Abstract
Performing mineral exploration operations within remote, mountainous areas is always difficult, expensive and time consuming. This case study highlights an example where a high quality Digital Elevation Model (DEM), derived from satellite imagery, is an extremely effective tool to use within these operations. The study area is located in the Andes Mountains in Southern Peru. The large elevation range and the remoteness of the area justified the use of a high resolution DEM as part of the exploration process. The 5-metre resolution ALOS World 3D (AW3D) topographic data was identified as a superior solution to off-the-shelf medium resolution DEMs. The use of AW3D within the exploration process has resulted in significant time savings in the crucial interpretation and planning stages, improving the ability of field teams to access the highest priority targets first. This data will continue to add value throughout the exploration stages of the projects including accurate siting of drill pads and 3D modelling of other datasets. This case study provides a good example of how a high quality satellite derived dataset, such as AW3D, can be employed within the mineral exploration phase of a mining operation.
Introduction
Mining operations within remote areas can often provide a number of challenges, requiring innovative ideas or solutions to optimise efficiency. For clients, operating in areas such as the Andes mountains these problems need to be overcome very early on in the exploration phase. The use of remote sensing datasets, such as ALOS World 3D (AW3D) Digital Elevation Model (DEM) within the mineral exploration phase of the mining life-cycle is an example of such innovation. The AW3D dataset, when combined with Very High Resolution satellite imagery can provide a wealth of information for a number of phases, particularly during exploration and planning.

Challenges
The Project Area is 678sqkm in size, located within the Andes Mountain Range in Southern Peru and is mountainous with elevations ranging from 1809m to 4791m and slopes ranging between 0 to 81 degrees. Such steep terrain means that vehicular access within the region is limited, due to a multitude of un-crossable steep sided valleys that cut through the project area. Navigating within these steep sided creek valleys on foot provides the best means to map the project, due to the fact that they incise geology and provide good geologic exposures. However, navigating around the creek valleys is also necessary for accessing the further afield regions of the project, as well as for the purposes of taking gridded samples for analysis and for less detailed surface geologic mapping. Therefore, consultation of 3-dimensional terrain models and imagery is vital before going into the field. Such consultation allows large savings in time and energy that otherwise would have been used in the field walking down dead ends. This is especially important in locations like the Andes, where high altitude walking exacerbates energy and effort spent.

Applications/Solutions
During the early exploration phase of the project, freeware such as Google Earth was sufficient to use for basic navigational mapping purposes. However, as it became clear that the project would advance beyond the generative exploration phase, the decision to invest in high resolution satellite imagery and terrain models became compelling. The large size and remoteness of the project area lent itself to the utilisation of imagery and DEM derived from satellite imagery. Complete imagery coverage over the area was available from Maxar’s extensive, very high resolution imagery archive. However, only monoscopic imagery was available. The lack of archive, stereo data meant that a decision regarding the DEM dataset was required.

Figure: 3D visualisation WorldView-2 over AW3D DEM
The option of acquiring very high resolution, stereo data was considered and was rejected for the following reasons:

- The possibility of cloud, and cloud shadow being present within the fresh capture imagery. Any portions of the stereo data that contains cloud, or cloud shadow, preclude the production of elevation values. The resultant “holes” would require infilling with low resolution datasets such as Shuttle Radar Topography Mission (SRTM) 90m data, or ASTER GDEM 30m data;

- Very High Resolution satellites typically acquire data, including stereo captures, at off-nadir angles that were deemed undesirable over the project area. Given the topography throughout the area, there was a high risk of no stereo data due to occlusion, particularly over the steep creek valleys. Again, these “holes” would require infilling with SRTM or GDEM data; and

- The overall requirement did not necessarily dictate that an expensive 1m DEM dataset was necessary.
Once the decision was made to reject a 1m DEM dataset, AW3D was then considered. When considering suitability for this particular area, AW3D was found to have the following benefits:

- AW3D is generated from the large archive of triplet mode imagery acquired by the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) sensor on the Japanese ALOS satellite. The dataset is produced by using numerous triplet datasets, which serves to either reduce or totally remove cloud and smoke effected areas. In our case, a dataset was available over the area that had no cloud effected area, and therefore fully covered with 5m elevation data;

- The PRISM Triplet dataset involves forward-looking, backward-looking and nadir sensors. Of further benefit, ALOS typically acquired data with minimal off-nadir capture angles. The triplet configuration, combined with direct overflight of the satellite meant that there was a significant reduction of occlusion holes, caused by slope;

- Because the AW3D is produced as an “off-the-shelf” product, there was minimal delivery time of the product, this combined with a relatively low expense, meant that the data could be quickly incorporated within the exploration operations; and

- The 5m resolution was considered more than adequate to support operations.
Outcomes/Benefits

The 5m DEM and high resolution satellite imagery are now vital parts of the 3D geologic model. Interpretation of geochemical and geophysical data using the 3D terrain model is essential in such rugged terrain. The DEM and imagery also assist with drill hole and environmental planning as well as a higher resolution dataset to examine for terrain accessibility.

Importantly the satellite imagery is a few years more recent than the Google Earth, as such it has more updated roads and infrastructure information.

The purchase of the detailed satellite imagery has the added importance of having a dated image showing the environment before any invasive exploration or mining activity has been initiated; therefore providing a baseline of the undisturbed land that can be used as part of any environmental permitting that may take place in the future.

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