

Recreating and Exploring the DPRK Nuclear Test Site in 3D to Calculate Possible Overburdens for Detonations

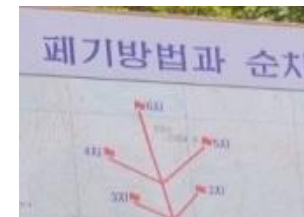
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**CTBTO Science and Technology Conference 2019,
Vienna.**

Background

On May 24th 2018 the DPRK invited a small number of international journalists to witness an event at the DPRK nuclear test site at Punggye-ri.

- No experts were invited.
- Effect of explosions on site's capabilities were not verified.
- A map was shown with the test locations marked on it.
- First time the DPRK had indicated where the tests had occurred.



AWE The map

An annotated topographical map of the region showing:

- Location of the tests;
- Location of adits (tunnel entrances);
- Schematic of the tunnels;
- Location of some buildings;
- Contours and point heights of the terrain.

But... no way to know accuracy or precision of marked locations.





The Work

Our work consisted of six tasks.

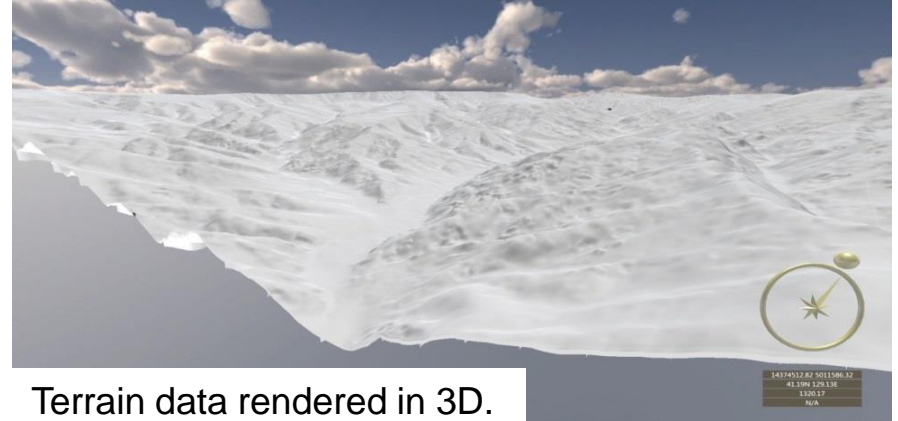
1. Assess photographs and video openly available after the event.
2. Geolocate the displayed map and extract from it the coordinates of the tests.
3. Calculate the test locations using:
 - Seismic waveforms from the tests, and
 - Indicated location of the 2009 test.
4. Compare calculated locations to the indicated locations from the map.
5. Use photographs and video to geolocate the tunnel entrances (adits) for simple overburden calculation.
6. Display those results in a 3D reconstruction of the site, including photographs from the event.

Data

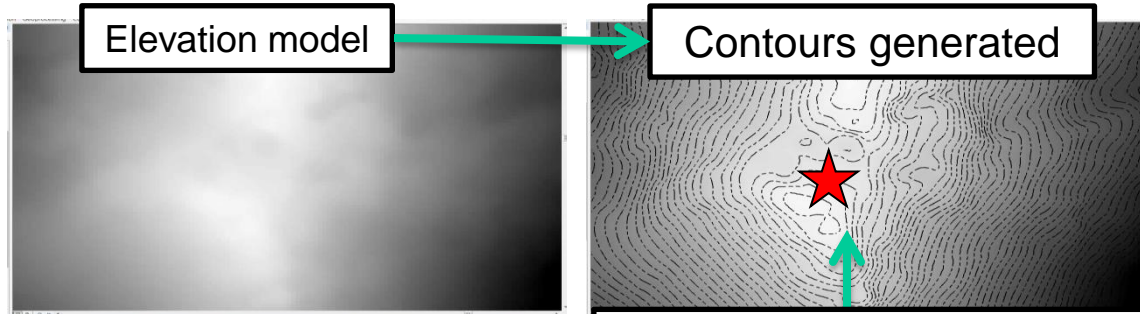
- USGS terrain data at 5 m horizontal spatial resolution.
- Photographs of the map.
- Imagery from ground level.
- High resolution satellite imagery from ESRI web service and Google maps.

Tools

- Workstation class laptop.
- Geographic Information System Software (ArcGIS Desktop)
- 3D visualisation tool (GeoVisionary)

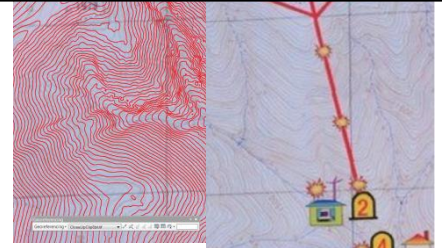


Process to geolocate the map image.

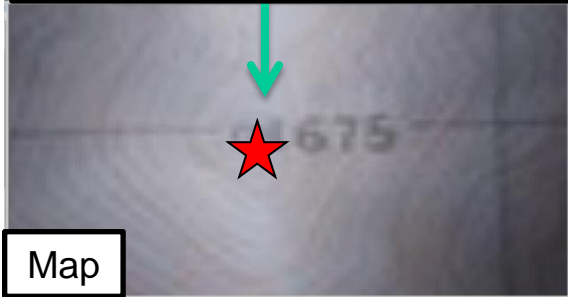


Reference points used to scale, warp and locate map spatially.

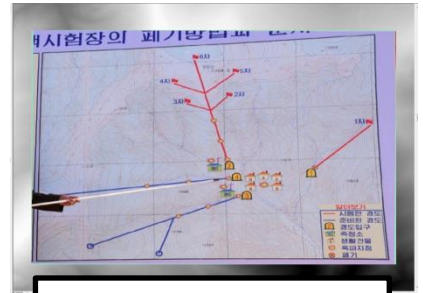
Compare geolocated map and elevation data



Compare topography



Approximately 12 reference points generated this way.



Geolocated map on elevation model

- As map included point heights.
- Compare contours around height point with contours from elevation model.
 - Match areas/points on elevation model to points on map, e.g. a marked point height.
 - Use that point as *tie* point for geolocation process.



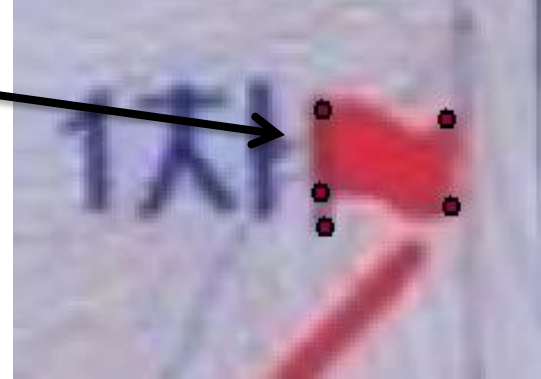
Geolocated map wrapped onto 3D landscape.



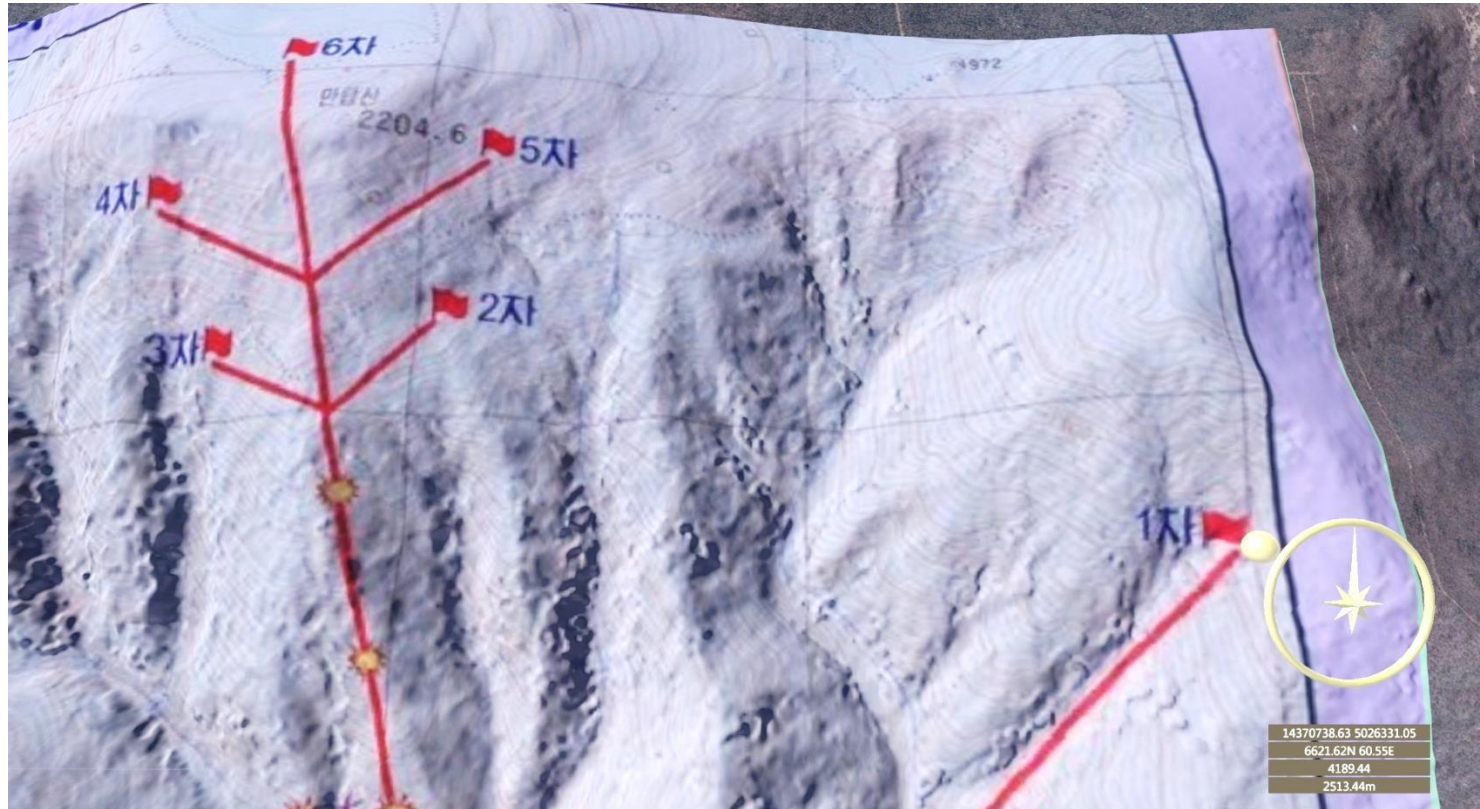
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Seismic calculation

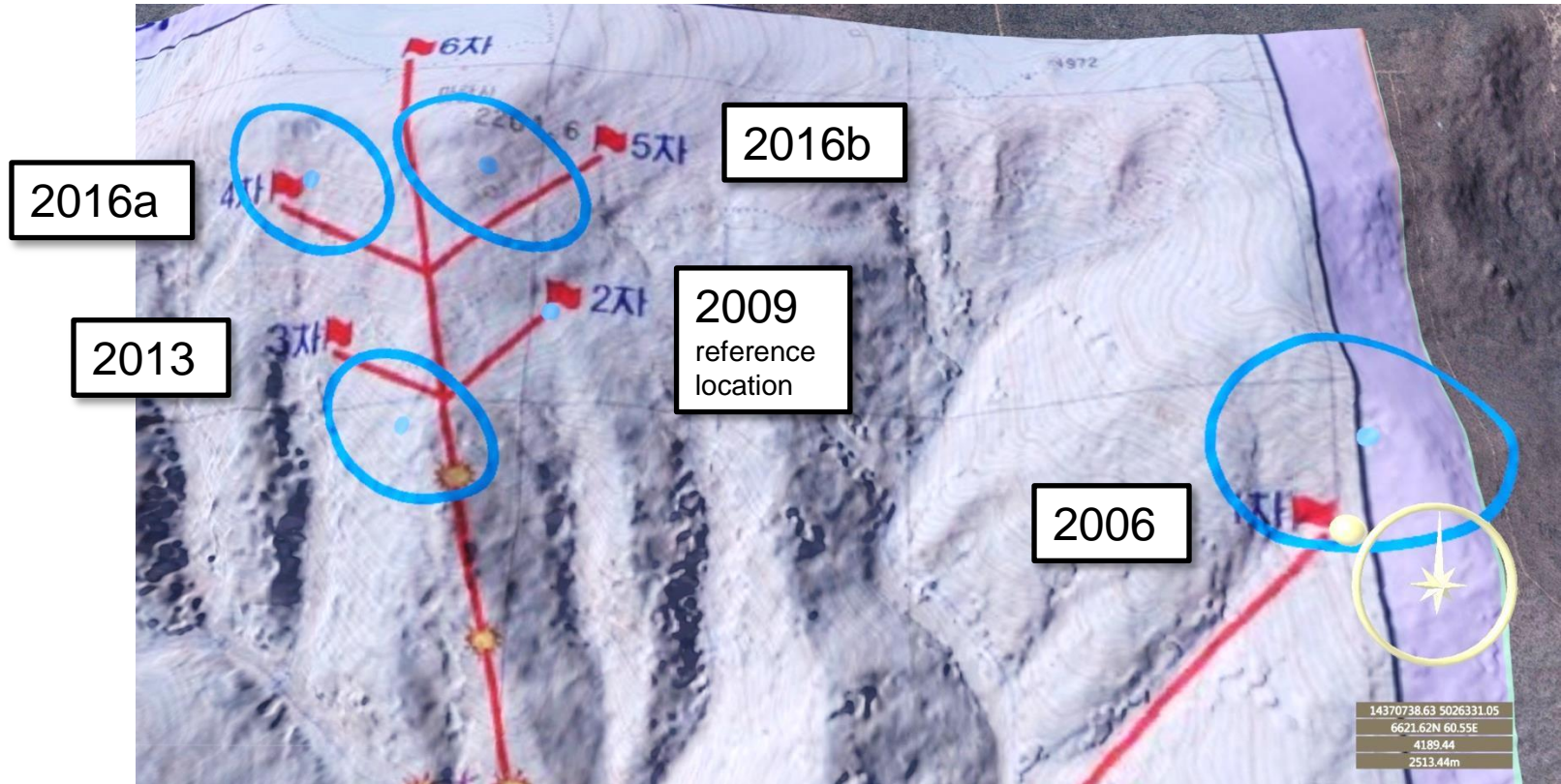
- Extract coordinates of declared locations from map.
- Select reference point.
 - Base of the flagpole for the 2009 test.
- Calculate the epicentres and uncertainty ellipses for all tests.
 - 90% probability that the true epicentre location lies within the ellipse.
- Those data were converted into a shapefile and plotted.
- They were loaded into 3D visualisation tool.



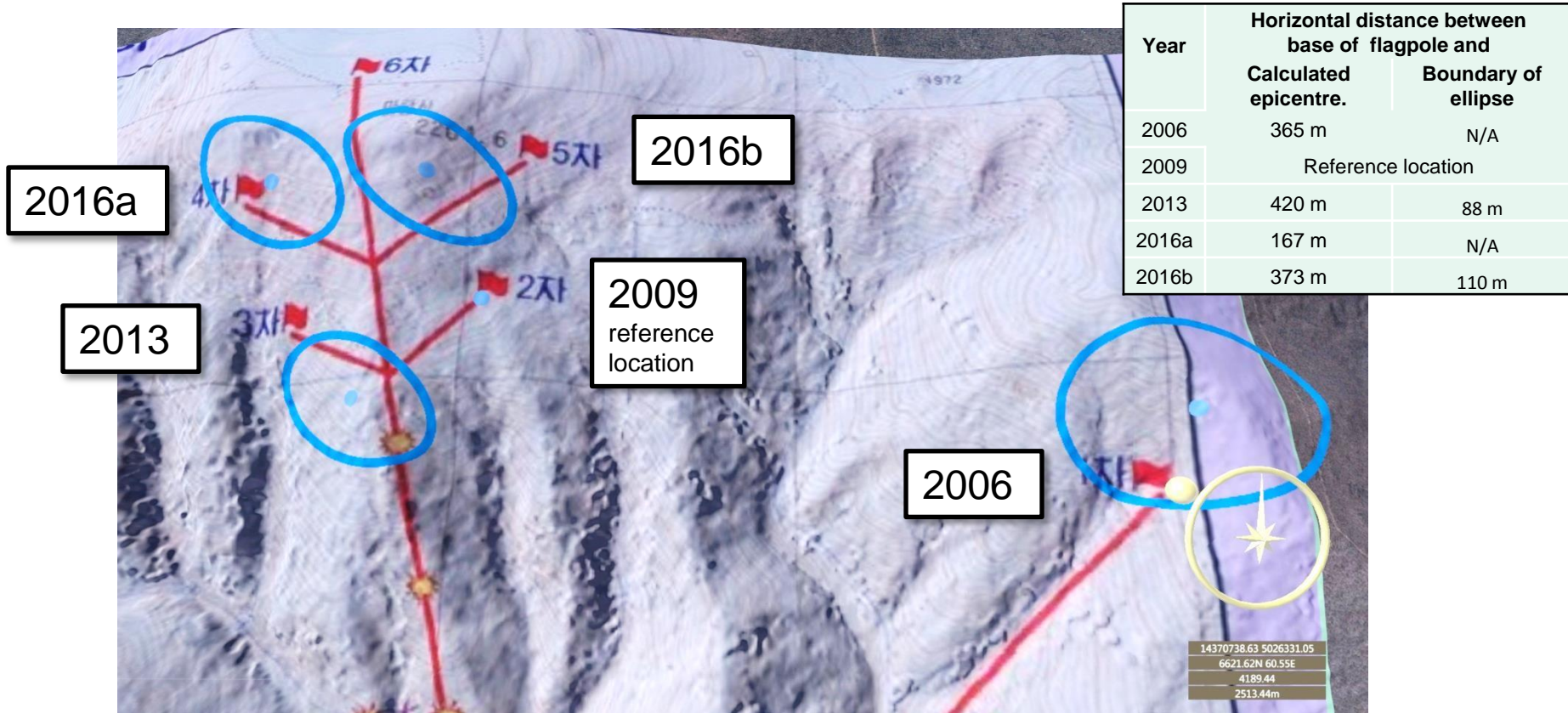
New epicentres and ellipses calculated from flag data.



New epicentres and ellipses calculated from flag data.



New epicentres and ellipses calculated from flag data.





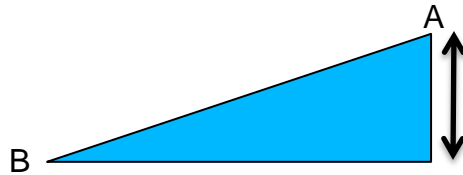
Calculating the overburdens.

Simple overburden calculation.

A= height of ground directly above epicentre.

B= height at adit

Overburden = A-B



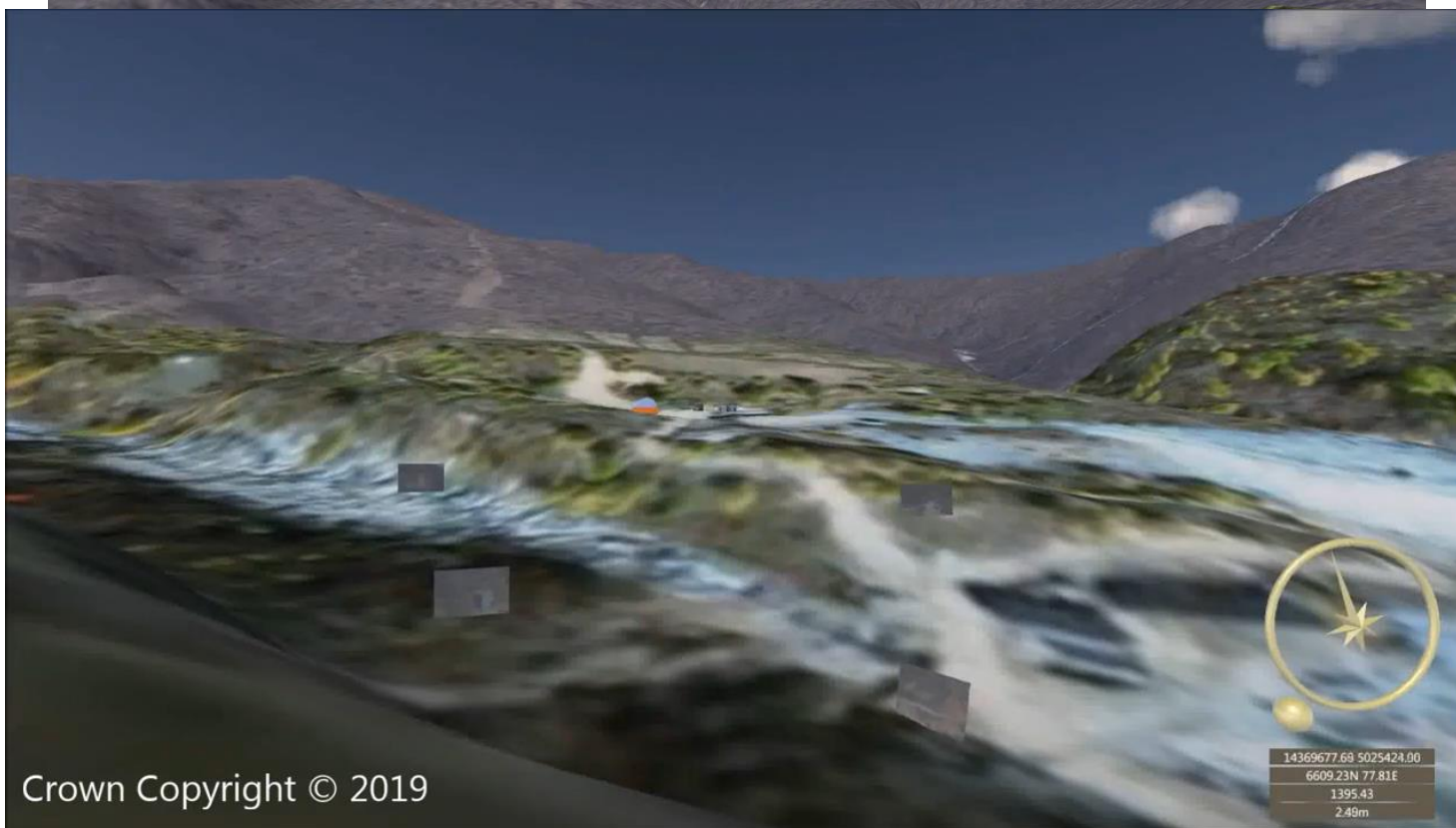
Heights taken from USGS terrain data.

But, exactly where were the adits?

Location deduced from features captured in both the ground photography and satellite imagery.



Locating the adits



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Overburden results and comparison

Summary of results

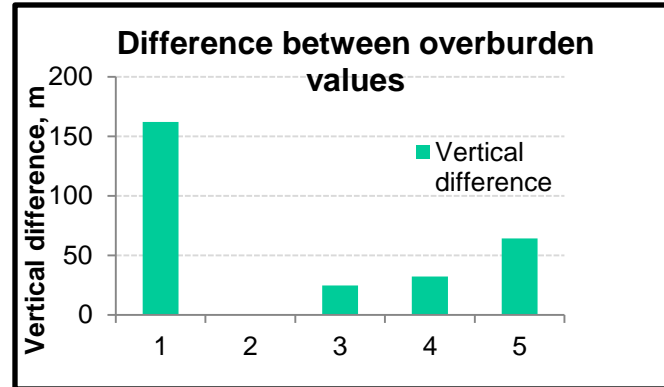
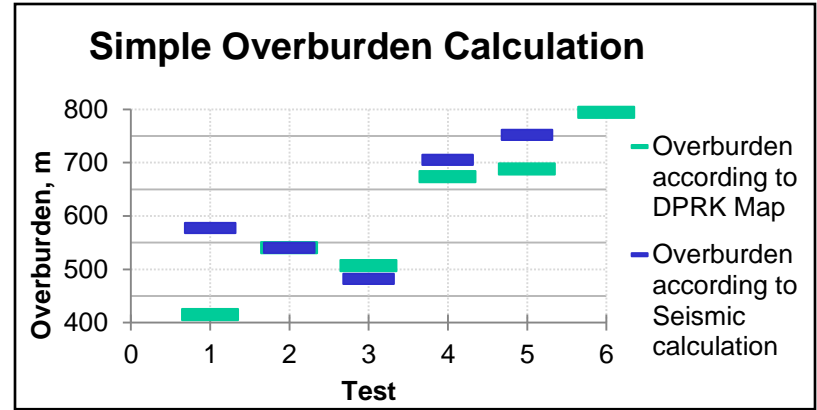
Overburden (vertical height)

General increase in overburden from ~400m to ~800m.

Calculated overburden matches DPRK value within 70 m for most tests.

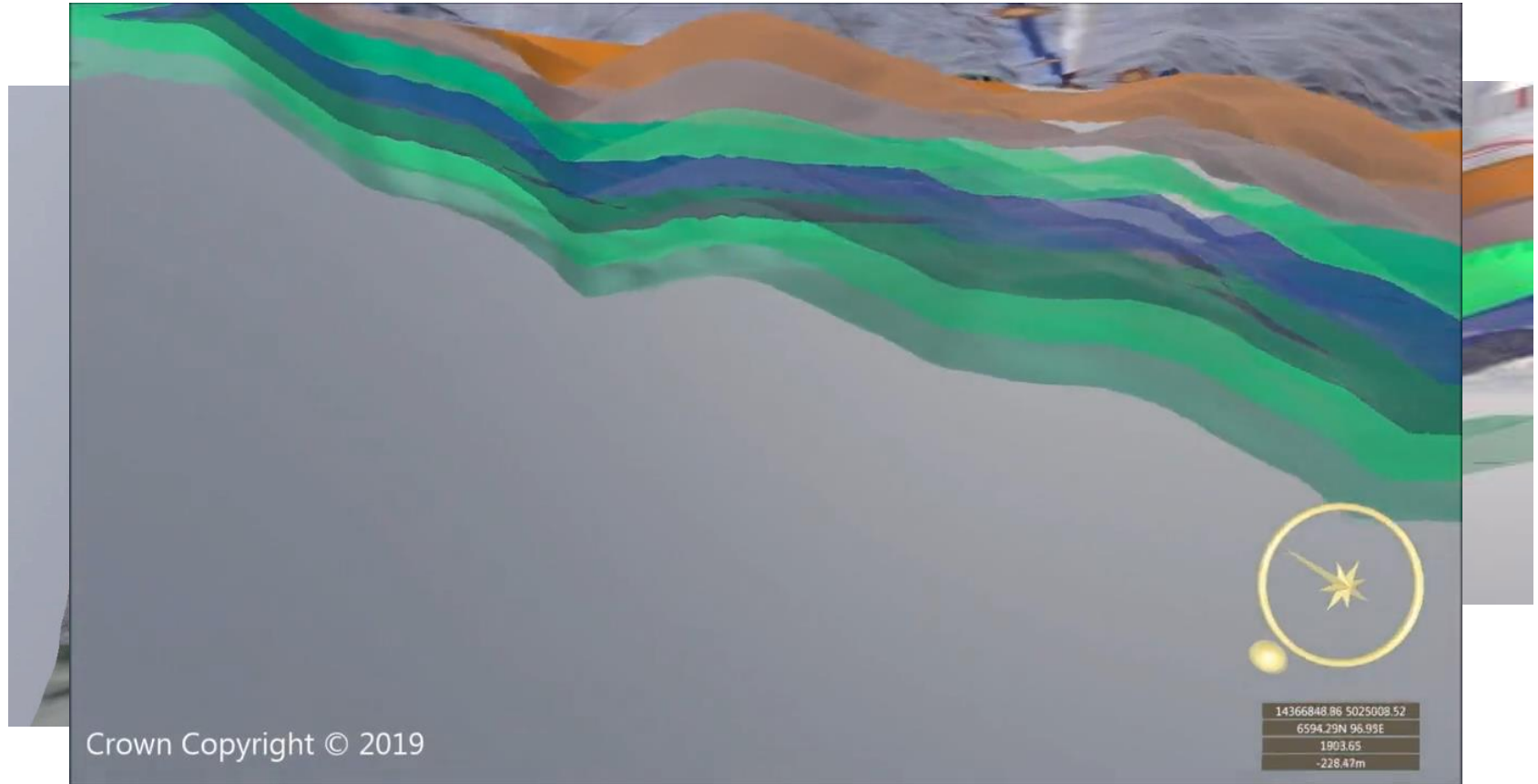
- Largest vertical difference due to local topography.

The outlier is the 2006 but there may be some non-technical reasons for that difference.





Visualising the overburdens



Conclusion

Imagery from the DPRK nuclear test site event in 2018 were used to geolocate map which indicated the locations of the epicentres for tests.

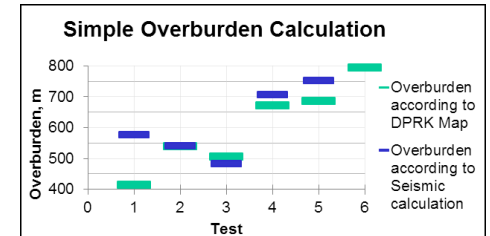
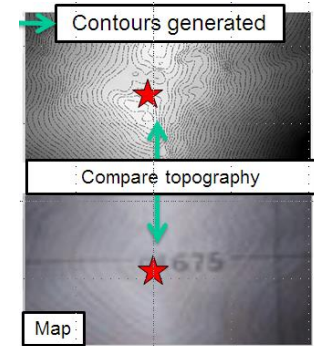
The test locations then calculated from their seismic waveforms.

- There was a reasonable match between the indicated and calculated locations, with a maximum of 420 m horizontal distance between an indicated epicentre and a calculated one.

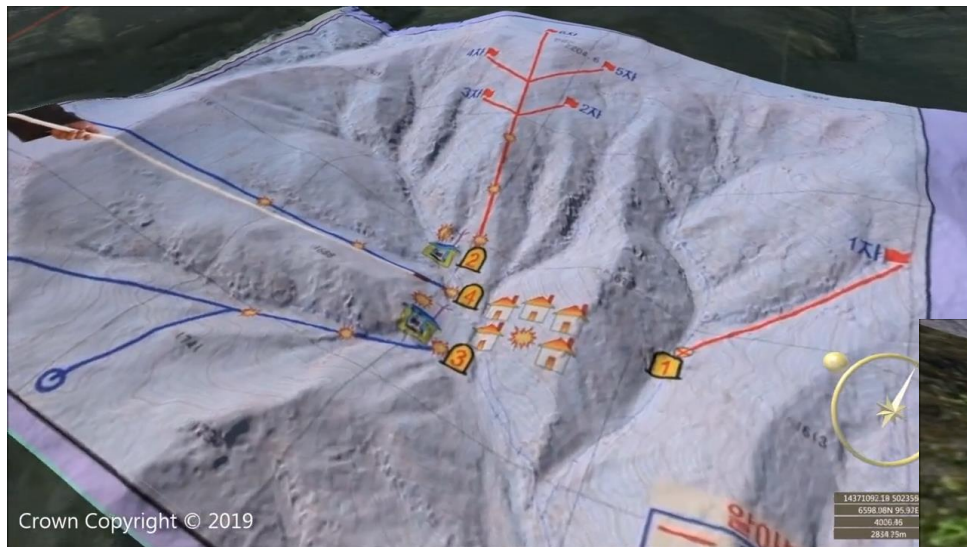
Tunnel adits were also geolocated, so a simple overburden calculation could be made for both indicated and calculated epicentre locations.

- Good agreement between indicated and calculated overburdens.
- General increase in overburden with time from approximately 400 m to 800 m.
- Vertical difference generally less than 70 m. (Outlier, 2006 test was 160 m)

A 3D model of the site was built to aid analysis, aid understanding of the site and explore it in virtual reality.



Questions?





The map





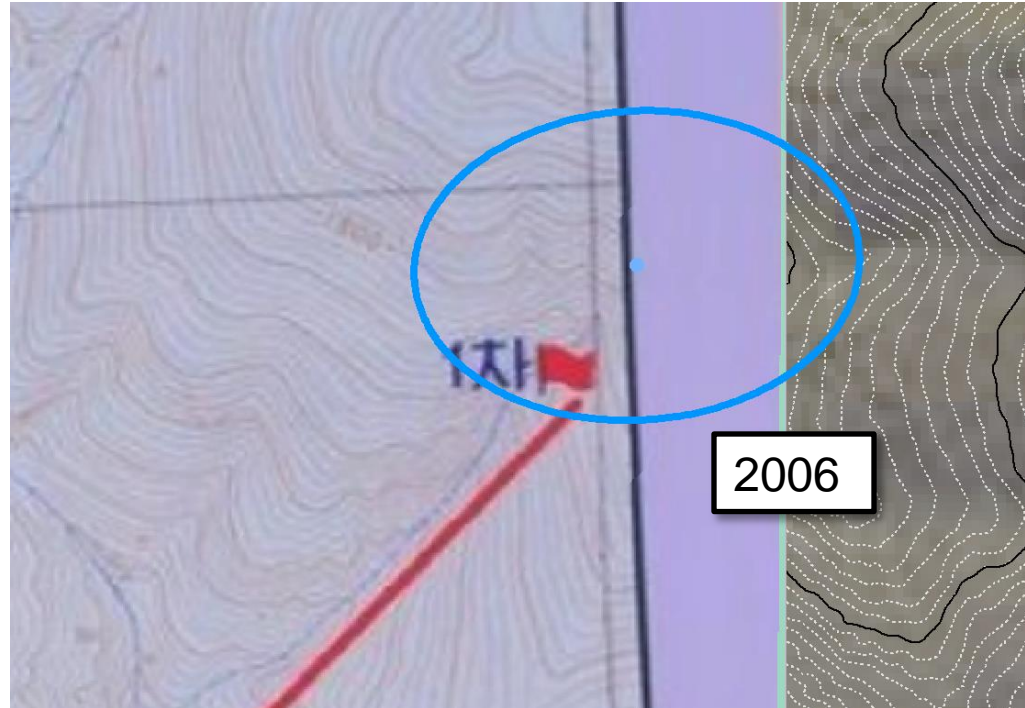
Comparing overburdens: The Outlier

2006, the outlier

Largest difference between map and calculated location.

Could the outlier be a victim of cartographical convenience?

Declared location is very close to edge of the map.





Comparing overburdens: The Outlier

2006, the outlier

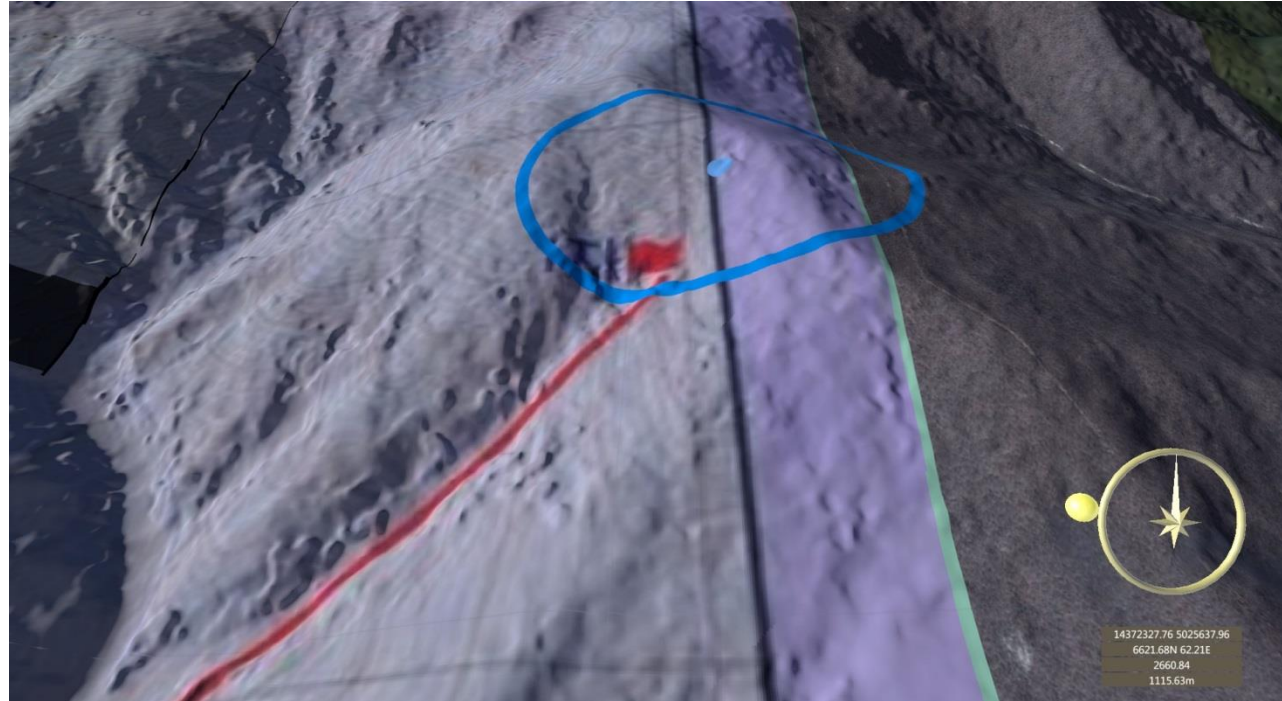
Largest difference between map and calculated location.

Could the outlier be a victim of cartographical convenience?

Was the location shifted slightly to fit on the map?

The calculated location was 365 m up slope from the declared location.

Would have given an extra 160 m of overburden for an additional 360 m of tunnelling.





Comparing overburdens: The Outlier

View of 2006 locations from 60 m above the ground.

Position used for declared location.

Position of calculated location.

