Development of Digital Techniques for Open Pit Mapping, Coolgardie, Western Australia

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INTRODUCTION

Photogrammetry has revolutionised in the last decade, with the advent of computer vision techniques such as Structure from Motion (Westoby et al., 2012).These techniques now allow us to capture outcrops, in 3D, at high resolution simply with a digital camera and inexpensive software (e.g. AGISOFT PHOTOSCAN PRO).The objective of this study was to test the variables that make high quality photogrammetric models and develop a workflow for reliable geological mapping of legacy open pits, for the exploration geologist and mine geologist. The case study site is Lindsays Pit, Coolgardie, Western Australia.

PHOTOGRAMMETRY

Photogrammetry is the conversion of 2D images into 3D models. The principle behind photogrammetry is the matching of points (pixels) shared by two or more images in order to determine a unique 3D location (Westoby et al., 2012). Once a point cloud is generated it can be converted into:

1. A 3D wiremesh model and textured by the original photographs
2. A Digital Elevation Model (DEM) and
3. Orthorectified photo mosaics.
4. Errors are estimated for camera positions and point locations.
5. 3D models can be fully georeferenced. We used a method where UTM coordinates were accurately determined for ground control points (total of 17), spread across the entire pit, using a survey grade GPS.

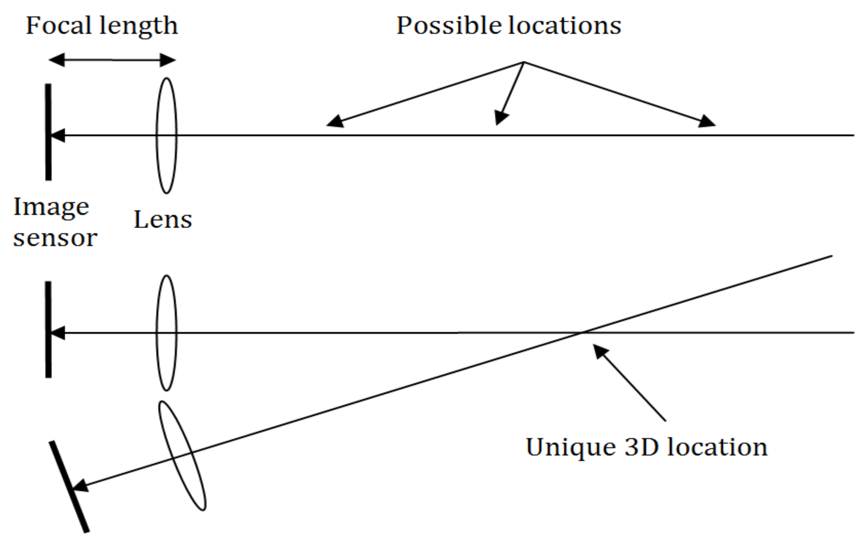


Fig 1.

GEOLOGICAL CONTEXT

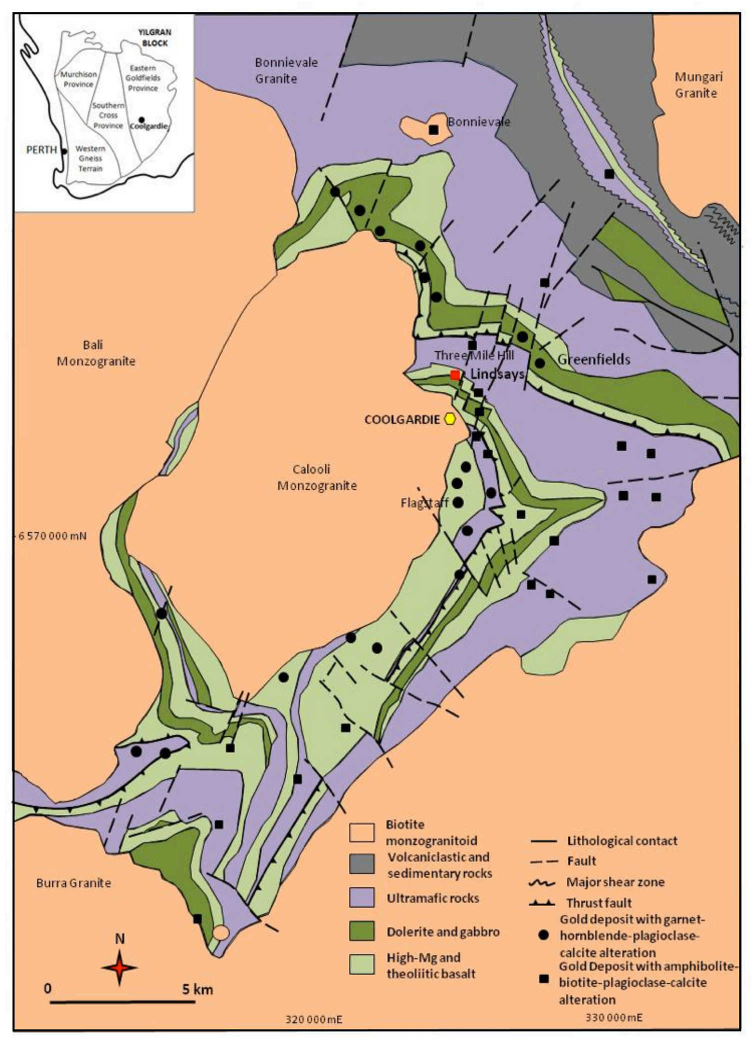
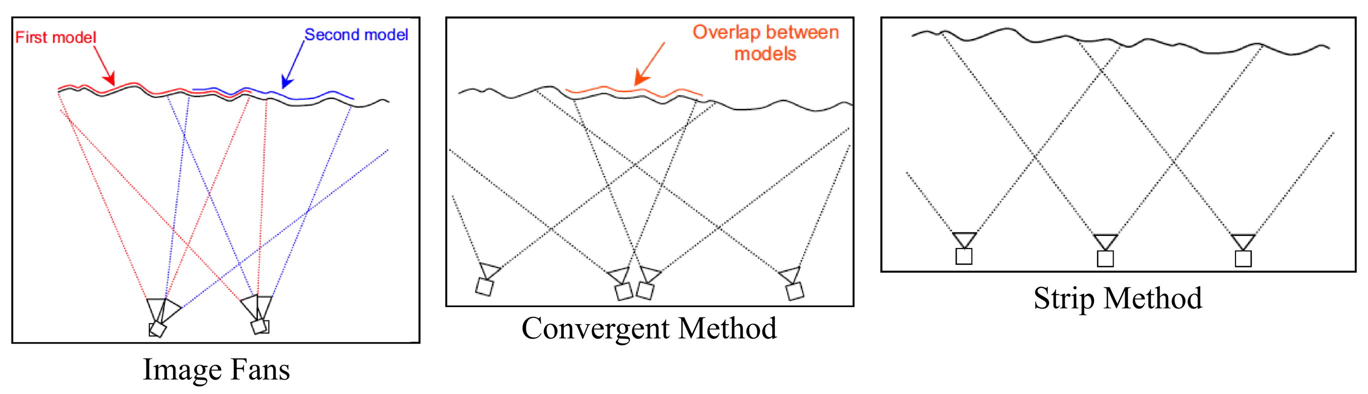


Fig 2. Geology of Coolgardie region. The red square represents the mine location (Modified from Knight et al., 2000)

METHODOLOGY

Photographic Survey



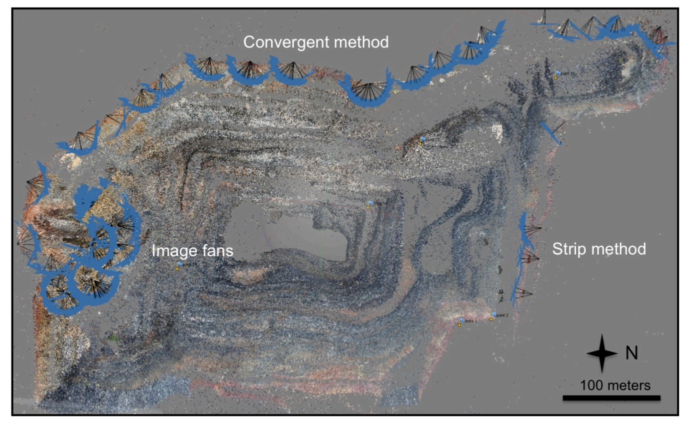


Fig 3. Point cloud showing various image capturing techniques used. Blue markers are showing locations of camera and facing of particular image.

Table 1. Shows number of captured photographs with respect to focal length of lens.

Focal length of lens (mm)	Total number of photographs	Total length of survey (hours)
28	230	1.5
50	2000	3-4
105	1650	> 4

Photogrammetric Experiments

Different results depends on the following main factors:

1. Number of photographs and details covered
2. Lighting condition which depends on time of the day and lighting angles
3. Position of the camera and their angle to the subject
4. Quality of the camera (DSLR vs Digital camera etc)
5. Configuration of the camera which includes ISO, aperture, focal length, shutter speed and different type of lenses etc

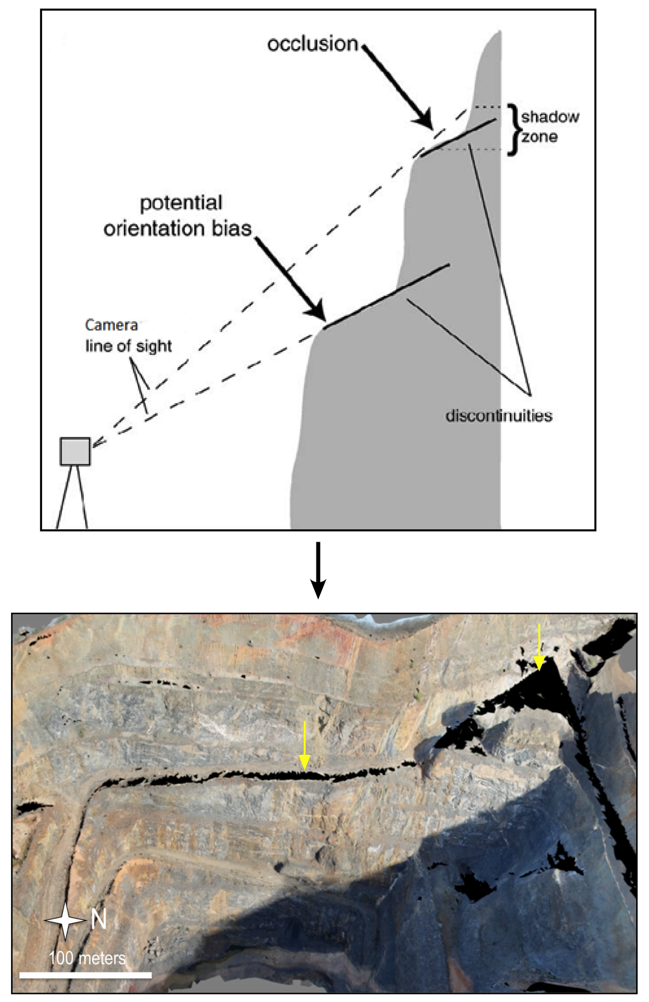


Fig 4. Illustration of occlusion and vertical orientation bias (modified from Sturzenegger et al., 2007).

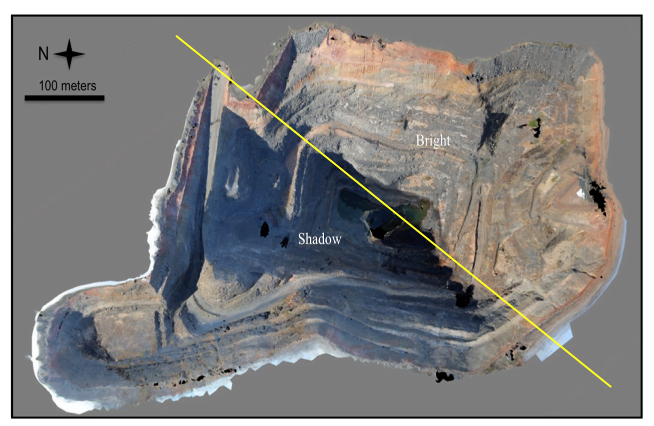


Fig 5. Figure showing impact of shadow on final model.

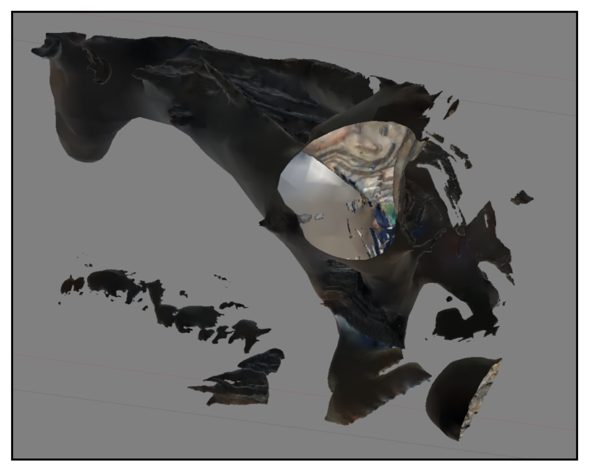


Fig 6. Distortion caused by mixing photographs from different lighting conditions.

Survey Conditions

Important considerations for the photographic survey in an open pit mine are:

1. Fixed focal Length
2. Lightening conditions and time of the day
3. Camera flash
4. Angle of capture to the object
5. Quality of the camera
6. Duration of photographic survey
7. Overlap between Images
8. Variety of camera positions and orientations

Lenticular Print Area

3D Modeling

Table 2. Shows total data processing time required using different parameters.

Type of lens (mm)	Number of photographs	Quality of model	Number of Polygons (Approx.)	Total processing time (hours)
28	150-250	High	90000	5-8
		Medium	40000	4-6
50	500-700	High	300000	30-35
		Medium	160000	20-25
		low	50000	10-15
105	600-700	Medium	250000	30-35

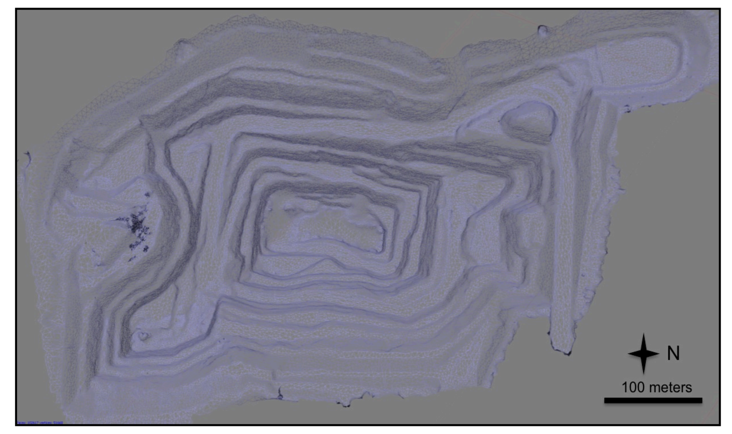


Fig 7. Geometric construction of a three dimensional wireframe model having total of 158353 faces.

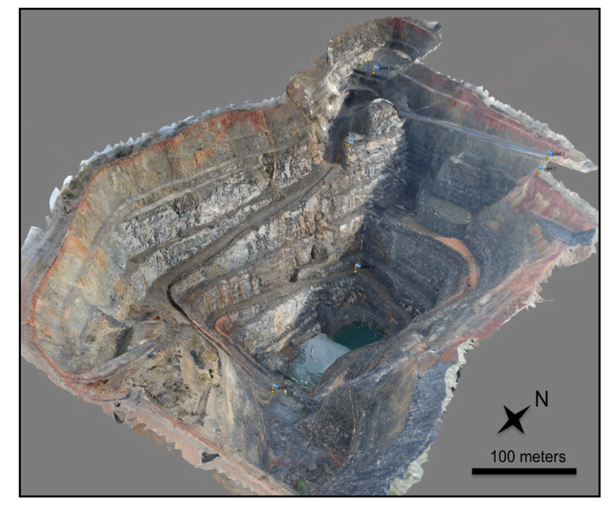


Fig 8. 3D textured model view toward NW, created using images from 50 mm focal length lens. Digital flags represent locations of ground control points for georeferencing.

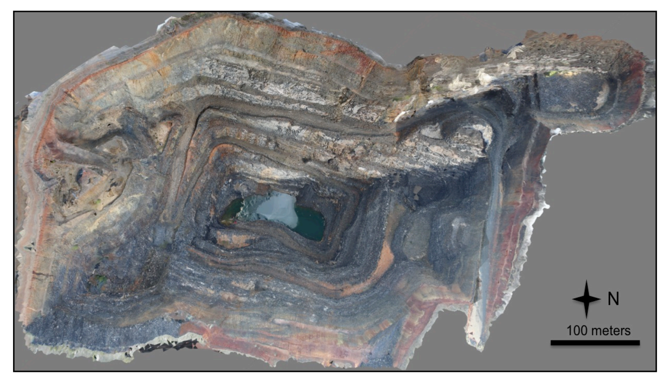


Fig 9. 3D model of Pit in map view. Created using images taken from 50 mm focal length lens.

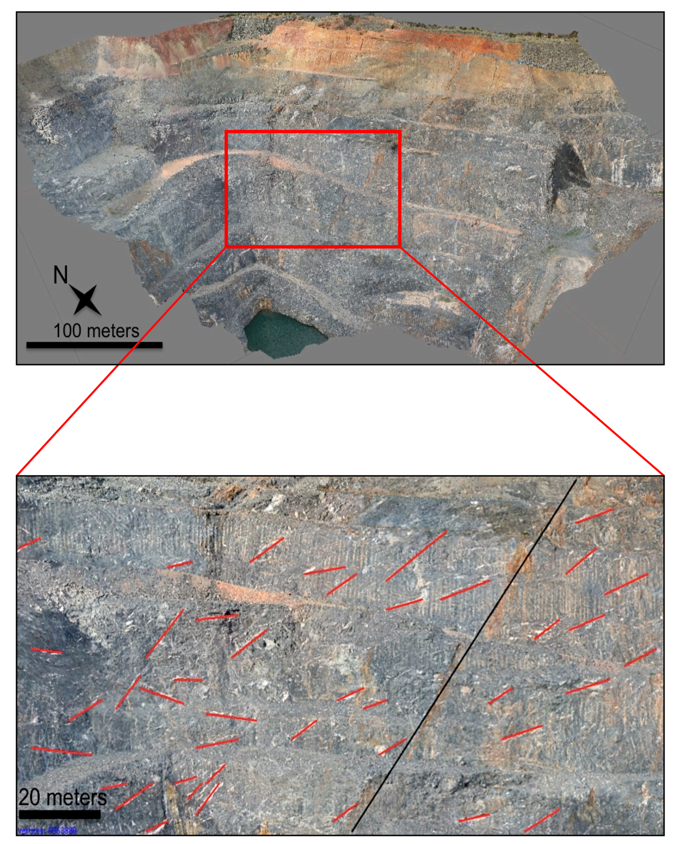
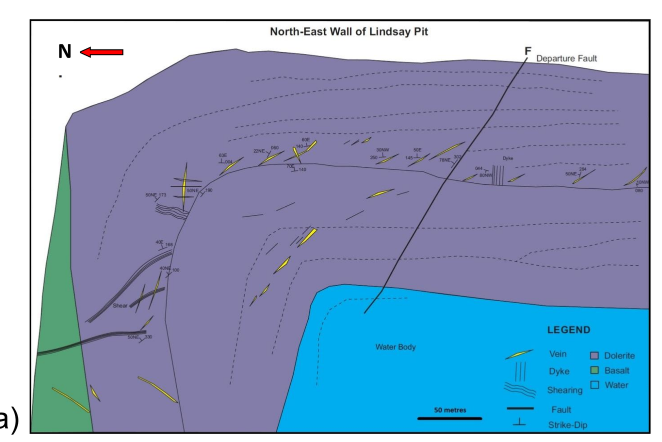


Fig 10. 3D model of north eastern wall, focal length: 50mm. Veins (red) and fault (black) marked.

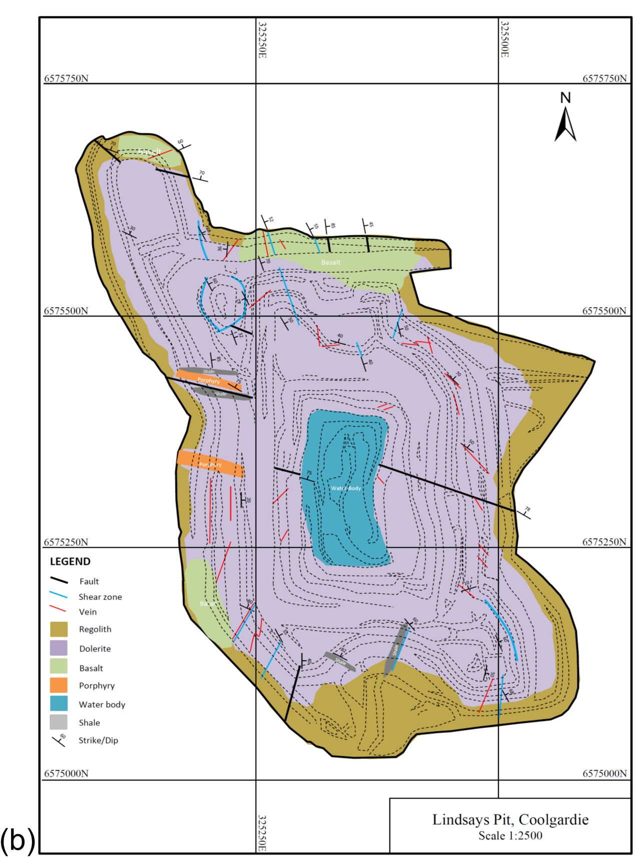
Field Mapping

Fig 11 (a & b). Field maps of Lindsays Pit showing the distribution of the larger structures and contacts around the pit.

(a)



(b)



Extraction of DEM and Orthophoto

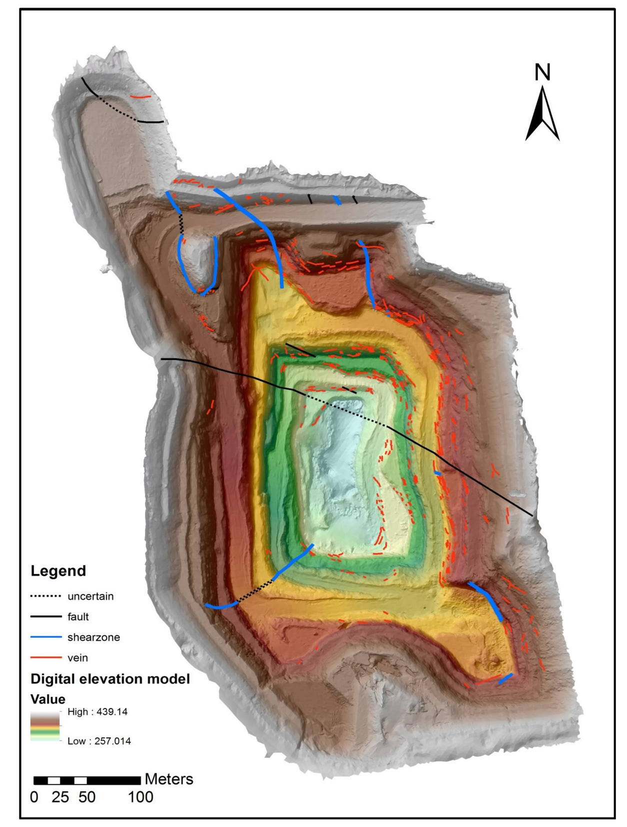


Fig 12. Digital elevation models (DEM) of entire pit with interpreted structural data. Elevation values are in metres.

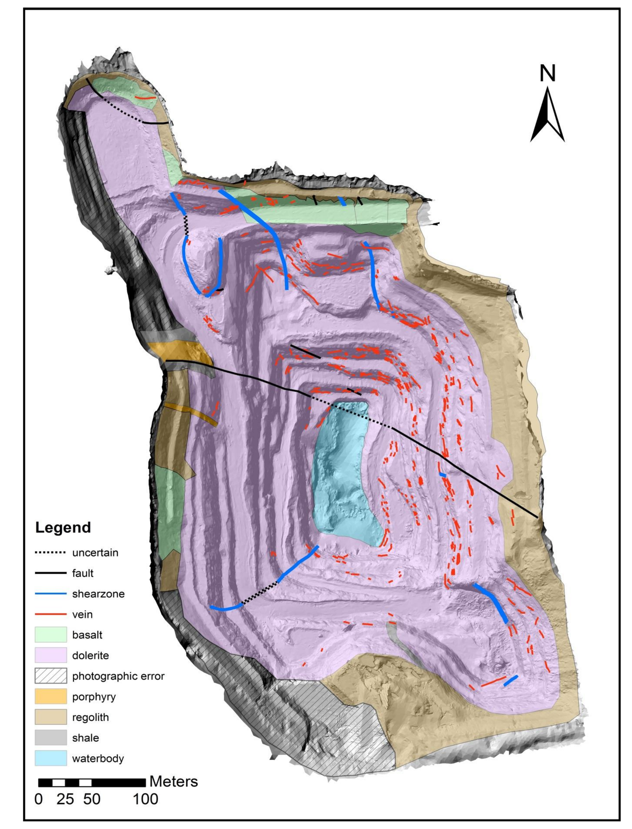


Fig 13. Digital maps produced in ArcGIS, showing trace of lithologies and structures mapped on georeferenced Orthorectified image of Lindsays pit.

RESULTS

Field and Digital Comparisons

Approximately 50% of the pit could not be accessed directly for geological mapping. In contrast, the photogrammetric model and orthorectified images of the pit allowed geological mapping over 100% of the pit at pixel resolutions of 23x23mm (50 mm lens model). Interpretations from the digital data were able to identify significantly more structures, especially quartz veins relative to field interpretations (at a ration of ~5:1).

Field observations were essential in order to be able to identify rock types and verify structural interpretations. It is concluded that this technique is a powerful enhancement to geological mapping in open pit mines, especially because of safety, accessibility and time pressures, however it is best complimented with field observations.

SIGNIFICANCE

Our preliminary trials have shown a number considerations must be taken into account to achieve satisfactory results, and that model quality is influenced by main parameters (Beamis et al, under review):

1. Lighting conditions: Reflective surfaces and strong contrasts in light across a scene negatively affect point matching. Diffuse lighting conditions are preferable.
2. Duration of survey: Because the sun's azimuth continues to change as a survey progresses, point matching between photographs becomes complicated by changes in shadow length and surface albedo. It has been found that model quality degrades significantly for durations >30 mins. For long-duration surveys,this affect can be circumnavigated by returning to the outcrop at approximately the same time the next day.
3. Image network geometry: The capture of photographs from a limited number of poorly distributed locations (stations) can lead to model distortions (e.g. Wackrow and Chandler, 2011; James and Robson, 2014) and missing regions.

The use of GCPs and convergent imagery is important to minimize (and identify) any such distortions. Convergent imagery will also allow reconstruction of complex surfaces with a wide variety of face directions. Outcrops, mine sites and quarries are best reproduced if there is access all around (including inside) and images are captured in an organised semi-continuous manner.

Photogrammetric digital mapping and the workflows developed in this study are now an ideal compliment to field mapping, being inexpensive and relatively efficient to produce. Large amount of digital data can be stored, shared and archived for future use.

References

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