spotmine
Geological Exploration Services

Case Study

Discovering Mineralized Pegmatites from Space

Advanced Satellite Detection of Pegmatite Mineralization Using Hyperspectral Data

Introduction

The results presented in this report are part of a case study conducted in Namibia (Erongo region), in which advanced remote sensing techniques were applied to identify pegmatites.

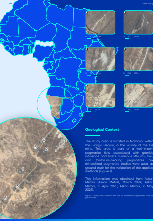
The objective is to demonstrate how our best-performing approaches are effective in detecting pegmatites using hyperspectral data.

Challenge

01

In situations where the target mineral shares the pixel space with other materials, the resulting spectral signature becomes highly mixed, containing information from all components within a single pixel. This mixing can mask or dilute the spectral signature of the target mineral, making its identification more challenging.

In this context, hyperspectral data, particularly from the PRISMA satellite, with 239 spectral bands, offers a decisive advantage by enabling a more detailed discrimination of geological materials.



Geological Context

The study area is located in Namibia, within the Erongo Region, in the vicinity of the Uis mine. This area is part of a well-known pegmatite field associated with granitic intrusions and hosts numerous lithium-, tin-, and tantalum-bearing pegmatites. Six mineralized pegmatite bodies were used as ground truth for the validation of the applied methods (Figure 1).

This information was obtained from Askari Metals (Askari Metals, March 2024; Askari Metals, 15 April 2025; Askari Metals, 16 May 2025).

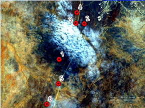
Figure 1. Study case location and the six mineralized pegmatites used as ground truth.

Data and methods

Data used

02

A hyperspectral image from the PRISMA satellite, covering the spectral range from 400 nm to 2500 nm, was acquired and processed. The PRISMA image used contains cloud cover affecting pegmatite 1 and partially pegmatites 2, and 3 (figure 2), which is directly reflected in the results obtained.
In addition, spectral signatures from the USGS Spectral Library (Version 7) were used as endmember (pure spectra) to map minerals related to pegmatite mineralization.



Methods

Minimum Noise Fraction (MNF)

MNF performs data reduction by separating noise and reducing the computational requirements of the dataset. This method generates the so-called coherent images (MNF bands), which can be combined into RGB composites to discriminate different lithologies.

Sequential Maximum Angle Convex Cone (SMACC)

SMACC is a spectral tool that extracts endmembers directly from the image and subsequently maps their abundance. Although it is less precise than MTMF, it allows for the automatic extraction of endmembers without the need for external spectral libraries or detailed prior knowledge of the target, which represents a significant advantage when applied to greenfield exploration areas.

Mixture Tunned Matched Filtering (MTMF)

MTMF is a powerful spectral unmixing method that maximizes the spectral response of the target while minimizing the background response, making it a highly effective approach for mapping the abundance of a target mineral. In this study, MTMF was applied in two different ways:

- By extracting a pure pegmatite spectrum directly from the hyperspectral image, using it as an endmember.
- To map alteration minerals indicative of pegmatite-related mineralization using external spectra from the USGS Spectral Library, including cookeite, montmorillonite, cassiterite, and illite.

While extracting pegmatite spectral signatures directly from the image allows the mapping of pegmatite bodies across a region, the identification of alteration minerals, such as cookeite, helps to assess whether a given pegmatite body is mineralized.

Results

Minimum Noise Fraction (MNF) 03

In Figure 3, an MFN band combination is shown, which effectively differentiates distinct lithologies within the study area. In addition, this band combination was also effective in highlighting the known pegmatites, which appear in bluish tones.

Pegmatite number 1 was affected by cloud cover; therefore, the signal and the blue tones are weaker. Even so, it is possible to verify that there is some spectral difference, although weak, between the pegmatite location and the background.

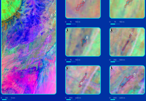


Figure 3. MNF band combination

Mixture Tunned Matched Filtering (MTMF)

With the exception of pegmatite 1, which was affected by cloud cover, all pegmatite bodies were successfully identified using the MTMF approach.

Method 1 (figure 4), based on the extraction of endmembers directly from the image, correctly identified all five pegmatitic bodies, including pegmatites 2 and 3, which was partially affected by cloud cover.

This method demonstrated high sensitivity, being capable of mapping even very low pegmatite abundances, with a reduced number of false positives when compared to traditional image classification methods.

Method 2 (figure 5), which employed external endmembers, detected the presence of Cookeite in all five pegmatites, indicating that these bodies have potential for lithium mineralization.

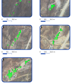


Figure 5. MTMF results to map Cookeit.

Figure 4. MTMF results with endmember extracted from the image.

Conclusion

Sequential Maximum Angle Convex Cone (SMACC)

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The SMACC algorithm was also able to correctly map the abundance of pegmatites at the pixel level. However, pegmatite 2 exhibited a significantly lower spectral response compared to the other bodies.

SMACC is particularly suitable for application in greenfield areas with limited prior information, and its results can be effectively used as a complementary approach to MTMF, especially for endmember identification and selection.

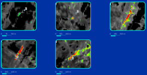

Figure 6. SMACC results to map pegmatite abundance.

The methods applied in this study successfully mapped all pegmatite bodies used as ground truth, demonstrating the robustness of hyperspectral remote sensing for pegmatite detection in complex geological environments.

The results show that MTMF is a highly effective approach for accurately identifying pixels with pegmatite abundance, while simultaneously mapping alteration minerals indicative of mineralization. This dual capability allows for a more reliable distinction between potentially mineralized and non-mineralized pegmatites, significantly enhancing targeting confidence and supporting more informed exploration decisions.

This case study clearly demonstrates the value of hyperspectral satellite data for mineral exploration workflows. By integrating advanced spectral unmixing techniques with spaceborne hyperspectral imagery, it is possible to reduce exploration risk, optimize field campaigns, and accelerate target generation, positioning hyperspectral remote sensing as a powerful tool for next-generation mineral exploration.

Although SMACC is less sensitive than MTMF, it produced consistent and reliable abundance maps for most of the pegmatites analyzed. Its ability to automatically extract endmembers directly from the hyperspectral image, without the need for external spectral libraries or detailed prior knowledge, represents a strong advantage when applied to greenfield exploration areas, where geological information is often limited.