

# Automatic 3D Reconstruction from Photographs: Applications in Archaeology and Heritage

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Rock art, Wanmanna (West Australia)

# Introduction and motivation

- Creating richer objects (compared to photographs) for recordings in archaeology and heritage.
- Creation of assets for virtual environments and serious games. Avoid the need for manual and time consuming model generation and the inevitable interpretation on the part of a human modeller.
- Create models for 3D analysis. For example: geoscience applications.
- Wish to avoid any in-scene markers required by some solutions. Often impractical (access) or not allowed (heritage).
- Want to target automated approaches as much as possible. [Current site surveys recorded 100's of objects].



Temple facade  
Commateswara (India)

# Algorithm/pipeline outline

- Compute lens calibration (only done once)
- Read images, correct for lens, and compute feature points between them (eg: SIFT - scale invariant feature transform)
- Compute camera positions and other intrinsic camera parameters
- Create sparse 3D point cloud, called “bundle adjustment” (eg: Bundler)
- Create dense point cloud (eg: PMVS2 - patch-based multi-view stereo)
- Form mesh from dense point cloud (eg: ball pivoting)
- Reproject images to derive texture segments
- Optionally simplify mesh (eg: quadratic edge collapse decimation) and fill holes
- Export in some suitable format (eg: OBJ files with textures)



# Software options

- Photosynth: Not possible to extract the geometry, only exist as an online experience. Based upon Bundler.
- PhotoScan (AgiSoft): Seems like older algorithms, in any case didn't compete well with other options.
- Visual SfM (University of Washington)  
Based upon Bundler.
- PhotoModeller (EOS Systems): High end commercial software. Not entirely automated. In general requires a larger number of photographs with significant overlap.
- 123D Catch (AutoDesk): Very easy to use highly reliable cloud base software.
- Developed work flows using Bundler and various algorithms to reconstruct the mesh from the point cloud and re-project photographs to derive textures.
- Otherwise 123D catch and PhotoModeller performed the best. The former for a hands-off solution, the later for higher precision at the price of greater rigour and manual guiding.

# Low photograph count : 2.5D

- A relatively low number of photographs are required for 2.5D surfaces.
- Degree of concavity determines the number of photographs required. Can't reconstruct what cannot be seen.
- Facades and engravings typically require between 3 and 6 images.
- Photographs can be orientated at any angle.
- Each object takes perhaps 15 sec to capture, 10 minutes (on average) to process.

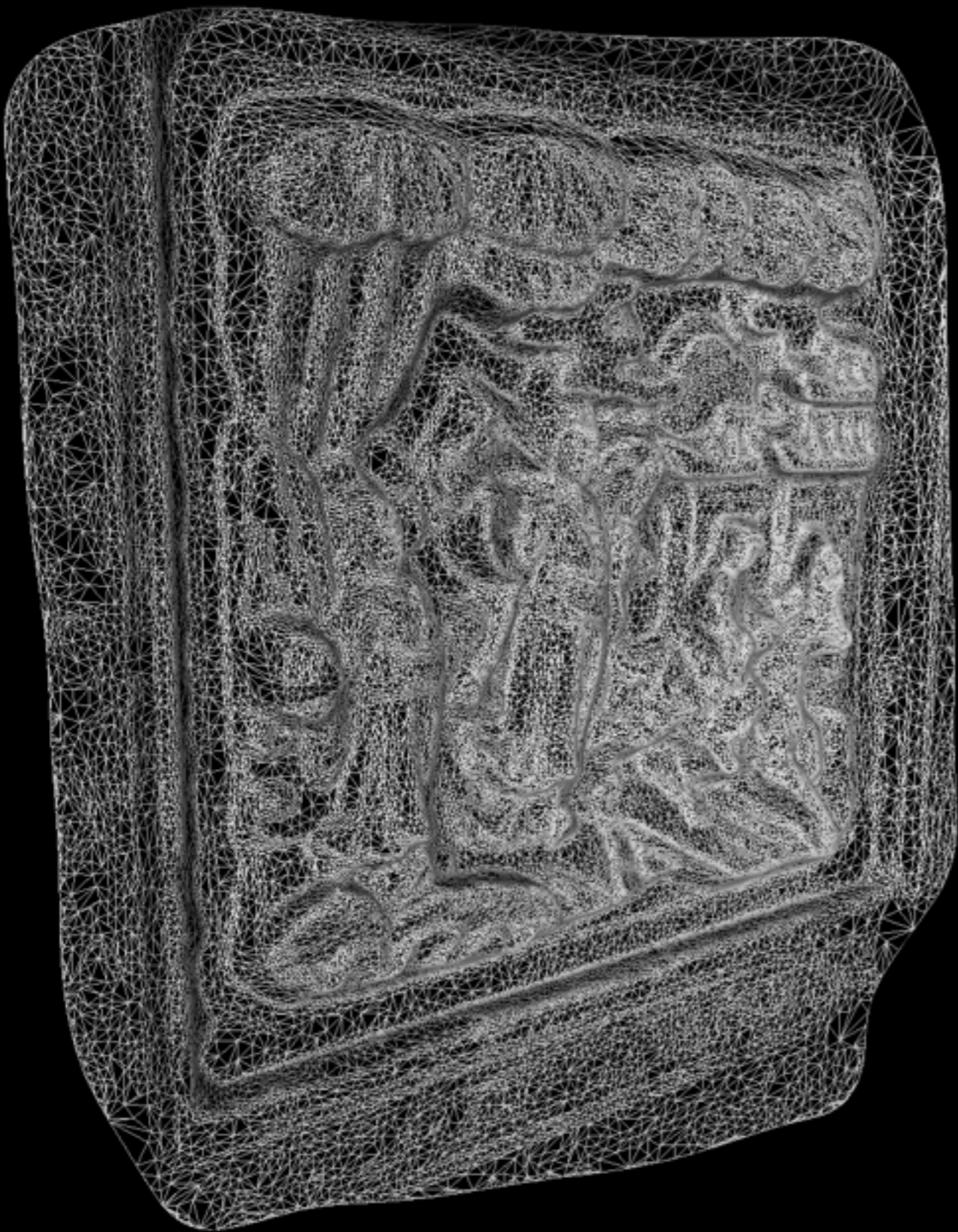






Ho Ann temple, Terengganu







# Image relighting





# Full 3D objects

- Require significantly more images.
- Some algorithms perform better if the images are captured in sequence with the best matches at the start of the bundle adjustment.
- Move to more rigorous capture: fixed focal lens combined with lens calibration.



Aphrodite (Lady of Cythera)  
33 images

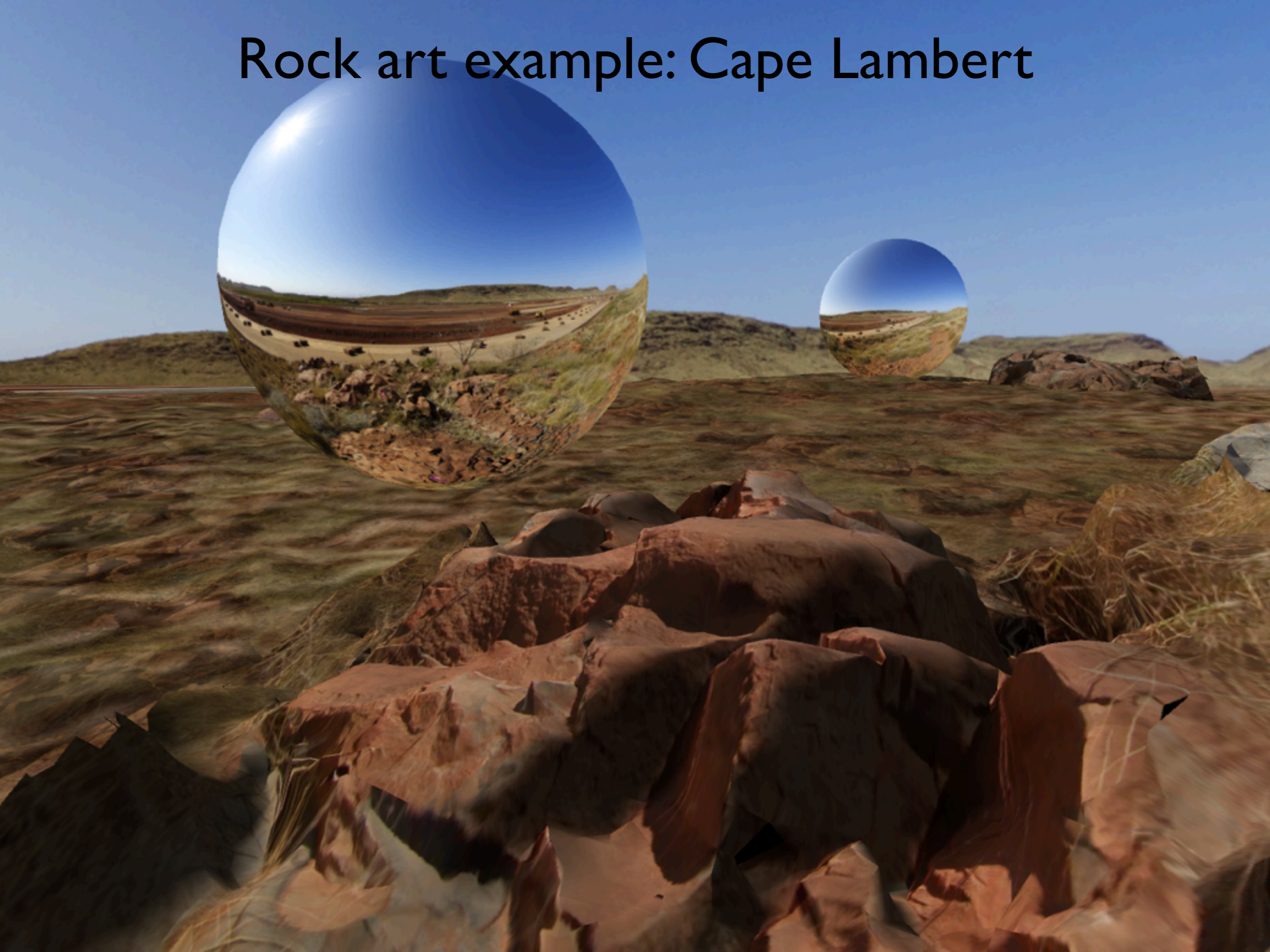


# Rock art example: Wanmanna





# Rock art example: Cape Lambert





# Rock art example



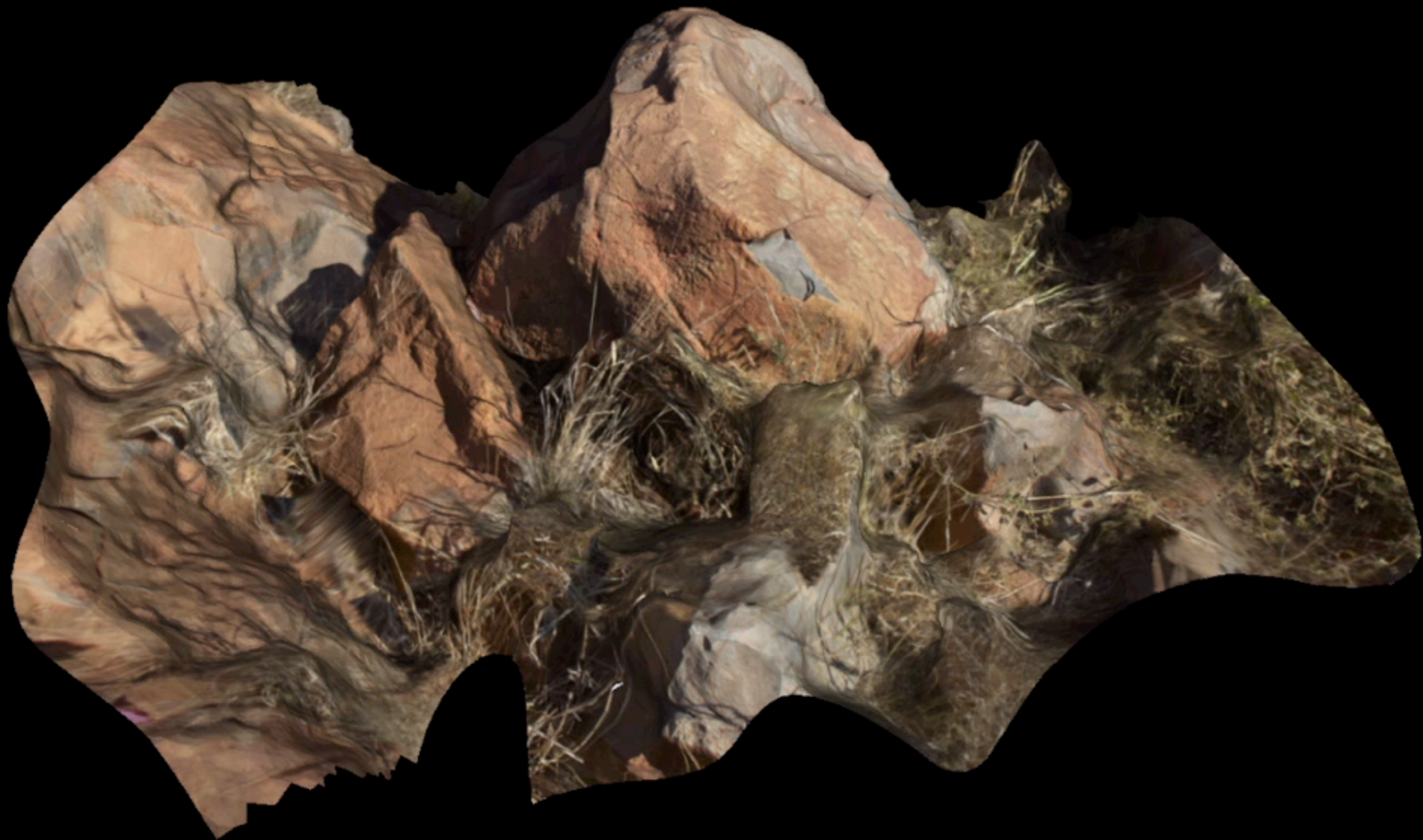
18 images

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Cape Lambert (West Australia)







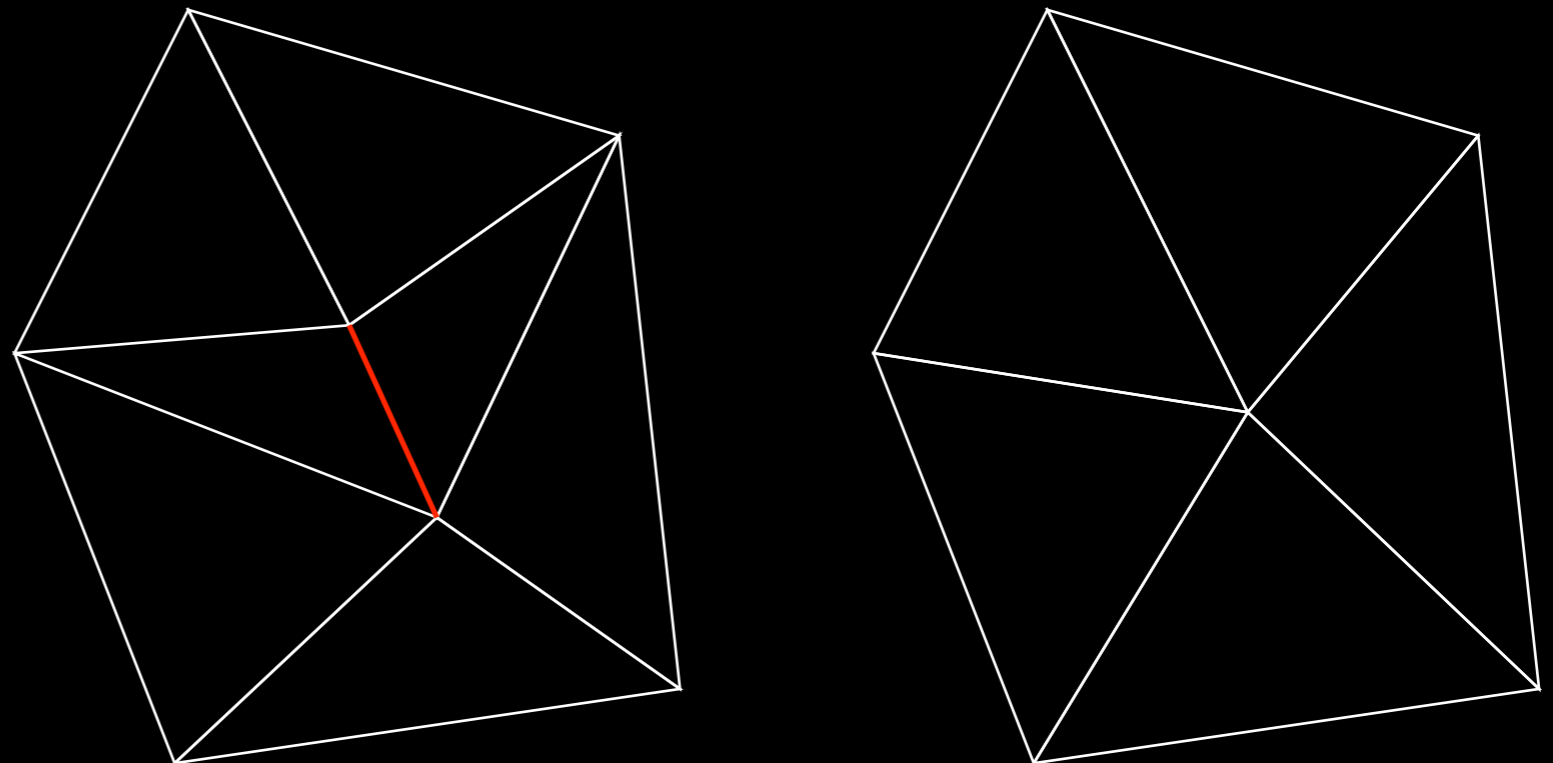
# Limitations

- Baked on shadows. Solution: Choose cloudy diffuse lit days.
- Movement of the object during capture, eg: grass in the wind. Testing solution taking pairs of images at each location and find moving objects and removing them.
- Thin structures, eg: grass.
- Access to all sides of 3D object can be problematic. Only hand held shots.
- Difficult to control the boundary shape. May clean up manually, testing culling boundary shapes.

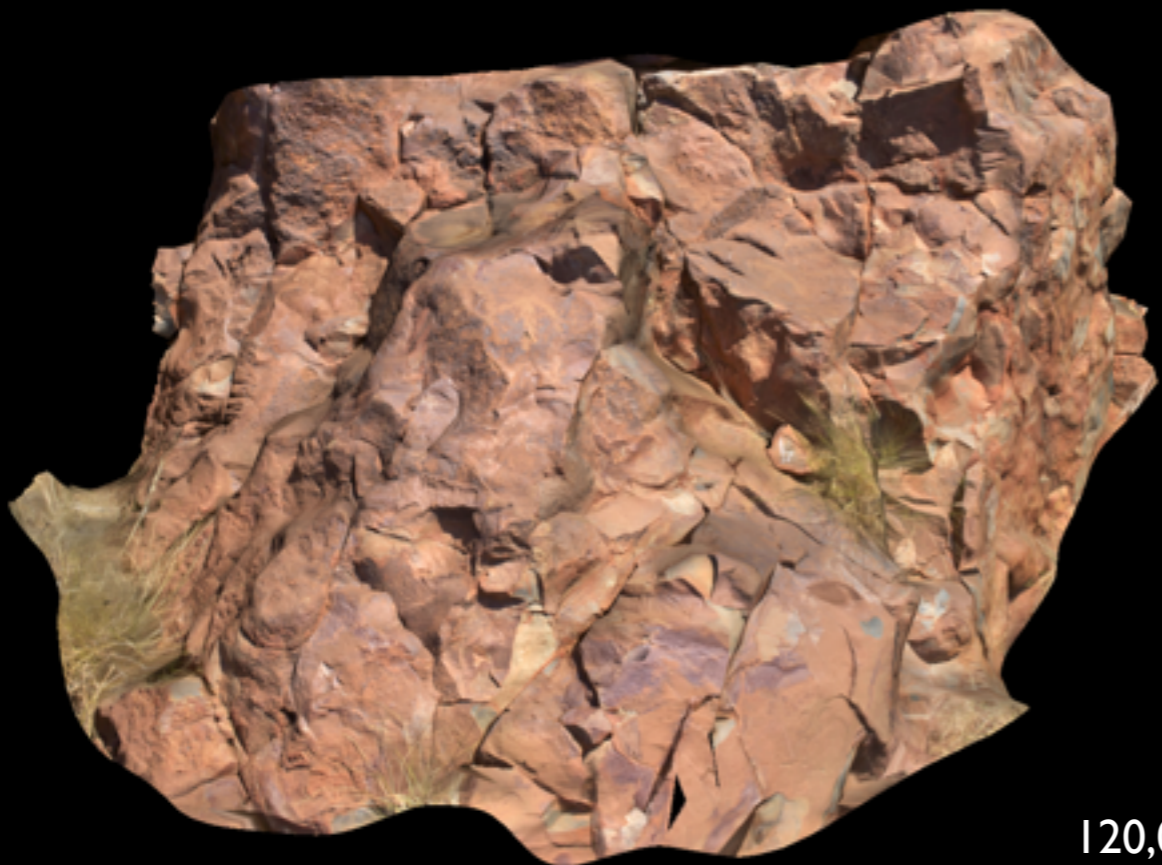


# Mesh simplification

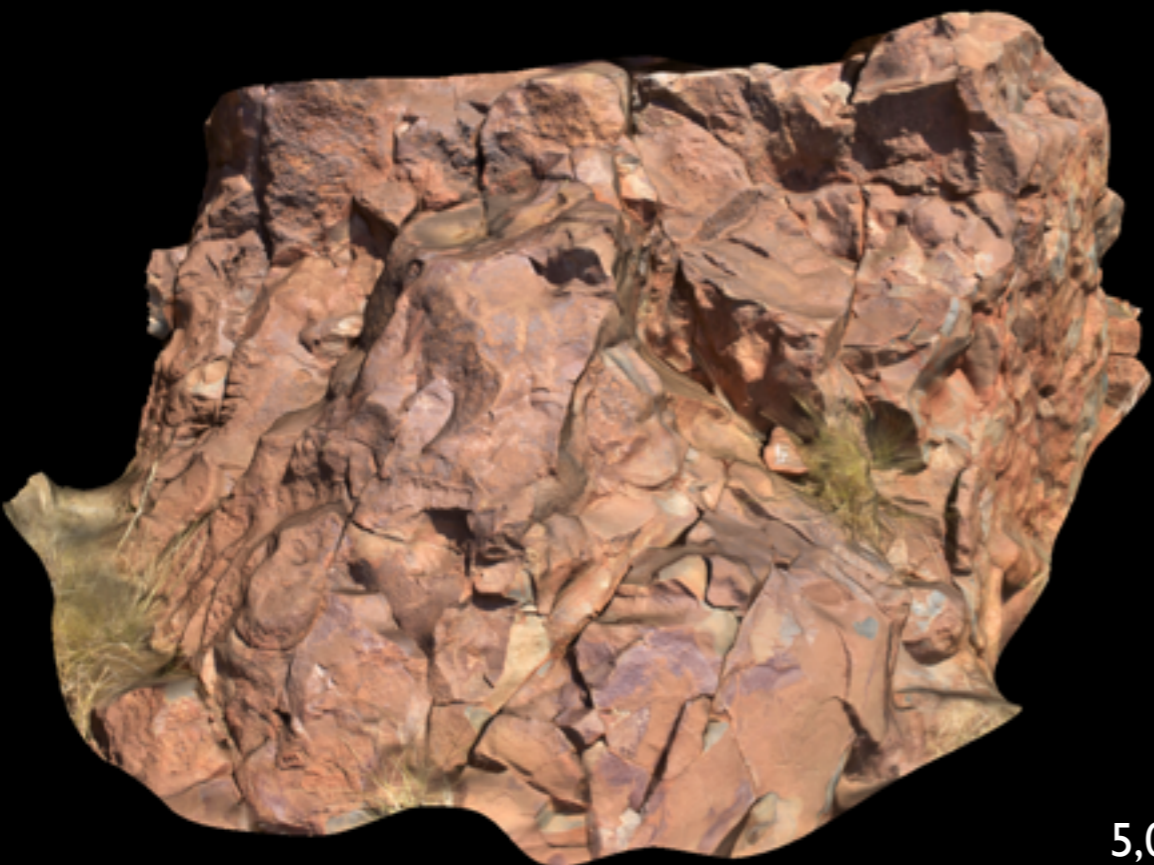
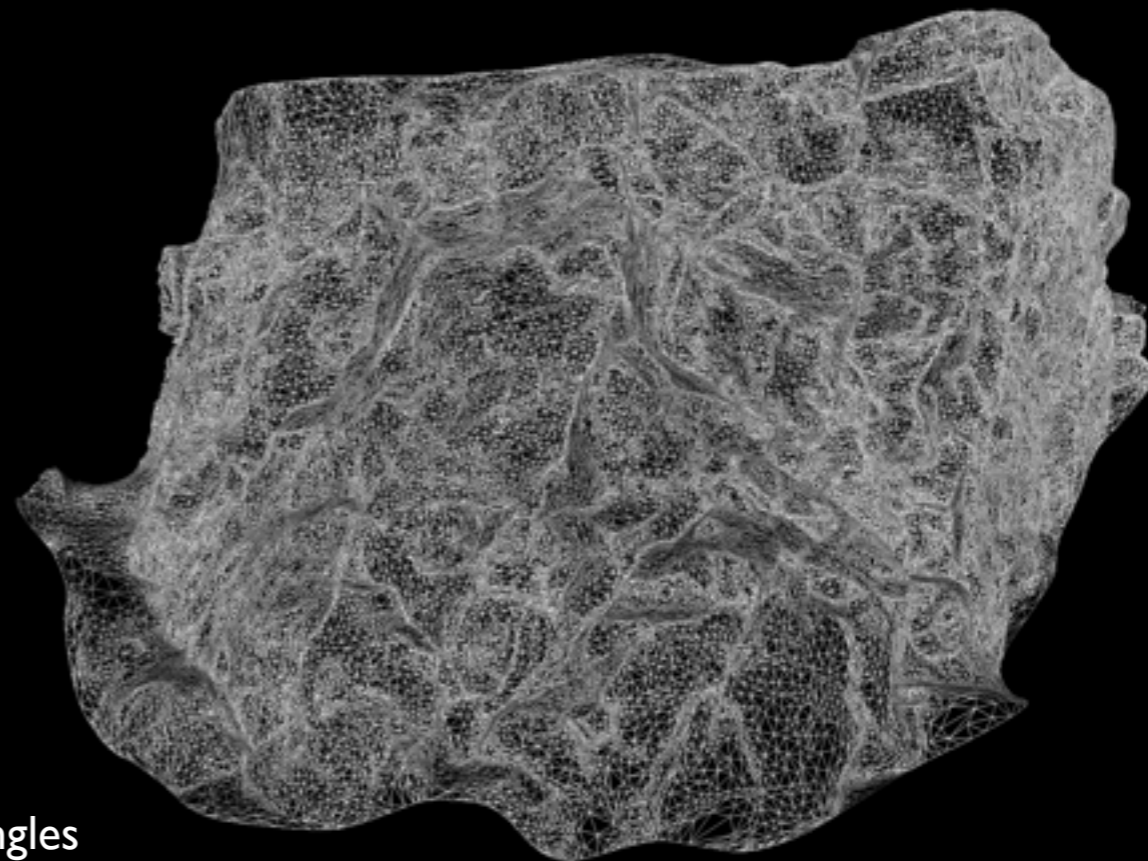
- Meshes directly from the reconstruction (generated from the dense point cloud) are generally inefficient. Need to reduce them for realtime applications and web based delivery.
- Simplest case is to iteratively remove the shortest edges. (Example below)
- The refinement is how the edges are chosen and where to place the new vertex. Implemented the “quadratic edge collapse decimation” - edge selection weighted by edge length and surface flatness.
- A texture and geometry approximation.
- Can preserve the boundary.



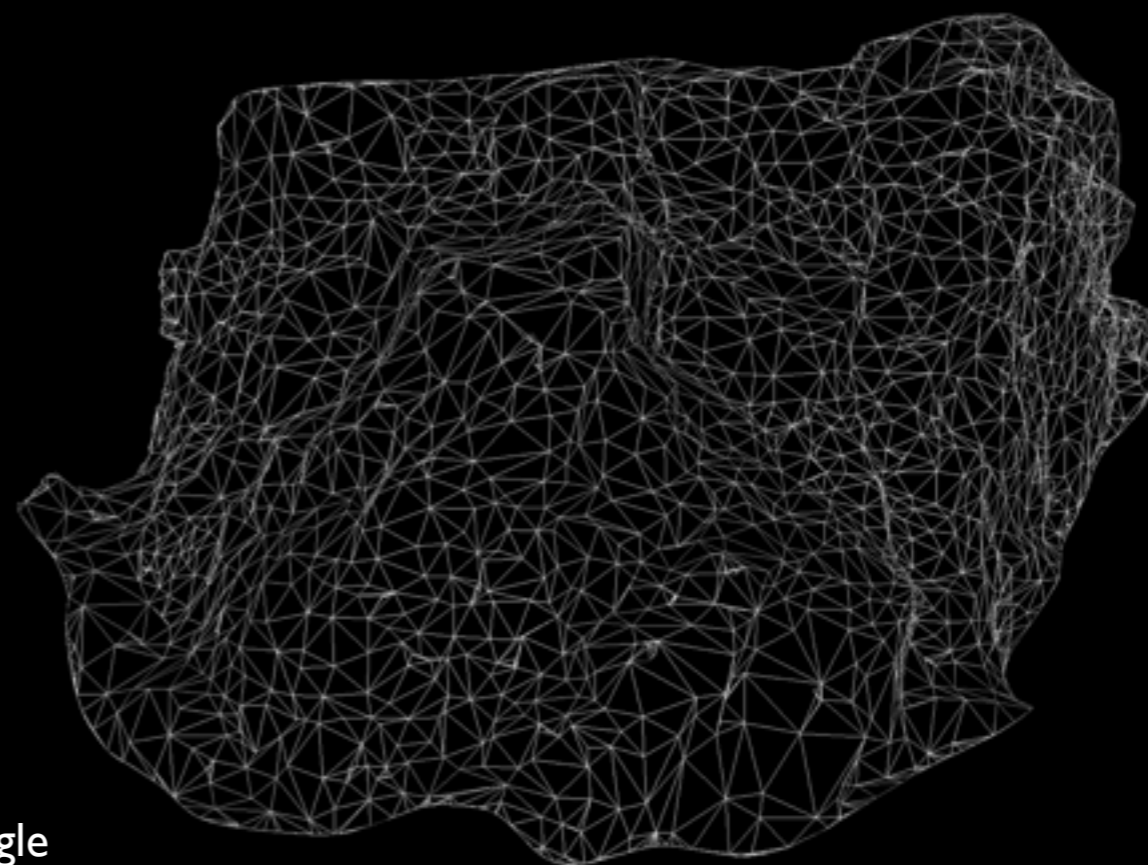




120,000 triangles



5,000 triangle





# Annotating

- Textures from the reconstruction algorithms are often “interesting”.
- But can generally still be drawn on.







# Online viewer

- Disappointed that there still does not seem to be a widely used - cross platform - browser independent viewer for textured meshes.
- 3D PDF support seems patchy. Even Adobe products don't all support it.
- VRML / X3D seems to be in the same poorly supported situation it has always been in.
- CS student project in 2012 developed a browser based viewer for textured OBJ files.
- Doesn't require external downloads, plugins etc.  
Javascript and HTML5 (canvas) based, no hardware acceleration.
- Has been tested and known to work on the following browsers:  
Mac OS X: Safari, FireFox and Chrome  
Windows 7: FireFox, Chrome, Internet Explorer (V9 or later)  
Linux: (Tested set incomplete)
- Also works on IOS devices (iPhone, iPad) except for 2K texture limitations.



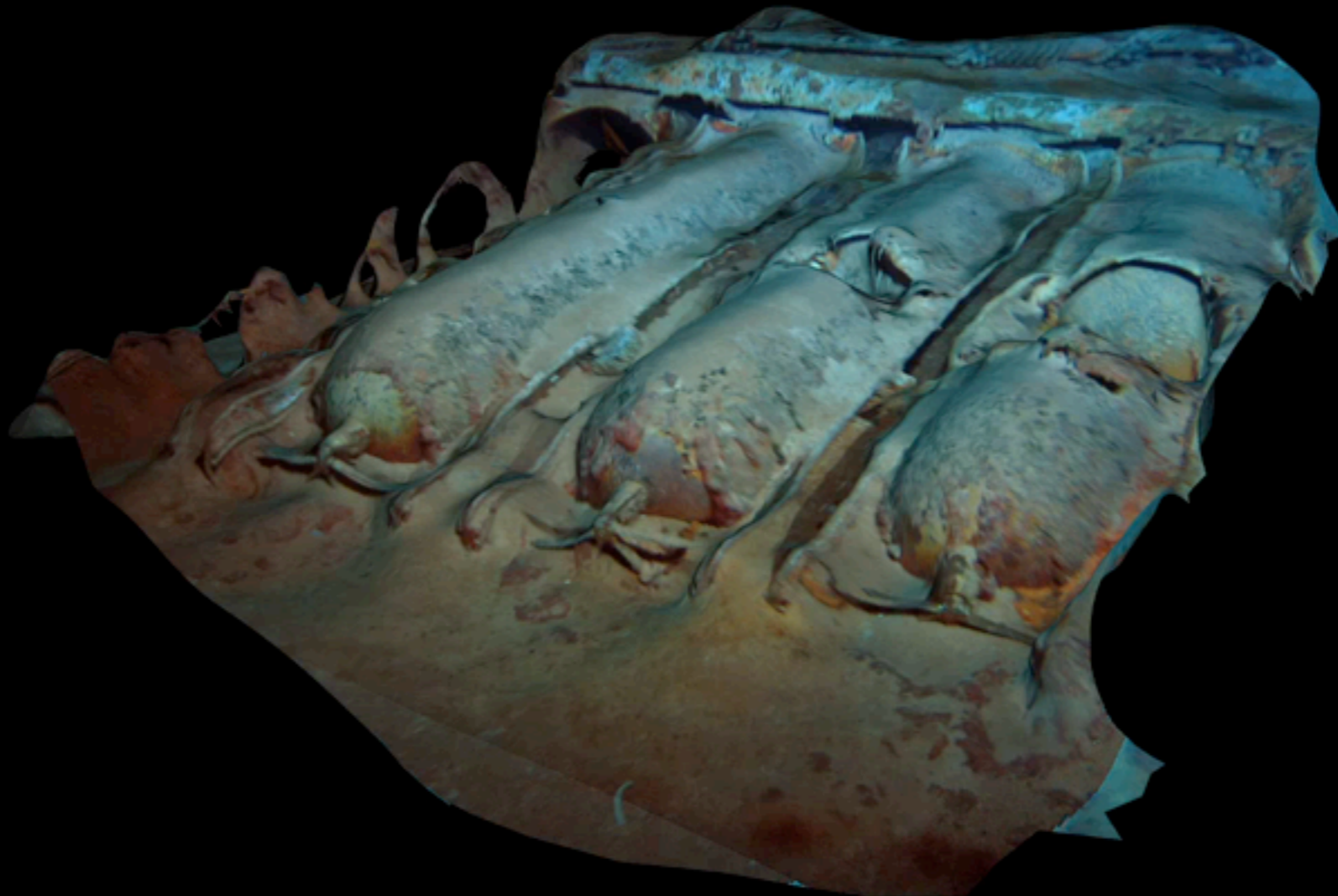
# Summary

- Exploring our own workflows for photographing and reconstructing 3D textured meshes from a series of photographs.
- Identified the process trade-offs between fast but less accurate reconstructions vs more rigorous slower processes that (may) result in more accurate models.
- Identified range of tools for transforming, editing, simplifying, and annotating the 3D meshes.
- Developed online browser for the textured meshes, works directly from the wavefront OBJ meshfiles and JPEG textures.
- Applying techniques learnt to projects in Australian rock art, virtual heritage in India and shipwreck/marine archaeology.



# Future projects

- Apply to more demanding environments, namely underwater archaeology.



Torpedo bay  
HMAS Sydney



# The 3D tourist

- I find myself taking photographs suited to 3D reconstruction while travelling.
- Sitting in my hotel at night processing the results and uploading the 3D mesh to make it available online.



Cairn to  
HMAS Sydney  
(Carnarvon)



# Questions?



For all those who dismissed  
Erich von Däniken.

In case you doubted aliens  
visited West Australia