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Mineral mapping with ASTER

Geoscience Australia has developed a new remote sensing tool that will assist explorers discover Australia's future mineral wealth.

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Mineral index maps generated using data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) have put Geoscience Australia at the global forefront in the provision of remote sensing products tailored for mineral exploration.

ASTER mineral index maps have improved the way we map alteration mineralogy. While previous studies required many months of detailed mapping and sample collection, ASTER maps enable alteration to be identified before field work is undertaken, maximising the value of time spent in the field.

They are one of the few remote sensing products to map mineralogy on a regional scale with sufficient spatial and spectral detail for mineral exploration, and are highly suited to first-pass reconnaissance and selection of exploration targets in areas of outcrop to moderate surficial cover.

ASTER data

Launched in December 1999 aboard the Terra satellite, ASTER is the result of a cooperative effort between NASA, Japan's Ministry of Economy, Trade and Industry, and the Earth Remote Sensing Data Analysis Centre (ERSDAC).

Terra has an orbital path similar to Landsat 7's. Five instruments on the spacecraft, including ASTER, can be combined to monitor all earth systems (Abrams et al 2002) and generate data in 60 km x 60 km scenes.

ASTER data are used for a range of applications, including land-use studies, mapping, water resources, coastal resources, environmental monitoring, generation of digital elevation models (DEMs), and mapping alteration patterns or specific mineral assemblages known to be associated with mineral systems.
There are two Level 1 ASTER products:

- L1A (Reconstructed Unprocessed Instrument Data) for the production of DEMs
- L1B (Registered Radiance at the Sensor) for spectral studies.

ASTER's eyes

ASTER consists of three separate instrument subsystems:

- Visible and Near Infrared (VNIR)
- Shortwave Infrared (SWIR)
- Thermal Infrared (TIR)

ASTER has 14 bands of information:

Instrument	VNIR	SWIR	TIR
Bands	1–3	4–9	10–14
Spatial resolution	15 m	30 m	90 m
Swath width	60 km	60 km	60 km
Cross track pointing	± 318 km (± 24 deg)	± 116 km (± 8.55 deg)	± 116 km (± 8.55 deg)
Quantisation (bits)	8	8	12

Band 3 has nadir and backward telescopes for stereo pairs from a single orbit. The stereo pair capability of ASTER means that detail DEMs can be produced.

Geoscience Australia's remote sensing unit (ACRES) maintains an extensive archive of ASTER data covering the entire Australian continent, including raw imagery for DEM generation and Level 1B map ready product.

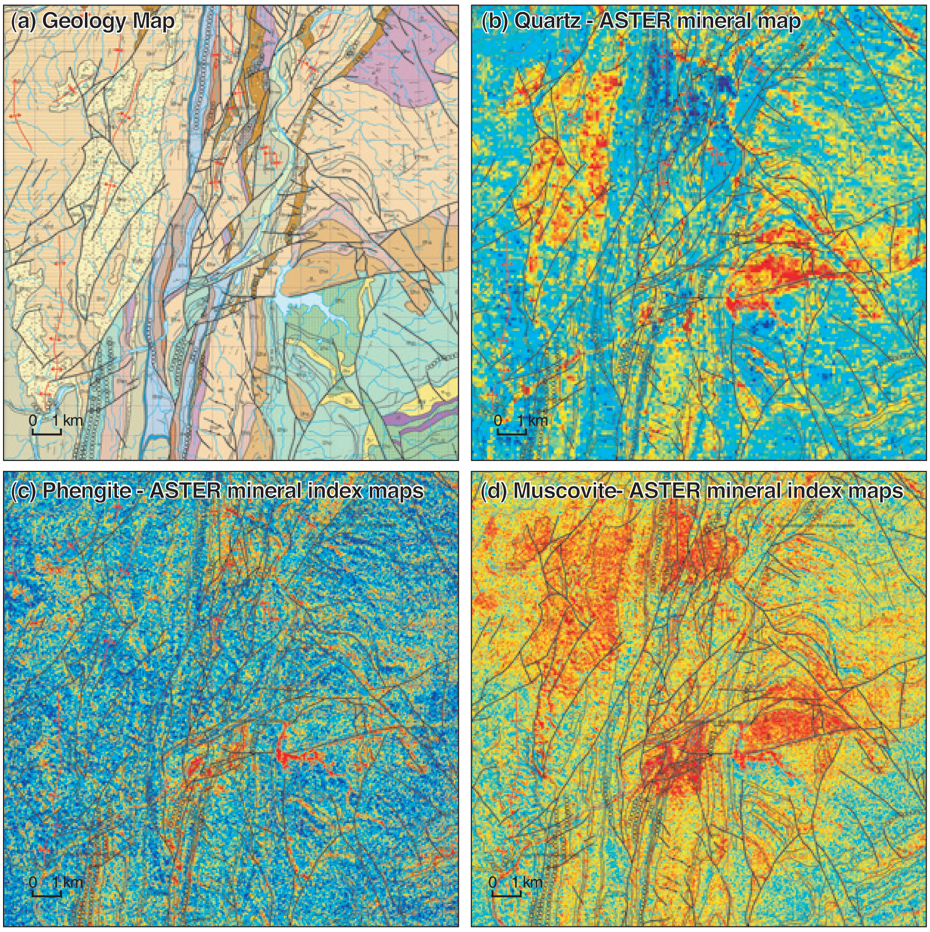
In 2002, ACRES enabled visualisation of its ASTER holdings through the ACRES Digital Catalogue, providing a tool to efficiently retrieve and process data covering entire geological provinces. Under the distribution agreement between Geoscience Australia and ERSDAC, Geoscience Australia provides access to future acquisition requests for Australian users of the data. ERSDAC holds processed products of over 700 000 Level 1A scenes and over 180 000 Level 1B scenes.

ACRES can search this archive, purchase these products on behalf of clients, and organise for ERSDAC to process ASTER data into higher level products.

Development and testing

ASTER can map the distribution of various minerals, including white mica, silicification, carbonates, clays, alunite and iron oxides (Rowan & Mars 2003, Rowan et al 2003; Hewson et al 2005). ASTER-derived mineral index maps are simple band and relative band depth ratios that correspond to absorption features for particular minerals (figure 1).

Geoscience Australia's Remote Sensing Science and Strategy project developed an add-on for ER-Mapper™ (figure 3) that automates the production of ASTER mineral index maps. In addition, the tool provides for automated spatial adjustment using Landsat panchromatic data (www.ga.gov.au/image_cache/GA4050.pdf).



▲ **Figure 1.** Geological map of Mt Gordon Fault Zone, Western Succession, Mt Isa Inlier (Hutton et al 1985) and ASTER-derived mineral index maps of the same area for muscovite, phengite and silicification. The mineral index maps can be interpreted in a similar way to radiometics; that is, red and orange areas contain the mineral of interest, whereas blue and green areas are less likely to contain the mineral.

The effectiveness of ASTER to map minerals has been tested in the Mount Isa region as part of a pilot study within the *pmd**CRC I1 project (Crustal Architecture and Mineral Systems). This involved ground-truthing of the ASTER-derived mineral maps through a portable short-wavelength infrared mineral analyser (PIMA) capable of identifying many of the same mineral species. Individual, cloud-free ASTER L1B scenes were chosen to cover the study area.

ASTER L1B data require several phases of pre-processing (Kalinowski & Oliver 2004) to enable production of mineral index maps. Good correlation (van der Wielen et al 2005) of ASTER mineral index maps for white micas, silica and carbonates was obtained in the Isa region pilot study (figure 2), interpretation of which is complicated by effects of weathering, vegetation growth, fire scars and/or human impact.

Geoscience Australia has an extensive catalogue of ASTER imagery that can be used to produce regional ASTER mosaics to map the distribution of minerals (van der Wielen et al 2004, 2005).

ASTER mineral index maps have been produced for various Geoscience Australia projects, including studies of the Mt Isa Inlier, the Paterson Orogen and the Eastern Goldfields. An interactive online example of ASTER mineral index maps from Mt Isa shows four separate images: a 1:100 000 geology map; silicification and phengite mineral index maps; and a VNIR (pseudo natural colour) image (satmap.ga.gov.au/IWS/images/mtisa/mt_isa_shtml).

Implications for exploration

The real potential for ASTER mineral index maps as an exploration tool lies in their identification of minerals distribution associated with alteration haloes and fluid flow. Walshe et al (2003) noted that large ore deposits lie on chemical gradients such as changes in redox, pH, temperature and pressure. ASTER can identify chemical gradients preserved in the rock record as subtle variations in mineralogy (van der Wielen et al 2005).

Many world-class gold and copper deposits have large, previously unrecognised, white mica haloes. Walshe et al (2003) recognised that deposit location corresponds to changes in white mica composition from muscovite to phengite. The variation in composition appears to reflect chemical changes in ore fluid chemistry resulting in the precipitation of metal. The distribution of both phengite and muscovite can be mapped with ASTER mineral index maps.

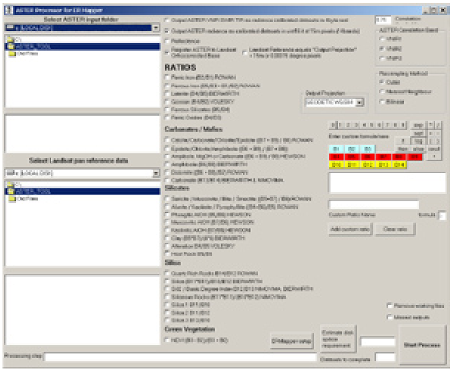
Two ASTER mineral index maps from Geoscience Australia projects demonstrate their potential.

Phengite and muscovite mineral index maps over Mt Gordon copper mine in the Mt Isa Inlier (figure 1) show that copper mineralisation occurs where there is mixture of muscovite and phengite.

◀ **Figure 2.** Hydrothermal phengite (pale colour) in the Mt Isa region that was identified using ASTER imagery and verified by ground-based PIMA and field work.

Muscovite and phengite mineral index maps of the Telfer Au–Cu deposit in the Paterson Orogen (figure 4) were combined to reflect areas that contain phengite and muscovite verified by PIMA ground truthing. The combined image was then draped over a single-band grey scale image.

The Telfer example shows a broad zone of phengite (yellow) to the south and muscovite (blue) to the north, with a mixture of phengite and muscovite around the Telfer deposit. The change from phengite to muscovite has been interpreted to represent a chemical gradient associated with mineralisation at Telfer. The image has highlighted several 'look-alike' targets in the vicinity of Telfer.



▲ **Figure 3.** Front end of the ASTER processing tool developed by Geoscience Australia to facilitate production of ASTER mineral index maps.

Conclusion

As the only remote sensing product able to map mineralogy on a regional scale with sufficient spatial and spectral detail for mineral exploration, ASTER mineral index maps from Geoscience Australia are a valuable new tool for Australia's explorers.

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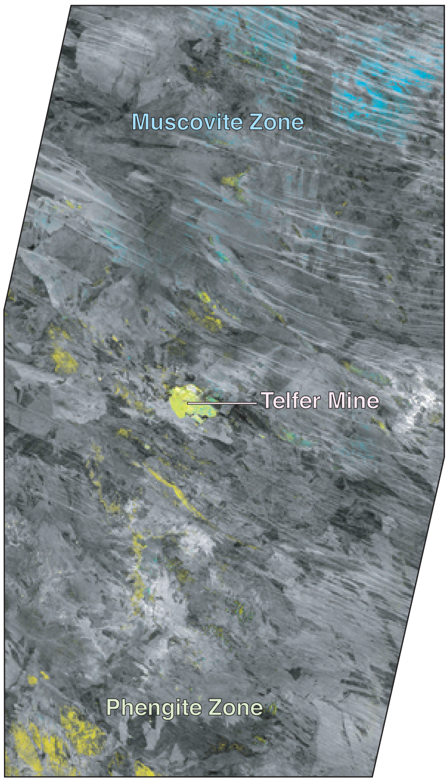

▲ **Figure 4.** Combined phengite (yellow) and muscovite (blue) mineral maps draped over grey-scale 1 ASTER image. Individual index maps were clipped using a mean plus two standard deviation algorithm, then re-coloured. Phengite forms a broad zone to the south whereas muscovite is restricted to the north. Telfer is located where the white mica changes from phengite to muscovite.

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Related websites

An interactive online example of ASTER mineral index maps from Mt Isa: http://satmap.ga.gov.au/IWS/images/mt_isa/mt_isa.shtml

How Geoscience Australia processes ASTER satellite imagery: www.ga.gov.au/image_cache/GA7833.pdf

Accuracy assesment of ACRES Landsat Orthocorrected Products: www.ga.gov.au//image_cache/GA4050.pdf

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