The Application of Highly Accurate Stereo Satellite Elevation Mapping to Mining Exploration Geology and Mine Development

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Introduction

Highly accurate stereo satellite elevation mapping is now an established technology used on mining exploration and development projects throughout the world. PhotoSat has produced over 350 highly accurate stereo satellite elevation mapping projects since high resolution stereo satellite data first became commercially available in 2004.

New geophysical stereo satellite elevation processing methods are producing stereo satellite Digital Elevation Models (DEMs) with unprecedented horizontal resolutions and vertical accuracies, demonstrated by direct comparison with thousands of ground survey points and LiDAR DEMs. In areas of sparse vegetation 1m posted DEMs produced from 50cm stereo satellite photos have elevation accuracies much better than 50cm RMSE. These DEM's have resolutions and accuracies similar to high quality LiDAR DEMs.

Figure 1. *Over 350 highly accurate stereo satellite elevation mapping projects completed by PhotoSat since 2004. 80% of these are mining projects.*

The most frequent application of PhotoSat's stereo satellite elevation maps has been for use in volume calculations for Canadian National Instrument 43101 mining reserve and resource estimates.

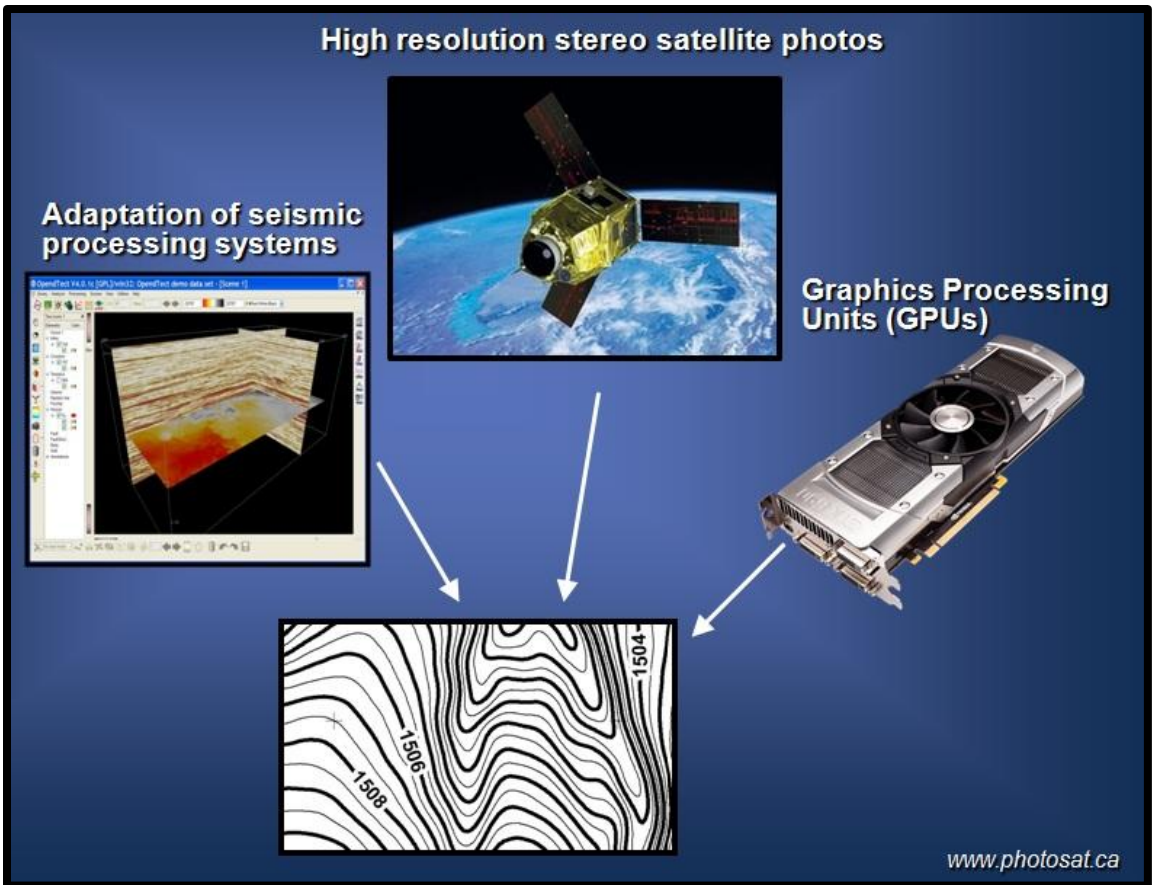

Figure 2. *The three main components that enable the creation of high resolution, high accuracy satellite DEM's are 50cm resolution stereo satellite photos, seismic processing concepts and systems and Graphics Processing Units. The 3D seismic display is from OpendTect, the satellite is Pleiades owned by the French government and the GPU is the NVIDIA Gforce GTX 690.*

Geophysical stereo satellite elevation mapping

This stereo satellite DEM resolution and accuracy is being achieved by adapting data processing concepts, algorithms and software, originally developed for oil and gas exploration seismic data processing, to process elevations from stereo satellite photos. The seismic processors' toolbox contains a wide variety of processing tools for identifying and attenuating correlation mismatches and other types of noise that have probably never before been applied to stereo photo elevation mapping problems. Elevation mapping from satellite photos to better than 50cm accuracy is enabled by two new technological developments and the application of an existing technology to a new field.

The new satellite technology is the stereo 50cm ground resolution GeoEye-1, WorldView-1, WorldView-2 and Pleiades satellites. These satellites have ground positioning accuracies of better than 5m and relative horizontal accuracies of

approximately 50cm in 10 km. One of the newest of these satellites, the Pleiades satellite, owned by the French Government, is shown in figure 2.

Graphics Processing Units (GPU's) are capable of performing floating point calculations three orders of magnitude faster than CPU's making the calculation of the hundreds of millions of 2D Fourier transforms necessary for precise elevation computation from the stereo satellite photos cost effective. A four teraflop NVIDIA GTX 690 GPU is shown in figure2.

The third element that enables high accuracy, high resolution stereo satellite elevation mapping is the application of oil and gas seismic exploration processing concepts, algorithms and software to processing elevations from stereo satellite photos. (Mitchell & Ehling 2010a). While the physics of the reflection seismic and stereo satellite problems are fundamentally different, both problems require accurate image matching. To our knowledge many of the image matching and noise attenuation concepts, algorithms and processes, developed over the past 50 years for matching reflection seismic data from different source and receiver geometries, have never before been applied to matching stereo satellite photos. We call this a geophysical stereo satellite elevation mapping process to differentiate it from conventional photogrammetric stereo photo elevation mapping processes.

Mining exploration geology and mine development

PhotoSat has provided stereo satellite elevation mapping for nearly 300 mining projects around the world, over 80 of which are in Mexico. Figure 3 shows a 200 km^2 stereo satellite elevation mapping project at Mag Silver's Cinco de Mayo project in Chihuahua. The stereo satellite elevation mapping was registered to a single ground survey point. The elevation mapping accuracy of 19cm RMSE was determined from 1,115 survey points.

Significant new geological information, particularly structural geology, can be mapped on many of these highly accurate stereo satellite elevation maps. A pattern of arcuate faults, symmetrical around a silicified breccia on the flank of a dacite dome in Western Zacatecas can be clearly seen in the stereo satellite slope direction image shown in figure 4. The slope direction image is derived from the stereo satellite elevation mapping.

PhotoSat has used stereo satellite elevation mapping to measure volumes in many mine sites. In February 2010 we carried out a demonstration project at the Penasquito mine in Zacatecas. We acquired stereo satellite photos of Penasquito on January 31 and February 27, 2010. From these two sets of satellite stereo photos, and the elevation maps derived from the stereo photos we measured the volume changes in the Penasquito pit, waste dump, ore stockpiles and leach pad during February 2010. The February 2010 volume increases and decreases in the Penasquito pit, waste dumps, ore stockpiles and leach pad and the volume increases due to blast heave are shown in figures 5 and 6.

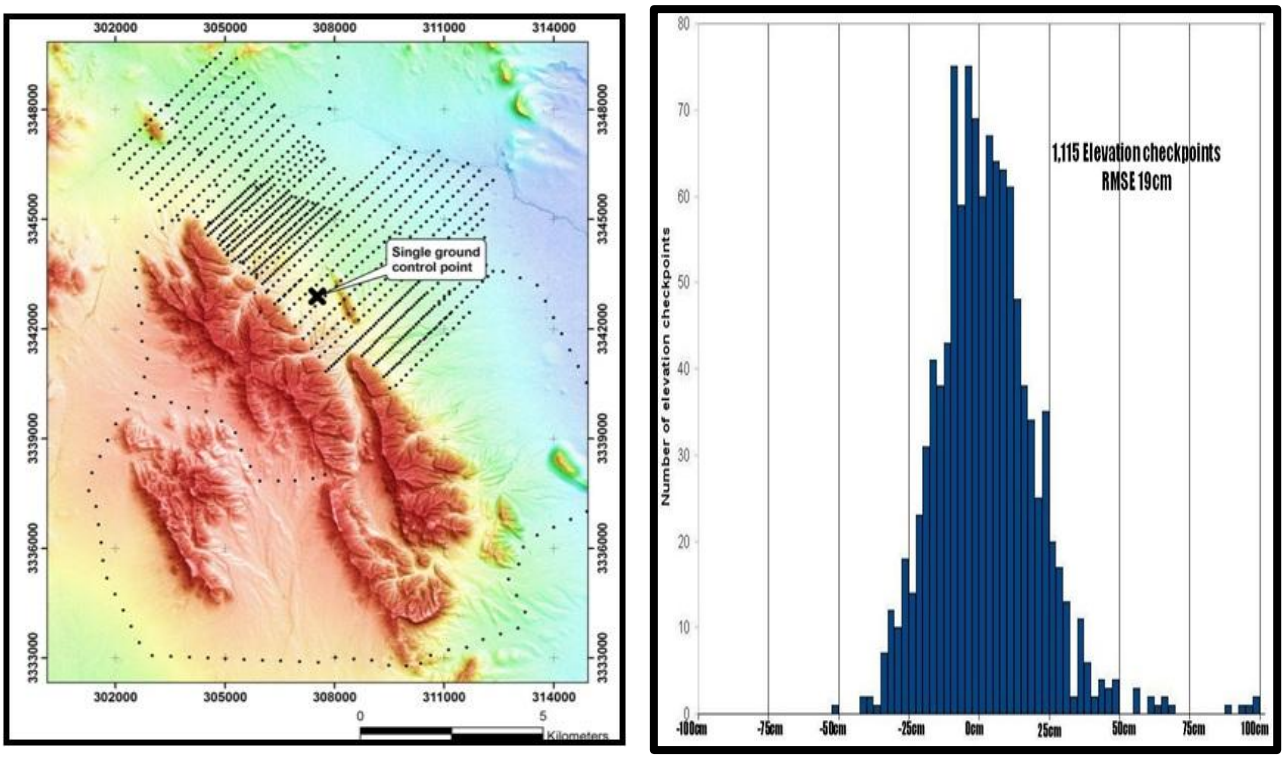

Figure 3. *Stereo WorldView satellite elevation image of the Cinco de Mayo project in Chihuahua. The satellite mapping was referenced to a single ground survey point. An elevation mapping accuracy of 19cm RMSE was determined from 1,115 survey points.*

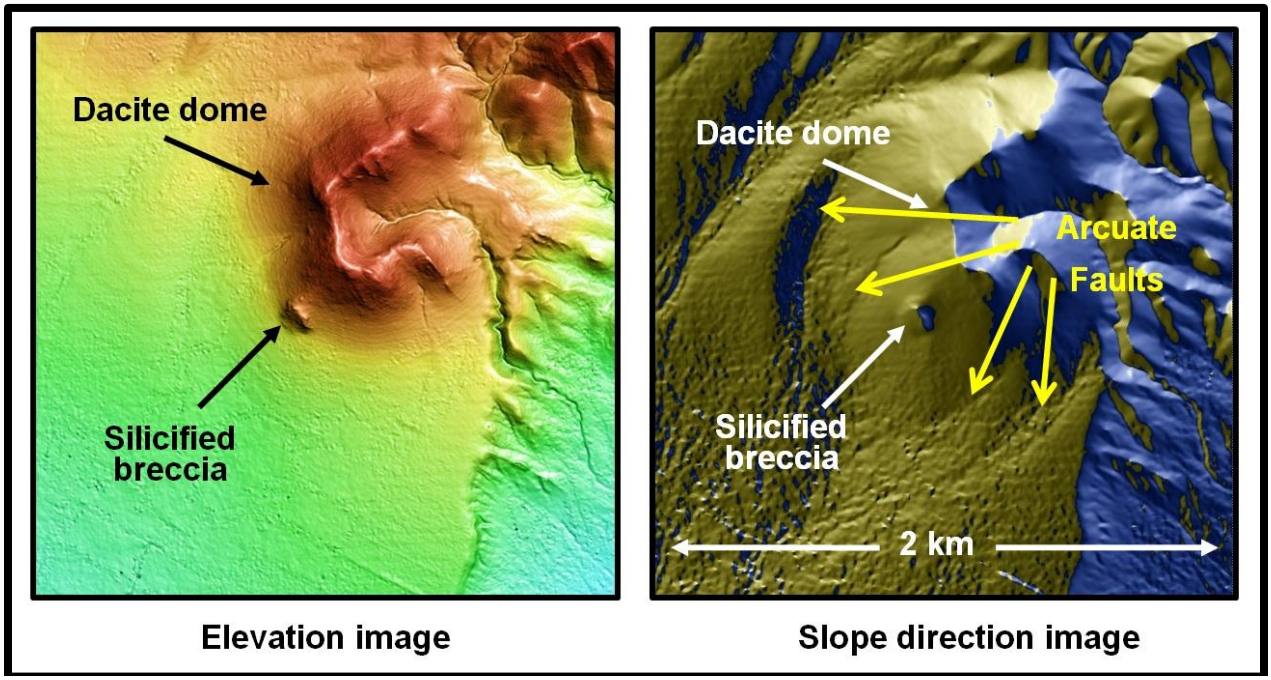

Figure 4. *Stereo WorldView satellite elevation image showing a silicified breccia on the flank of a dacite dome. The slope direction image, derived from the stereo satellite elevations, clearly shows a pattern of arcuate faults symmetrical about the breccia. These faults are not visible on the satellite photos nor on any other data set.*

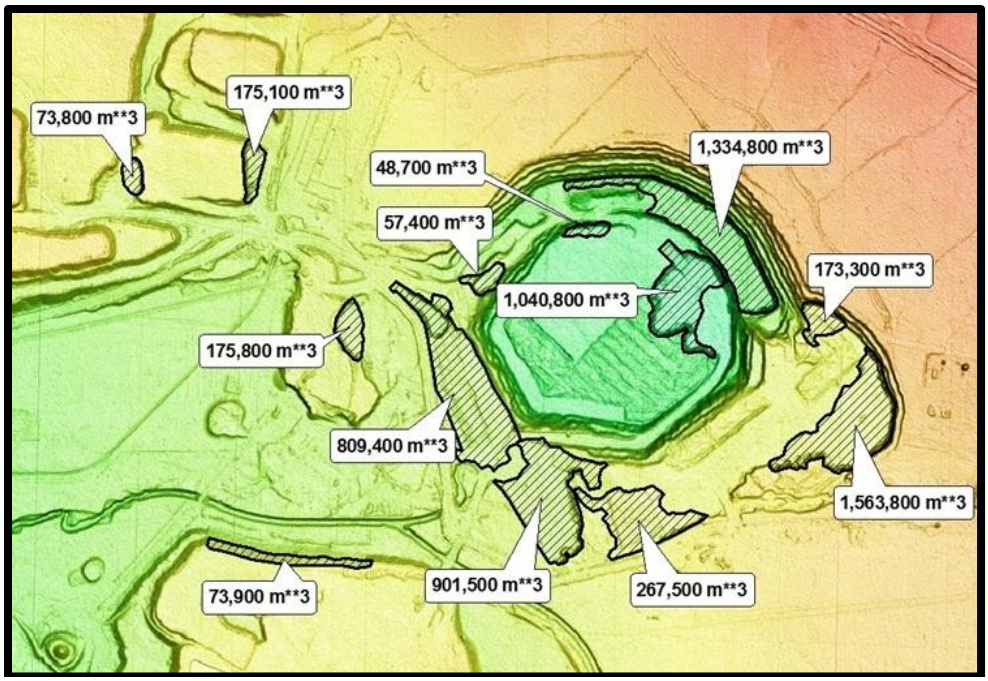

Figure 5. *Volume decreases at Penasquito during February 2010. The volume changes were determined from stereo satellite elevation maps for January 31 and February 27, 2010.*

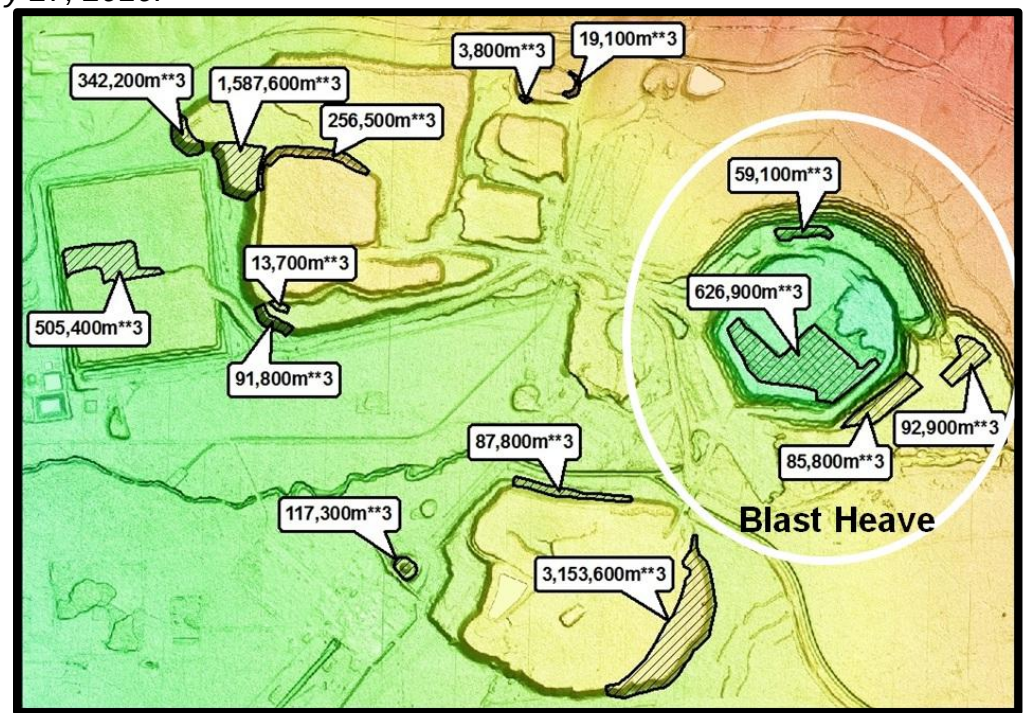

Figure 6. *Volume increases at Penasquito during February 2010. The volumes changes were determined from stereo satellite elevation maps for January 31 and February 27, 2010. There was extensive overburden stripping during February 2010 as can be seen from the over 3 million m^3 (~6 million tons) added to the waste dump.*

Verifying and quality checking drill hole locations is a challenge on many mining projects. The stereo satellite elevation maps and precision ortho photos are often used to accurately determine the coordinates of drill holes, trenches and other mine features. PhotoSat located over 700 drill hole collars on Orko Silver's La Preciosa silver project using stereo satellite elevation mapping and precision ortho photos. Each of the La Preciosa drill holes has a 40cm by 40cm white concrete block at the drill collar. The concrete block for one of these drill collars and the appearance of the concrete blocks on the high definition WorldView-2 satellite photos are shown in figure 7. PhotoSat was able to determine the locations of the 750 La Preciosa drill hole collars within 25cm in x, y and z using the stereo satellite photos.

Figure 7. *Photograph of a La Preciosa concrete drill collar white concrete block and the appearance of the drill collar concrete blocks on the stereo WorldView-2 satellite photo. PhotoSat was able to determine the coordinates of 750 La Preciosa drill hole collars to within 25cm in x, y and z from the stereo satellite elevation mapping and precision ortho photo.*

References

Mitchell and Ehling 2010a A Geophysical Stereo Satellite Elevation Mapping System. ASPRS Conference and Exhibition, Proceedings

Mitchell and Ehling 2010b High Resolution Stereo Satellite Elevation Mapping Accuracy Assessment. ASPRS Conference and Exhibition, Proceedings