• Better detection of important alteration minerals with the PhotoSat Deep Learning processing system
• Better identification and attenuation of false positives
Detecting small outcrops with important alteration minerals at Juanicipio

Detecting small but significant areas of alteration minerals is a significant geological mapping challenge. Even detailed field mapping can sometimes miss small outcrops with important geological information. The PhotoSat WorldView-3 alteration mapping has detected many small areas of opal/chalcedony and buddingtonite alteration at Juanicipio. The opal/chalcedony is probably small outcrops of the silica cap. The buddingtonite is probably from the Advanced Argillic alteration zone.

PhotoSat’s new Deep Learning alteration mineral mapping

PhotoSat’s new Deep Learning alteration mineral mapping system produces much better spectral matches and many fewer false positives than our previous more conventional engineering style spectral processing. Over the past few months we have transitioned our satellite alteration mineral mapping to our new Deep Learning system.

PhotoSat initially developed a more conventional engineering style spectral matching solution for alteration mineral mapping from multi spectral satellite photos. In parallel with the development of the engineering style system we developed the Deep Learning system. We have been developing Deep Learning processing tools for our stereo satellite survey grid production for the past two years.

PhotoSat Deep Learning alteration mineral mapping for epithermal, porphyry and carbonate replacement deposits

We have conducted Deep Learning alteration mineral mapping tests and verification on epithermal, porphyry and carbonate replacement deposits. We will be publishing a number of reports of WorldView-3 and ASTER Deep Learning alteration mineral mapping over the next few months. These reports will include the Red Mountain gold deposit in the Golden Triangle of BC, the Cuprite Nevada, Juanicipio Mexico, and Ixtaca Mexico epithermal deposits and the Rosemont Arizona and the Cerro Casale Chile porphyry deposits.

The incredible blind discovery of the Juanicipio silver deposit

The Juanicipio silver deposit was discovered by Dr. Peter Megaw and Mag Silver between 2003 and 2006. The tops of the silver veins are over 400m below surface. The discovery was based on ten years of research and geological field work. It was an amazing discovery of a blind deposit by drilling from the surface.
Figure 1. WorldView-3 image of PhotoSat’s Deep Learning alunite alteration mapping at the Juanicipio silver deposit, Zacatecas, Mexico. Red is strong or probable alunite alteration. Blue is weak or possible alunite. The silver veins are more than 400m below the current ground surface.
Figure 2. WorldView-3 image of PhotoSat’s Deep Learning kaolinite alteration mapping at the Juanicipio silver deposit, Zacatecas, Mexico. Red is strong or probable kaolinite alteration. Blue is weak or possible kaolinite. The silver veins are more than 400m below the current ground surface.
Figure 3. Geological model of mineral alteration zones for the epithermal silver deposit at Juanicipio, Zacatecas, Mexico. Model developed by Peter Megaw, modified from Buchanan (1981) and Simmons (1991). Peter Megaw and his team at Mag Silver used this model to make the amazing blind* discovery of the Juanicipio silver deposit discovery in 2003.

Alteration zone legend:
(1) Siliceous residue: opal, chalcedony, cinnabar, pyrite, specularite.
(2) Advanced argillic alteration: ammonium alunite, kaolinite, buddingtonite.
(3) Silicification: usually with adularia.
(4) Propylitic alteration: chlorite, epidote, calcite, pyrite, montmorillonite.
(5) Adularization: albite increases below the boiling level.

*There was absolutely no indication of gold or silver at surface above the Juanicipio deposit, making it a “blind” discovery. The ore zone is 450m below the ground surface. It was discovered through geological reasoning, interpretation, perseverance and courage.
Figure 4. Alteration minerals at the Juanicipio epithermal alteration zone mapped by PhotoSat using 16 band WorldView-3 satellite photos.
Figure 5. Area 1 from Figure 4 above. There are large areas of alunite and kaolinite alteration. There are relatively small outcrops with opal/chalcedony and buddingtonite alteration.

**Area 1 detailed images show first satellite detection of opal/chalcedony and buddingtonite**

In Area 1 of Figure 4, shown in Figure 5, there are extensive areas of alunite and kaolinite alteration and some very small areas of opal/chalcedony and buddingtonite alteration. We believe that this is probably the first time that these small areas of opal/chalcedony and buddingtonite alteration have been detected on satellite photos of Juanicipio.
Figure 6. Image of the alunite alteration of Area 1 from Figure 4. Red = strong or probable alunite. Blue = weak or possible alunite. Spectra of two WorldView-3 pixels are compared to USGS sample spectra for alunite.
Figure 7. Image of the kaolinite alteration of Area 1 from figure 4. Red = strong or probable kaolinite. Blue = weak or possible kaolinite. Spectra of two WorldView-3 pixels are compared to USGS sample spectra for kaolinite.
Figure 8. Image of the opal/chalcedony alteration of Area 1 from Figure 4. Red = strong or probable opal/chalcedony. Blue = weak or possible opal/chalcedony. Spectra of two WorldView-3 pixels are compared to USGS sample spectra for opal/chalcedony.
Figure 9. Image of the buddingtonite alteration of Area 1 from Figure 4. Red = strong or probable buddingtonite. Blue = weak or possible buddingtonite. Spectra of two WorldView-3 pixels are compared to two USGS sample spectra for buddingtonite.
Figure 10. Area 2 from Figure 4 above. There are large areas of alunite and kaolinite alteration. There are moderately sized outcrops with opal/chalcedony and buddingtonite alteration in this area.

Area 2 detailed images show extensive alunite and kaolinite

Area 2 of Figure 4 is shown in Figure 10. It is 5km SE of the known Juanicipio veins. There are extensive areas of alunite and kaolinite alteration and some moderately sized areas of opal/chalcedony and buddingtonite alteration in Area 2. To PhotoSat’s knowledge, there has been no deep drilling in this area.
Figure 11. Image of the alunite alteration of Area 2 from Figure 4. Red = strong or probable alunite. Blue = weak or possible alunite. Spectra of two WorldView-3 pixels are compared to USGS sample spectra for alunite.
Figure 12. Image of the kaolinite alteration of Area 2 from Figure 4. Red = strong or probable kaolinite. Blue = weak or possible kaolinite. Spectra of two WorldView-3 pixels are compared to USGS sample spectra for kaolinite.
Figure 13. Image of the opal/chalcedony alteration of Area 2 from Figure 4. Red = strong or probable opal/chalcedony. Blue = weak or possible opal/chalcedony. Spectra of two WorldView-3 pixels are compared to USGS sample spectra for opal/chalcedony.
Figure 14. Image of the buddingtonite alteration of Area 2 from Figure 4. Red = strong or probable buddingtonite. Blue = weak or possible buddingtonite. Spectra of two WorldView-3 pixels are compared to two USGS sample spectra for buddingtonite.
Figure 15. Spectral and spatial characteristics of the WorldView-3 satellite.
Alteration minerals that can be mapped with PhotoSat’s Deep Learning WorldView-3 processing

Depending on the presence of the alteration minerals on photo visible outcrops and subcrops the PhotoSat WorldView-3 alteration mineral mapping will include the minerals listed below. If the mineral is not present it will not be included in the maps and report.

**Opal / Chalcedony** $\text{SiO}_2 \cdot \text{n(H}_2\text{O)}$

**Calcite** $\text{CaCO}_3$

**Chlorite** $(\text{Mg,Fe,Li})_6\text{AlSi}_3\text{O}_{10}(\text{OH})_8$ / **Epidote** $\text{Ca}_2(\text{Al,Fe})_2(\text{SiO}_4)(\text{OH})$

PhotoSat cannot differentiate between chlorite and epidote minerals with 16 band WorldView-3

**Clay minerals**

**Alunite** $(\text{Na,K})\text{Al}_3(\text{SO}_4)_2(\text{OH})_6$

**Kaolinite** $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$

**Montmorillonite** $(\text{Na,Ca})_{0.33}(\text{Al,Mg})_2(\text{Si}_4\text{O}_{10})(\text{OH})_2 \cdot \text{nH}_2\text{O}$

**Micas**

**Sericite:** Sericite is hydrothermal alteration of orthoclase or plagioclase feldspars. It may consist of each or a combination of the mica minerals Muscovite, Illite, and Paragonite. PhotoSat cannot differentiate between these micas with 16 band WorldView-3 photos.

**Muscovite** $\text{KA}_2(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH,F})_2$

**Illite** $(\text{K,H}_3\text{O})(\text{Al,Mg,Fe})_2(\text{Si,Al})_4\text{O}_{10}[(\text{OH})_2,(\text{H}_2\text{O})]$

**Paragonite** $\text{NaAl}_2(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$
**Ammonium minerals**

**Buddingtonite** (ammonium feldspar) \( \text{NH}_4\text{AlSi}_3\text{O}_8 \)

**Ammonium-Illite**  very close match to ammonium-illite spectra

**Weak Ammonium-Illite**  equally close match to the spectra of ammonium illite and to the spectra of mixed illite and montmorillonite

**Iron Minerals**

**Goethite**  \( \text{Fe}^{3+}\text{O(OH)} \)

**Jarosite**  \( \text{KFe}^{3+}\text{3(SO}_4\text{)}_2\text{(OH)}_6 \)

**Hematite**  \( \text{Fe}^{3+}_2\text{O}_3 \)

**Iron Oxide Gossans**  \( \text{Fe}^{3+}\text{O} \)
Many different red, orange and brown iron oxide minerals

**Context images**

50 cm Natural colour image
50 cm Greyscale image
2 m Geology enhanced colour image
2 m Vegetation intensity image

**References:**


Mateer, Melissa A., Ammonium Illite at the Jerritt Canyon District and Goldstrike Property, Nevada: Its Spatial Distribution and Significance in the Exploration of Carlin-Type Deposits, Ph.D., Department of Geology and Geophysics, August 2010.