ASTER Imagery for British Columbia – An Online Exploration Resource[1]

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INTRODUCTION

The ASTER Imagery for British Columbia project, sponsored by Geoscience BC, increases the quantity and quality of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery available through the BC Ministry of Energy, Mines and Petroleum Resources' MapPlace website (www.MapPlace.ca). One hundred new images have been added to the collection, all available for analysis through the MapPlace's Image Analysis Toolbox (IAT) (Kilby *et al*., 2004; Kilby, 2005). A number of new derivative products have been generated from the imagery and made available for online viewing at the MapPlace website using the Google Earth viewer (Google, 2005). The products can also be downloaded for offline viewing.

ASTER is an imaging instrument flying on the Terra satellite, launched in late 1999. ASTER is a cooperative project between the National Aeronautics and Space Administration (NASA), Japan's Ministry of Economy, Trade and Industry and Japan's Earth Remote Sensing Data Analysis Center. The instrument has three subsystems that capture readings from different portions of the electromagnetic spectrum at different resolutions. The three subsystems are referred to as VNIR (Visible and Near Infrared), SWIR (Shortwave Infrared) and TIR (Thermal Infrared). Reflectance values in the SWIR range are particularly useful in differentiating rock and soil mineralogy related to alteration zones. An ASTER image contains 14 bands of information, 4 bands in the VNIR with 15 m resolution, 6 bands in the SWIR with 30 m resolution and 5 bands in the TIR with 90 m resolution. Two of the VNIR bands sample the same wavelength range but one is back-looking providing the ability to generate a stereo view of the scene. A single ASTER scene covers an area of approximately 60 by 60 km. The ASTER website (asterweb.jpl.nasa.gov) is an excellent source of information on the instrument, its mission, available imagery, usage examples and analysis tools.

The 39 previously existing ASTER images and 100 new images included in the IAT have been processed to relative reflectance values, a significant improvement from the calibrated radiance integer (DN) values previously available. A mask layer that filters out vegetation, clouds, water, snow and ice has been added to optionally restrict IAT image analysis processes to pixels with good ground exposure. Specialized maps with anaglyph background images (3-D images requiring red/cyan glasses) are now available through the IAT. In addition, a number of preprocessed layers are available that predict relative alteration-mineral distributions such as iron oxides, siliceous rocks, sericite and illite, and alunite and/or kaolinite. A series of video tutorials to assist in the use of the IAT and ASTER viewing tools are available on the site.

A number of products generated from the ASTER imagery are also available for downloading through the MapPlace. These include the original ASTER data, a 30 m resolution DEM (digital elevation model), a virtual reality world file, colour orthorectified anaglyph images and stereo pairs of digital images.

The new Google Earth viewer provides powerful viewing capabilities with the ability to incorporate external data. Several of the ASTER products, such as the near-natural colour image, anaglyph image and alteration-mineral images, have been incorporated into Google Earth files that are accessible through the MapPlace and provide an enhanced level of data viewing.

IMAGE ANALYSIS TOOLBOX ENHANCEMENTS

Image Preprocessing

New ASTER imagery was purchased as part of this project. Previously, ASTER imagery contained in the IAT included only those images that were available at no cost. ASTER imagery that in part covers the United States is available at no cost; imagery from all other locations is available for a handling fee of US$80 per image. The objective of this project was to obtain representative imagery from all parts of the province that could be of benefit in mineral exploration. The most recent, best quality images covering areas of interest to the mineral exploration community were selected (Fig. 1). Minimum cloud, smoke and snow cover were the primary quality factors. These conditions were usually found in images collected in late summer and early fall. If images of equal quality for a specific area were available then the most recent image was selected. Images with good ground exposure or including existing mining operations were selected initially. Imagery over the areas heavily affected by the mountain pine beetle infestations was also addressed in the hope of stimulating mineral exploration in these areas.

The ASTER images previously housed in the IAT and the new imagery were processed to bring them all to a new standard level of quality. The image data was orthorectified and atmospherically corrected. Orthorectification was per-
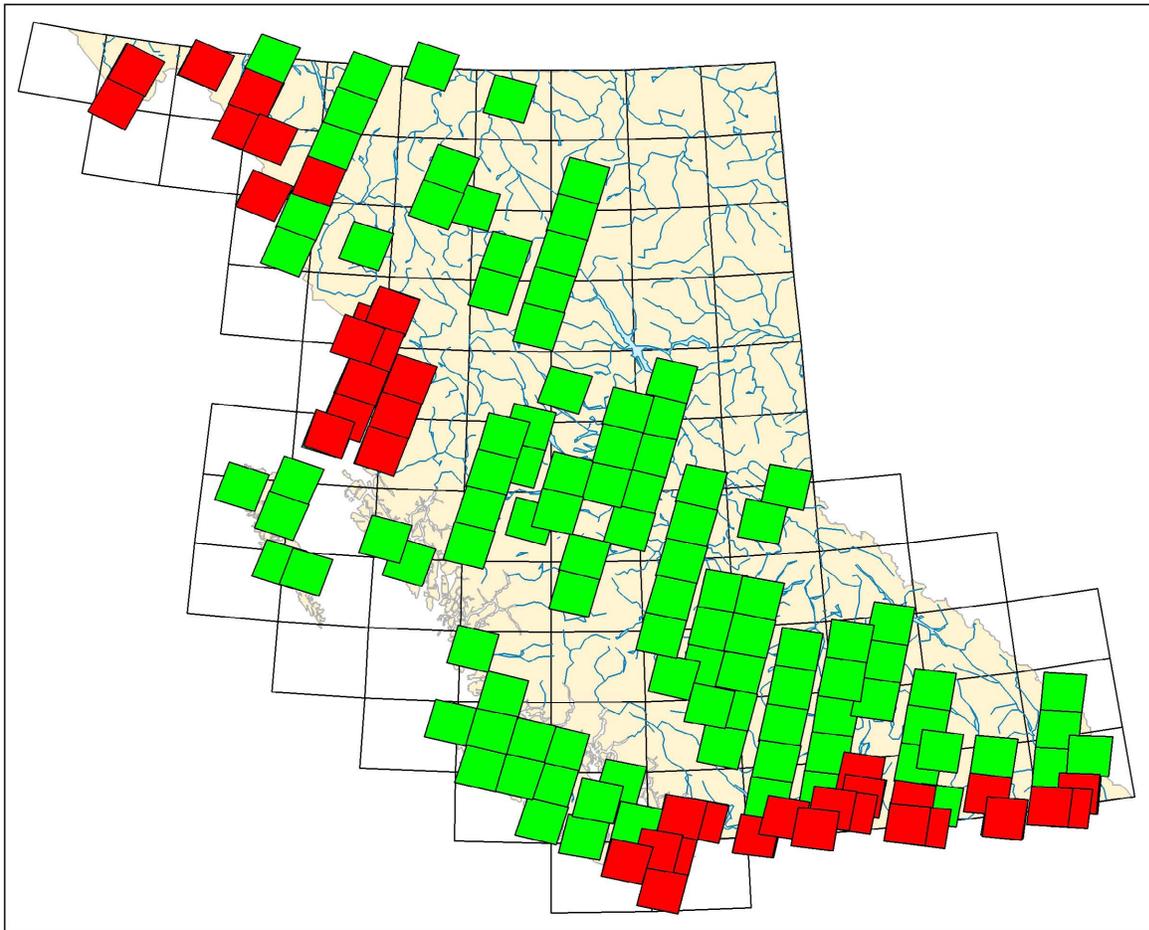
Figure 1. A display of ASTER image footprints; existing images are shown in red and the approximate locations of Geoscience BC project images are shown in green.

formed using the AsterDTM (SulSoft, 2005) add-on to the ENVI image analysis program (RSI, 2005). The orthorectified images were then manually adjusted to fit the TRIM (Terrain Resource Inventory and Mapping) 1:20 000 digital map data displayed on the MapPlace. This manual adjustment was necessary to compensate for some ASTER positioning errors: "Over the last 5 years, we have discovered several small errors that can affect the accuracy of these coordinates" (NASA Jet Propulsion Laboratory, 2005). For the purposes of this project, registration to the TRIM data provided the most appropriate adjustment.

Atmospheric corrections were performed on the VNIR and SWIR bands in all the images using the ACORN5 (Atmospheric CORrection Now) program (ImSpec, 2004). This program performs a radiance to relative reflectance correction of the image values by removing the effect of water vapour and other gases in the atmosphere using the MOTRAN4 technology. ACORN5 also corrects for atmospheric scattering as well as the shape of the solar irradiance curve that is variable by wavelength depending on solar incidence angle. ASTER imagery does not contain enough information to calculate the amount of water vapour found within an image so a standard value of 15 mm of atmospheric water was used for all images. Atmospheric water content obviously varies between ASTER scenes and

within the scenes but the value of 15 mm was selected as representative after a review of the MODIS Atmosphere Profile Product record (NASA MODIS Atmosphere Discipline Group, 2005). Atmospheric correction enhances the digital information available to the IAT from simple DN (calibrated radiance) values to relative reflectance values that more accurately portray the true reflectance spectra of a ground sample area. The relative reflectance values allow comparison of the image pixel spectra with natural and man-made materials in existing reflectance spectral libraries, such as the ASTER spectral library available online (NASA, 2000).

A major problem with analyzing a large area, such as a whole ASTER image, is that many very different types of surfaces are included in the analysis, often making subtle differences in the spectra of a target area difficult to identify. A traditional method of overcoming this problem is to apply a mask that removes all but the area of interest from the calculation. Such a mask was calculated for each MapPlace image and is available in the IAT to constrain the area of the image being analyzed. The mask blacks out all areas covered by vegetation, clouds, water, snow and ice; hopefully, leaving only those pixels that sampled good ground exposures. A simple toggle button in the individual tool panels of the IAT allows the user to make use of the
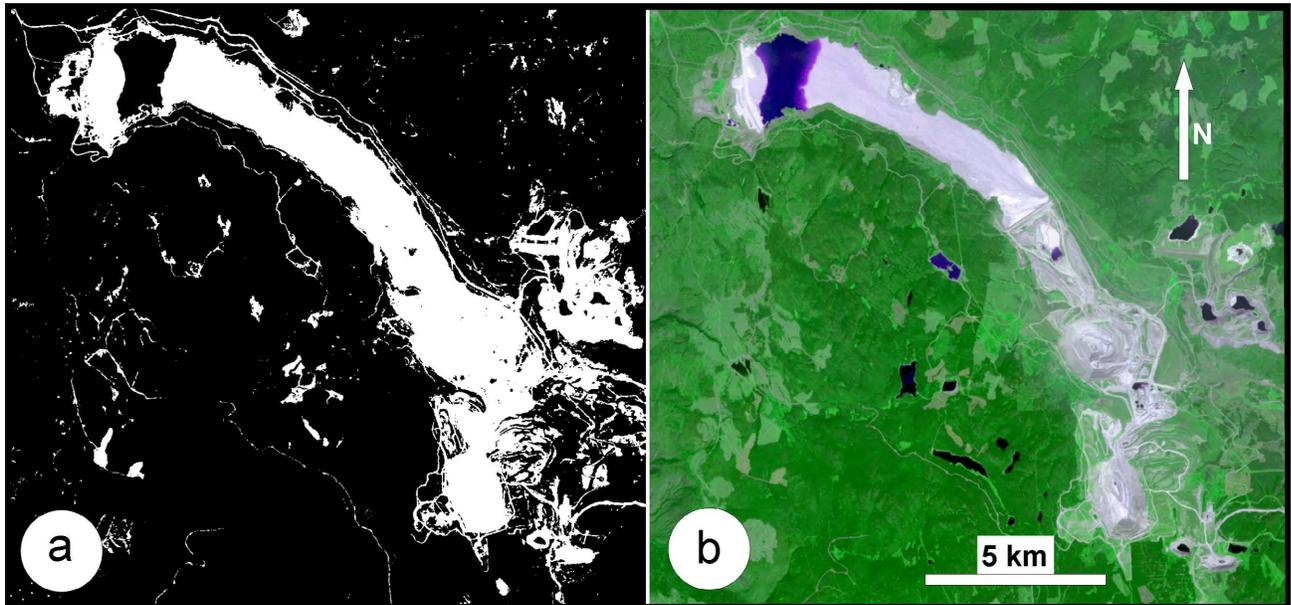
Figure 2. a) An enlarged portion of a mask and b) the corresponding coloured image. The white pixels in the mask overlay good ground exposures, such as the rock exposures in the mine, road-cuts, beaches around lakes and freshly logged areas. The mask effectively blacks out most vegetated areas and water bodies.

mask when desired. The available mask removes the vast majority of the pixels measuring nonrock surfaces but there are always some pixels which include a mixture of rock and nonrock materials (Fig. 2). The user should use caution when interpreting analysis results using this mask, a pixel of interest should be further investigated to confirm it does in fact represent a rock surface.

New IAT Options

The IAT basic functionality has been described previously (Kilby *et al.*, 2004; Kilby, 2005). The ASTER image data available to the analysis tools has been significantly improved and expanded – the major objective of this project. The major addition to ASTER analysis capability is the option for the user to include the image mask described above with several of the analysis tools.

Short video tutorials have been added to assist the first-time user though the operation of the analysis tools and also demonstrate the operation of several of the viewers that can be used to examine some of the ASTER products.

Four new selections have been added to the basic analysis tools, available when an ASTER image has been chosen for analysis. These four selections do not perform an analysis on the image but rather launch new displays related to the selected ASTER image. Figure 3 illustrates the new layout of the Image Analysis Tools panel when an ASTER image is selected for analysis in the IAT. The Anaglyph Map button will launch a new MapPlace map with the ASTER anaglyph image forming the main display. The Virtual Reality button will launch a low resolution virtual reality file of the ASTER scene draped over its DEM. If the user has a virtual reality viewer linked to their browser, it will be launched and the file immediately viewable. If no virtual reality viewer is linked then the user has the option to save the file for later viewing. The Google Earth button will launch the Google Earth package for the selected ASTER image on the client's computer, if they have

Google Earth loaded. If they do not have Google Earth loaded, they have the option of saving the file for later viewing. The Download Page button launches a web page that provides access to all the downloadable products associated with the selected ASTER image.

Anaglyph Maps

A new product that is accessible through the IAT is a map display with an anaglyph ASTER image as its base. These maps are rotated so that the satellite flight line is hori-
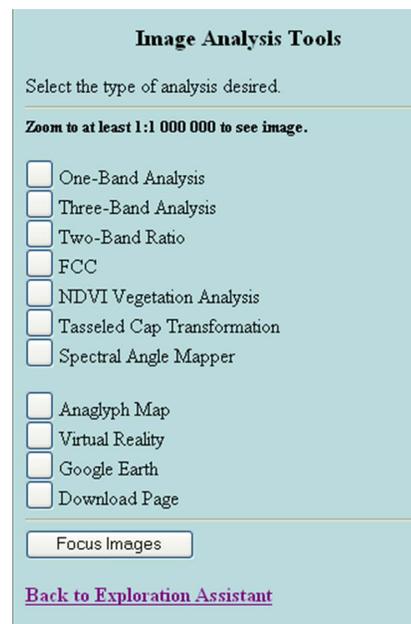

Figure 3. The ASTER Image Analysis Tools panel. The four new options are found at the bottom of the selection list.

zontal in the display, making map north to the right of the display. This aligns the viewer's eyes with the flight path and allows viewing of the image in 3-D. Anaglyph glasses are required to view the image. Glasses with red and cyan lenses are preferred but red and blue lenses will work reasonably as well. All available MapPlace layers can be overlain on these maps just as with any other MapPlace map. These images have been orthorectified and fit the existing TRIM base map data very well. Three-dimensional topographic surface views, such as these, provide an excellent tool for the interpretation of surficial and bedrock geological features.

Alteration-Mineral Images

Four alteration-mineral images have been prepared for each ASTER image and are available for viewing in the IAT. These images were produced using standard combinations of the ASTER bands. The four images can be used to map the relative abundance of siliceous rocks, iron oxides,

sericite and illite, and alunite and/or kaolinite. The band combinations (J.A. Zamudio, pers comm, 2005) used to calculate each of these images are

- siliceous rocks – $(B10+B11+B12)/3/(B13)$
- sericite and illite – $(B5+B7)/B6$
- alunite and/or kaolinite – $(B4+B6)/B5$
- iron oxides – $B2/B1$

All of the alteration-mineral images were calculated using the appropriate mask as discussed above. Figure 4 contains examples of these images. It must be remembered that these images show only the results of the various band combinations given above. These ratios have been used to identify the relative abundance of the specific materials, but they may also indicate other substances. They must be used as a guide to the location of mineral substances just as with any remote sensing technique. These images are only one of many tools that can assist in defining target areas for more detailed analysis and must not be considered an absolute indicator of the target material.
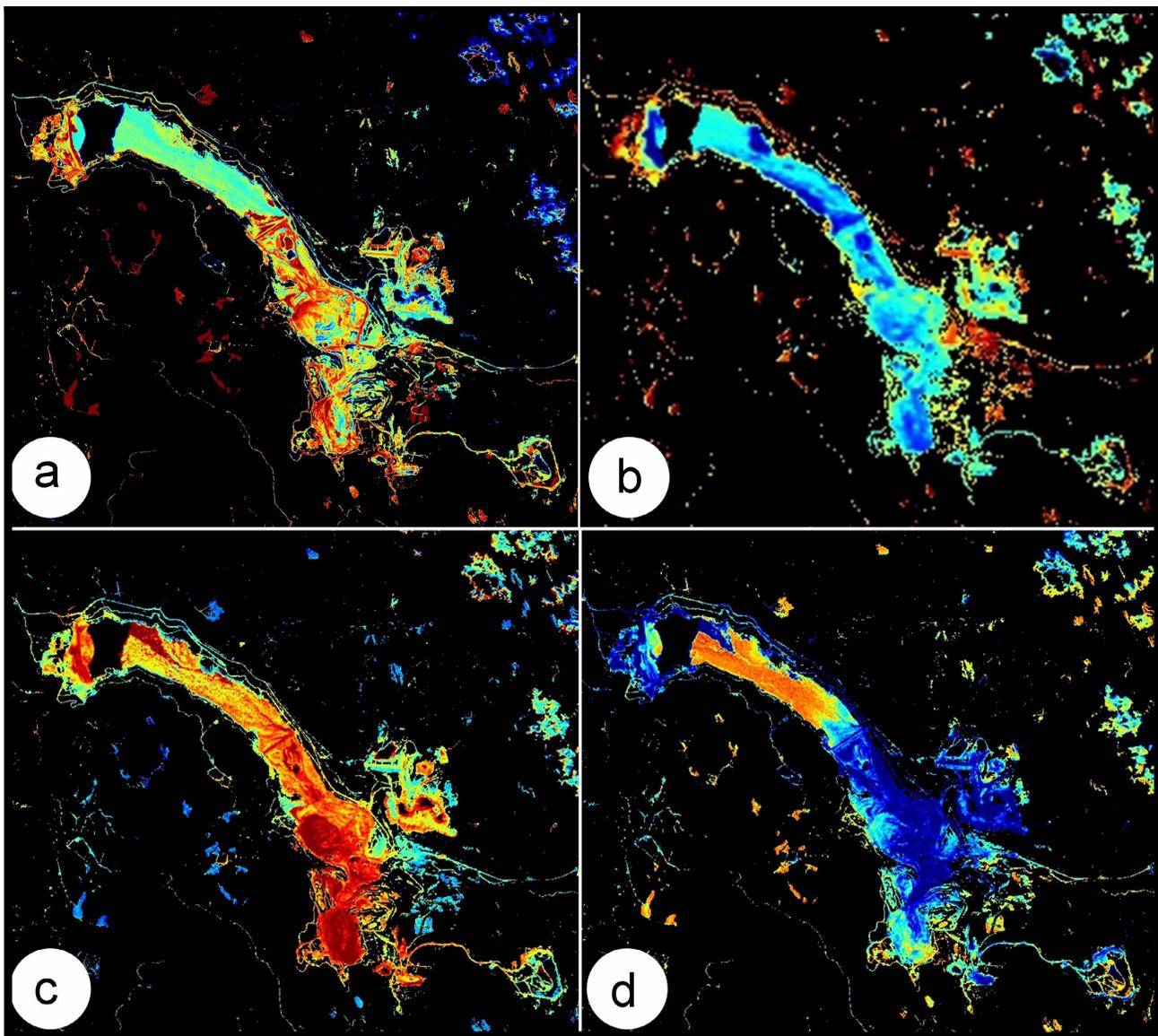

Figure 4. Alteration-mineral images from Highland Valley mine area; a) iron oxides, b) siliceous rocks, c) sericite and illite and d) alunite and/or kaolinite. The range of low to high values is shown as a range of cool to warm colours.
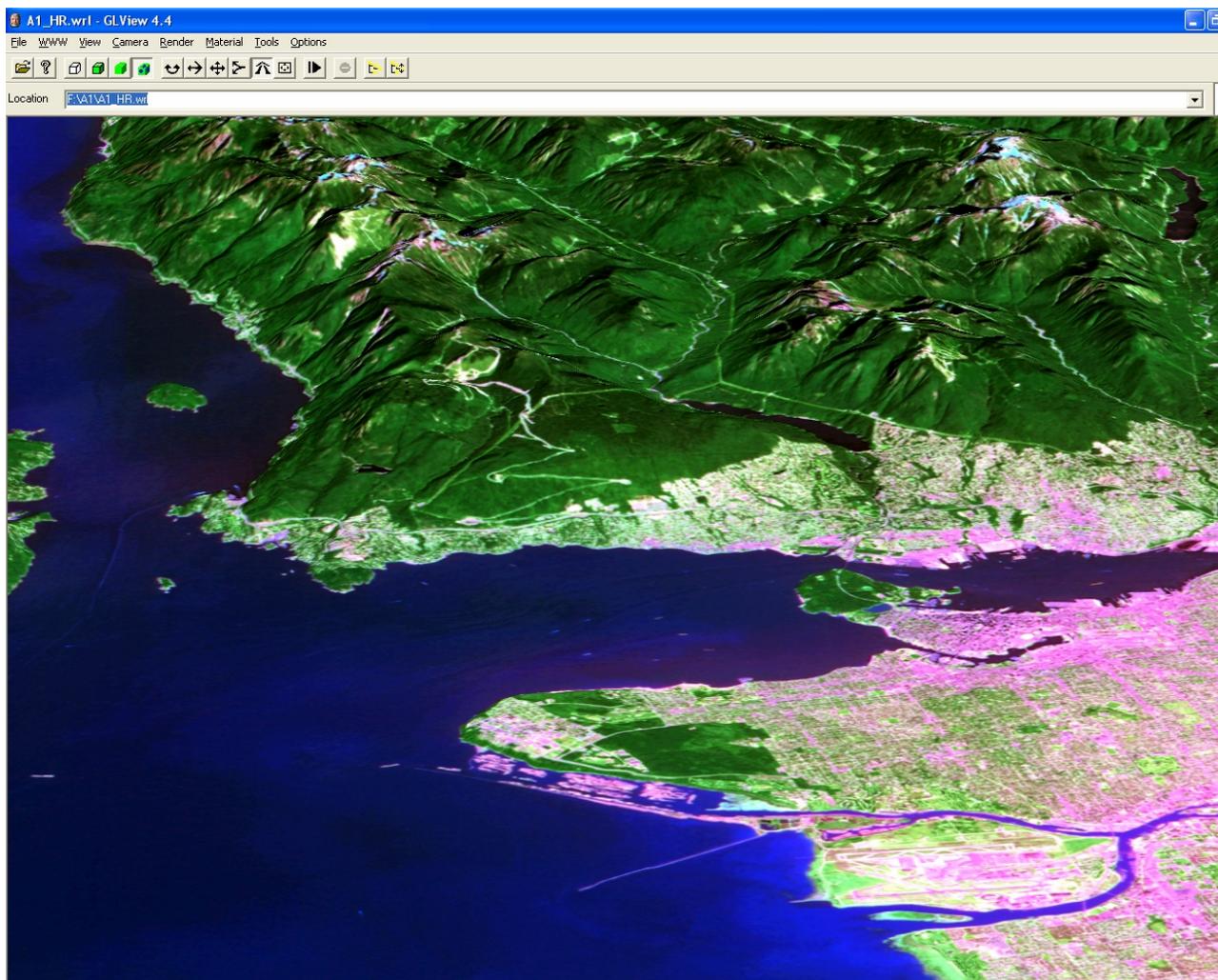
Figure 5. An example of a virtual reality viewer (GL View) with a view of ASTER image A1 (Vancouver area).

Virtual Reality

Virtual reality files (WRL format) have been produced for each image by draping the near-natural colour image over the DEM generated during the orthorectification process. When viewed with the appropriate viewing software, these files allow the user to fly through the terrain, generate perspective views and even incorporate new flight paths and viewpoints. Similar functions are available through the Google Earth products discussed below but the virtual reality files provided here are available on a much more detailed topographic base than presently available through Google Earth. The files have been prepared in two resolutions; the high resolution version is available through the download option while the low resolution version is available by direct link from the IAT map. There are a number of free virtual reality viewers available over the internet. One that works very well with these files is the GL View viewer available at http://www.snafu.de/hg (Fig. 5). The low resolution product has a DEM spacing of about 1.3 km and an image resolution of one pixel every 75 m. The high resolution product has a DEM spacing of about 160 m and an image resolution of one pixel every 15 m.

DOWNLOAD PRODUCTS

A number of products generated during this project are available for download. These products include the original ASTER imagery and a number of products generated from the imagery. The ASTER Download Page provides access to these products and is available by clicking on the Download Page button in the ASTER IAT panel.

Original ASTER Image Data

The ASTER image data, in its original format, can be downloaded for free by the user. The two original files associated with each image have been zipped together for convenience of handling but are otherwise in the original XML and HDF formats. As discussed above, images that do not include part of the United States were purchased at a cost of US$80 per image. This is a direct savings to any user wanting this data. A search of the internet will return a large number of free and high-end programs capable of manipulating this image format.
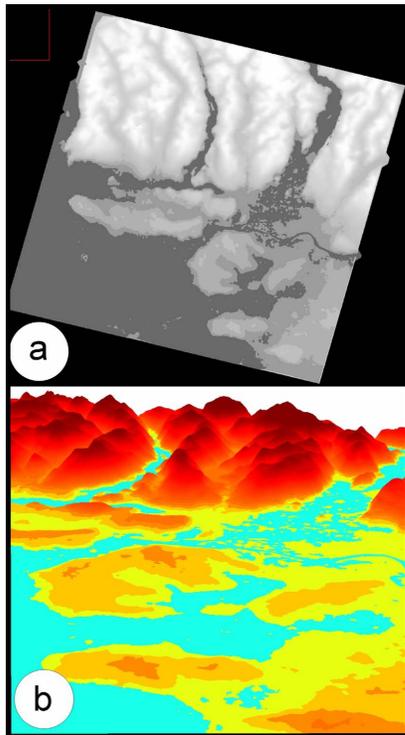
Figure 6. Two views of a DEM: a) a grey-scale map view of the dataset and b) a coloured perspective view of the same dataset.

DEM

During the orthorectification process a relative digital elevation model was constructed. This model is available for download. The model resolution is 30 m. Unlike many DEM where the grid points are interpolated from widely spaced data points, this model was generated by a calculation based on the Band 3N (Nadir) and Band 3B (back-looking) images at each grid point. The DEM is relative and has not been corrected to true elevations. A correction could be applied by the user if desired but for most applications the relative model is adequate (Fig. 6). Many of the ASTER images contain some cloud cover and the elevation of the cloud tops is what is recorded in the DEM rather than the ground elevation. Also in some images certain pixels in Band 3N or Band 3B were saturated and resulted in no elevation calculation being possible. These appear as holes in the DEM. This problem usually occurs over very large bright objects, such as glaciers. The DEM is provided in a standard DEM format, USGS DEM, which can be read by a large number of free and widely available software packages.

Virtual Reality File

The high resolution virtual reality file is only available through the download page. This product, discussed above, is too large for direct linking from a map but may be downloaded by the client and manipulated with a virtual reality viewer on the user's desktop (Fig. 5).

Stereo Pairs

Stereo pair images of the whole ASTER scene are available for download in JPEG format. These images have a 15 m resolution and when viewed with a standard stereoscope provide a 3-D view of the image scene. The files can be printed as whole images or subregions of the images may be enlarged to provide more detailed viewing. The Nadir image (vertically down-looking) has been orthorectified while the back-looking image has been left in its original state. This configuration provides stereo viewing of an orthorectified image. The Nadir image is in UTM projection (Fig. 7).
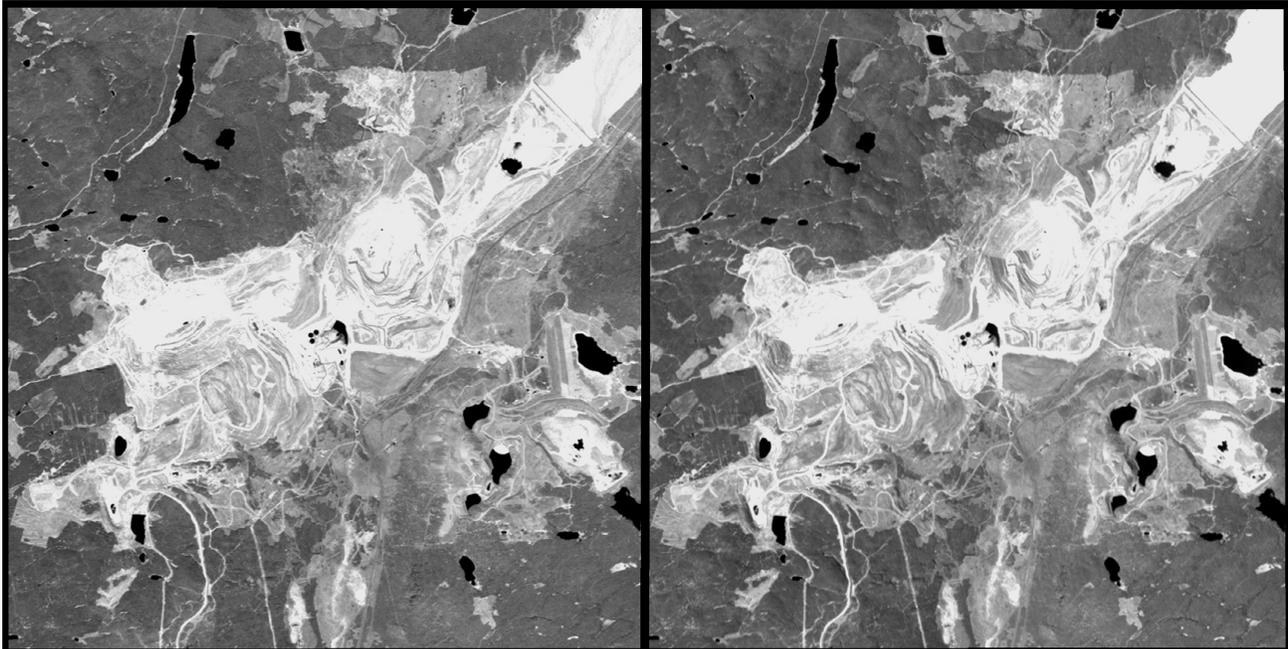

Figure 7. An example of stereo pair images from an enlarged section of the downloadable stereo pairs product. This view is of the open pits at the Highland Valley operation.
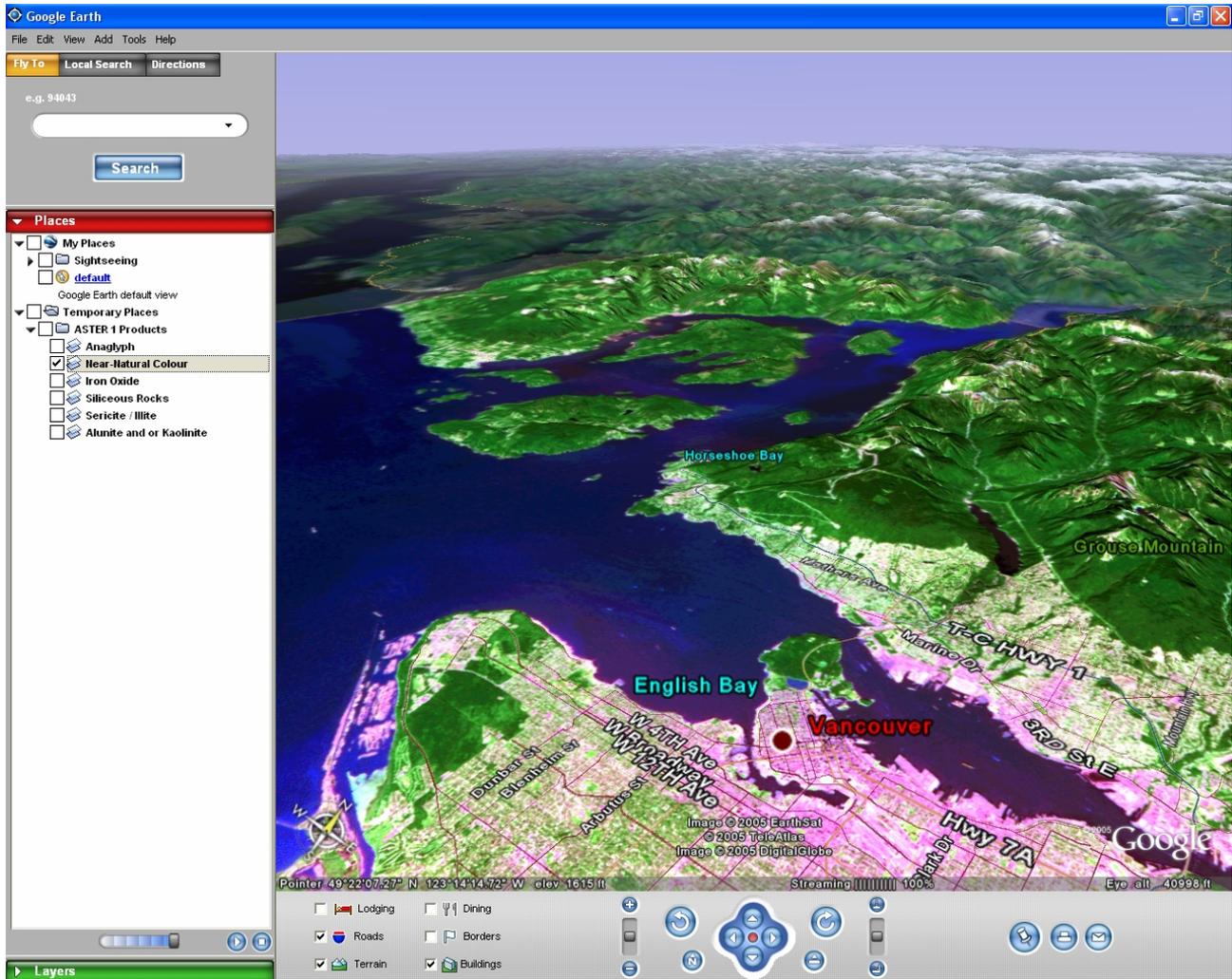
Figure 8. Google Earth viewer with Google Earth ASTER product for the Vancouver area. The near-natural colour image is displayed in this example.

GOOGLE EARTH PRODUCT

On June 28, 2005, the Google Earth viewer became publicly available. This free viewer provides a significant advancement in viewing geospatial information over the internet. The convenience and power of this viewer warranted its inclusion in the product mix provided by this project. A Google Earth display is available for each ASTER image (Fig. 8). Each display includes

- a near-natural colour image;
- an anaglyph image;
- a siliceous rock image;
- a sericite and illite image;
- an alunite and/or kaolinite image;
- an iron oxides image; and
- other imagery and spatial data available from Google Earth.

The Google Earth viewer allows the user to turn the various images off and on and adjust the opacity of a selected image. Double clicking on the anaglyph image name in the legend will cause the Google Earth viewer to rotate and zoom to the optimal position to view that anaglyph image (anaglyph glasses required). The Google Earth displays can be accessed by clicking on the Google Earth button of the ASTER IAT panel (Fig. 3). Unfortunately, use of Google Earth requires a relatively fast internet connection and computer so this product may not be readily useable by all site users. All ASTER-related information provided in the Google Earth format is also available through MapPlace map displays.

SUMMARY

ASTER imagery for a significant portion of British Columbia is now available for online analysis and downloading. The IAT provides the opportunity to remotely examine exposed ground surfaces for the presence of alteration minerals that may be associated with a variety of deposit types. Examination of vegetation variations may provide useful indications of underlying geology. Derivative products generated during this project provide a variety of 3-D visualization options. The 3-D visualizations provide powerful tools for examining and displaying ideas

about geology, exploration concepts and project planning. The site can also be used to help advance the understanding of the geology and mineral industry of British Columbia by the general public.

ACKNOWLEDGMENTS

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