often faster

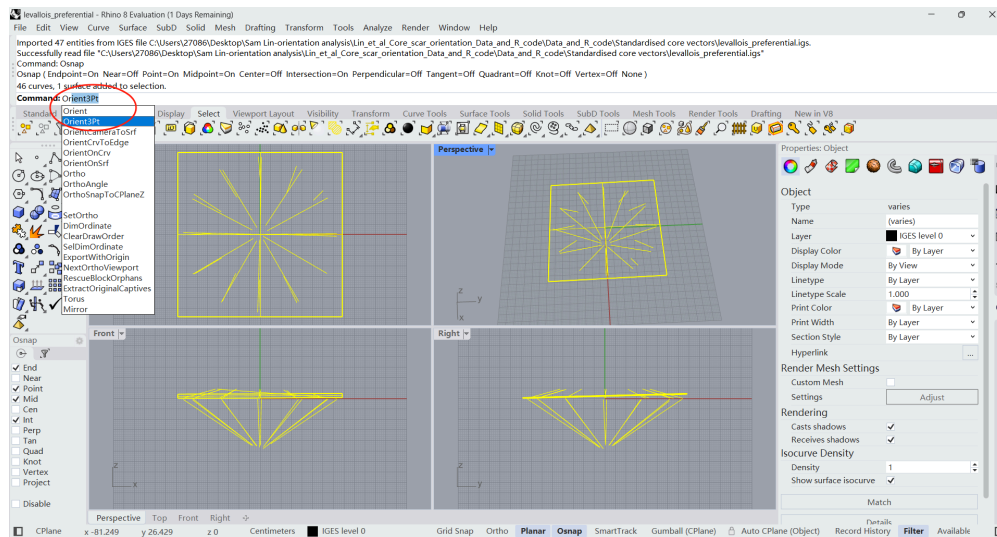
- Enable **Osnap** (or type [Osnap] in the command line) to assist with precise point selection



Snapshot of configured workspace, with labelled positions of the basic tools and functions which will be needed in the following steps

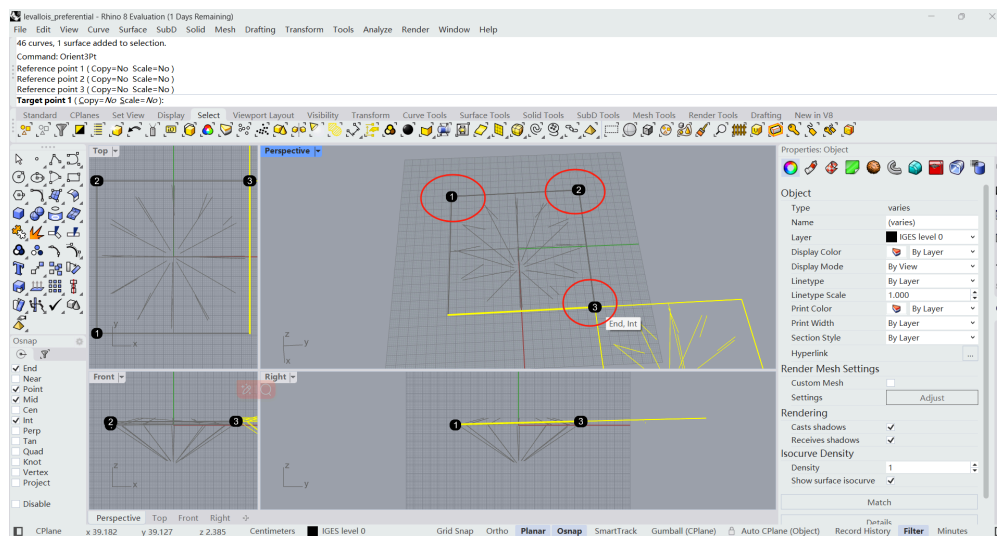
- 9 Orient the model's best-fit plane using three points
 - 9.1 Left-click and drag to select the line and plane features
 - Selected items will appear yellow
 - Be sure all features are selected
 - 9.2 In the command line, type [**Orient3Pt**] → press <Enter>





Snapshot of step 9.1-9.2

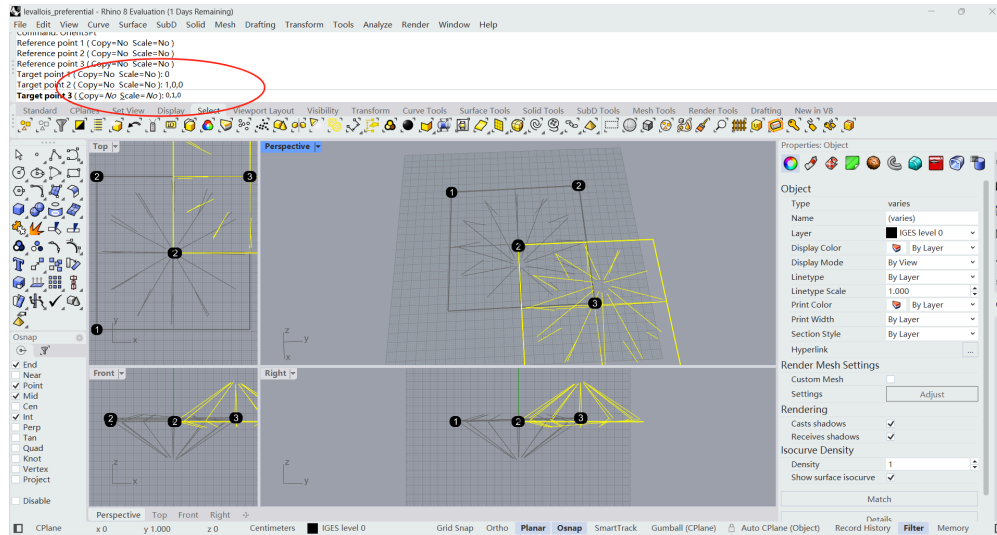
9.3 On the model's best-fit plane, click three reference points: **Reference Point 1, Point 2, Point 3**



Snapshot of step 9.3

9.4 In the command line, input coordinates for the target plane (we aim to align with the XY plane): type [0,0,0]→ press [Enter] type [1,0,0]→ press [Enter]

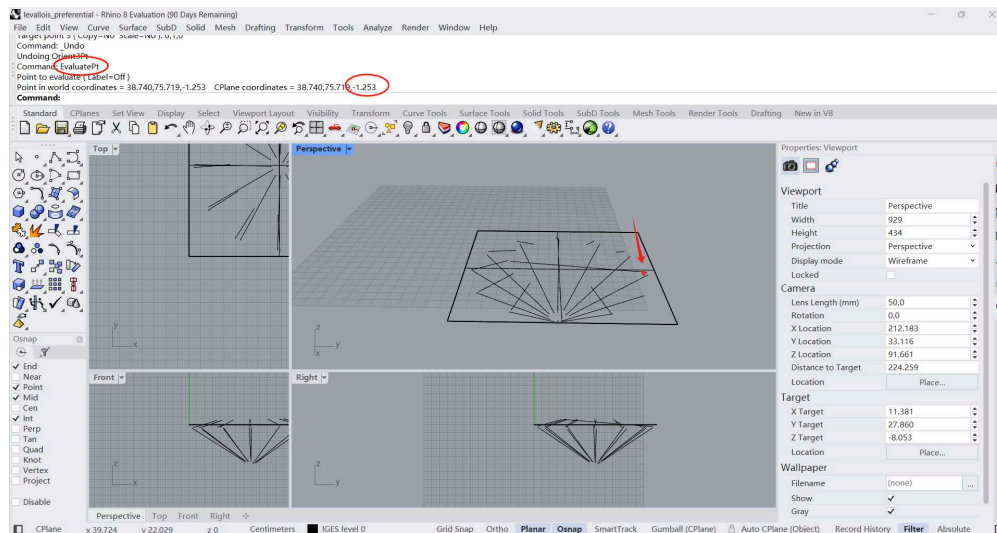
type [0,1,0] → press [Enter]



Snapshot of step 9.4

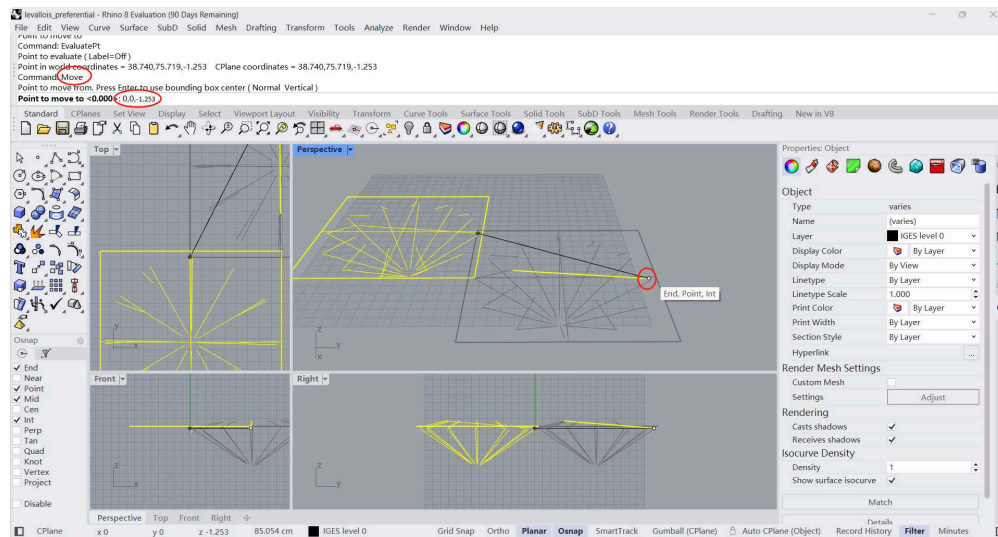
10 Move the longest line to X=0 and Y=0

- 10.1 In the command line, type [**EvaluatePt**] → press <Enter> → click the starting point of the longest line:
The XYZ coordinates will appear. Copy the Z-coordinate



Snapshot of step 10.1

10.2 Type **[Move]**→ press <Enter>→click the starting point of the longest line



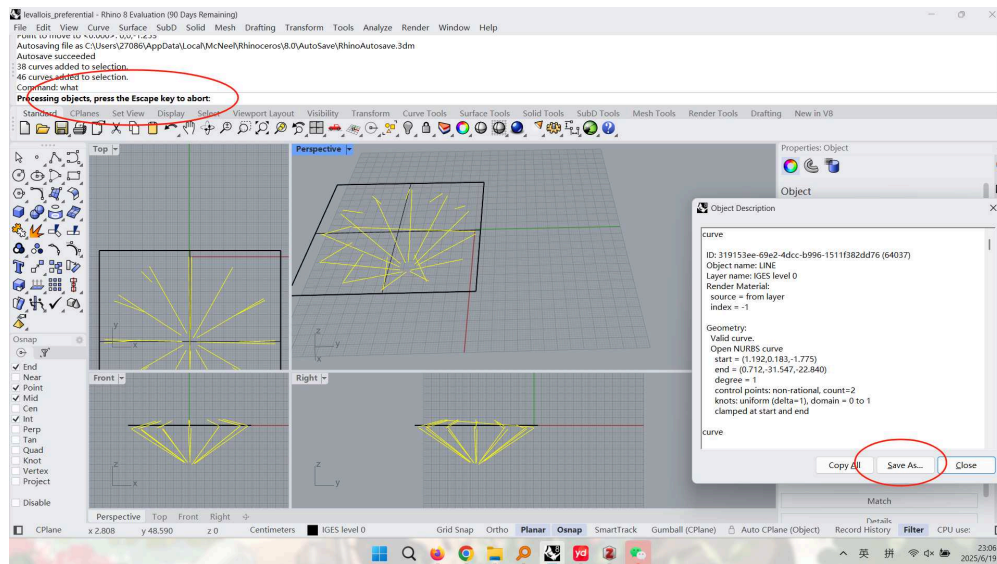
Snapshot of step 10.2-10.3

10.3 In the command line, type [0,0,Z-Coordinate of the starting point]→ press [Enter]

- This ensures that the best-fit plane remains aligned with XY plane

11 Export coordinate data

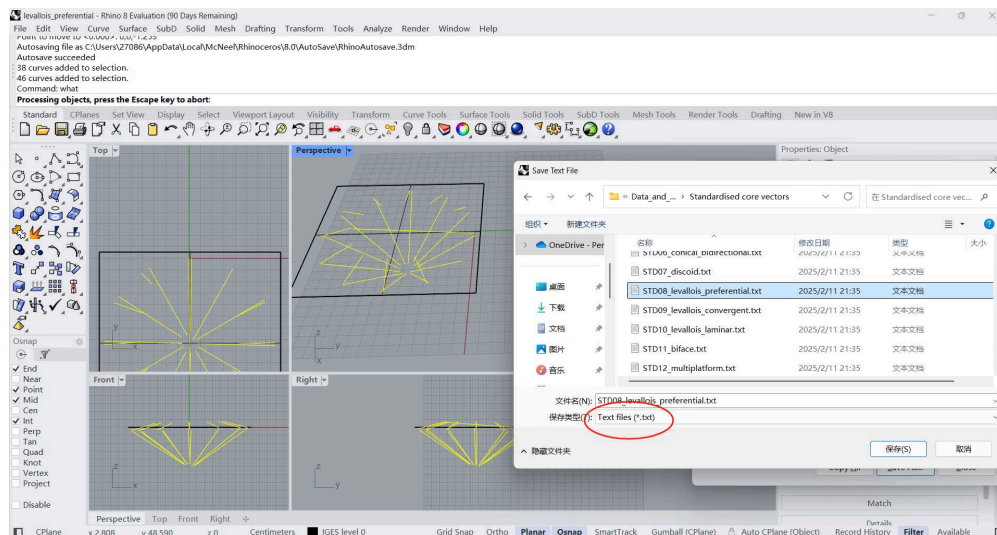
11.1 Select all the lines→In the command line, type **[What]**→ press <Enter>



Snapshot of step 11.1-11.2

11.2 In the pop-up dialog, **File > Save As**

11.3 Choose a location to save the coordinates as a .txt file



Snapshot of step 11.3

12 Now you are ready to analyse the coordinates in R



Protocol references

Lin S C, Clarkson C, Julianto I M A, et al. A new method for quantifying flake scar organisation on cores using orientation statistics[J]. Journal of Archaeological Science, 2024, 167: 105998.

<https://doi.org/10.1016/j.jas.2024.105998>.

Acknowledgements

I thank Ben Marwick for suggesting that this protocol be made publicly available, which helps researchers quickly acquire the skills needed to complete this type of work.

I also thank Sam Lin for his repeated and valuable feedback, which greatly improved the clarity and conciseness of the protocol.