Magna Scientia Advanced Research and Reviews

eISSN: 2582-9394

Cross Ref DOI: 10.30574/msarr

Journal homepage: https://magnascientiapub.com/journals/msarr/

Magna Scientia Open access publication

(RESEARCH ARTICLE)

Check for updates

Exploiting the potential of images from the aster and landsat 9 satellites for the mapping of hydrothermal alteration minerals associated with mineralization in the departments of Abtouyour and Guera, located in the Chadian massif central (republic of Chad)

AMINE KARIFENE [1], PODO MAHAMAT MATAR [2, *], MACKAYE HASSAN TAÏSSO [2], MAMADOU MALLOUM AHMAT [1] and MAHAMAT ALI ATEIB [1]

[1] *Department of Geomatics, Faculty of Mines and Geology, Polytechnic University of Mongo (Chad).*

[2] *Department of Geosciences, Faculty of Exact and Applied Sciences, University of Ndjamena (Chad).*

Magna Scientia Advanced Research and Reviews, 2024, 12(01), 005–020

Publication history: Received on 05 August 2024; revised on 14 September 2024; accepted on 17 September 2024

Article DOI: https://doi.org/10.30574/msarr.2024.12.1.0144

Abstract

This article deals with the use of remote sensing with Aster and Landsat 9 imagery for mapping hydrothermal alteration minerals and oxides in relation to mineralization. Aster VNIR (Visible and Near Infrared) and SWIR (Mean Infrared) data are used to calculate PCA (Principal Component Analysis), RBD (Relative Band Depth) and BR (Band Ratio). These different parameters are used to highlight the groups of hydrothermal alteration minerals and oxides. Landsat data are used for mapping lithological units using PCA and BR. The identified mining areas coincide with the gold planning sites of Toumka and Lellé and allow to know the interesting areas for future mining prospecting campaigns in the departments of Abtouyour and Guéra (Guéra province).

Keywords: Remote sensing; Satellite images; Raster data; Guéra

1. Introduction

African countries in general and Chad in particular, are concerned about the development of the country which involves increasing GDP, building educational, health, road infrastructure, etc. All these needs imply a substantial budget and an increase in state revenue. In this same vision, the Chadian government has launched the promotion of the mining sector throughout the national territory. To realize this new vision, the National Mining and Control Company (SONEMIC) was created to effectively manage the evolution of the mining sector. This article contributes to the promotion of the mining sector by using a new technology, that of satellite imagery and GIS for the detection of areas likely to contain mineralization.

The main objective of this work is to map hydrothermal alteration zones likely to contain mineralization. To achieve this objective, specific objectives are defined:

Determine the Principal Component Analysis (PCA); determine the relative band depth (RBD); integrate, process information and print the results in the GIS.

* Corresponding author: PODO MAHAMAT MATAR

1.1. Location of the study area

The study area is located between 17°30' and 19° East longitude, and 11° and 13° North latitude. The study area includes two departments: the department of Guéra and the department of Abtouyour. These two departments belong to the province of Guéra, the city of Mongo is the capital of the province. Figure 1 shows the location of the study area.

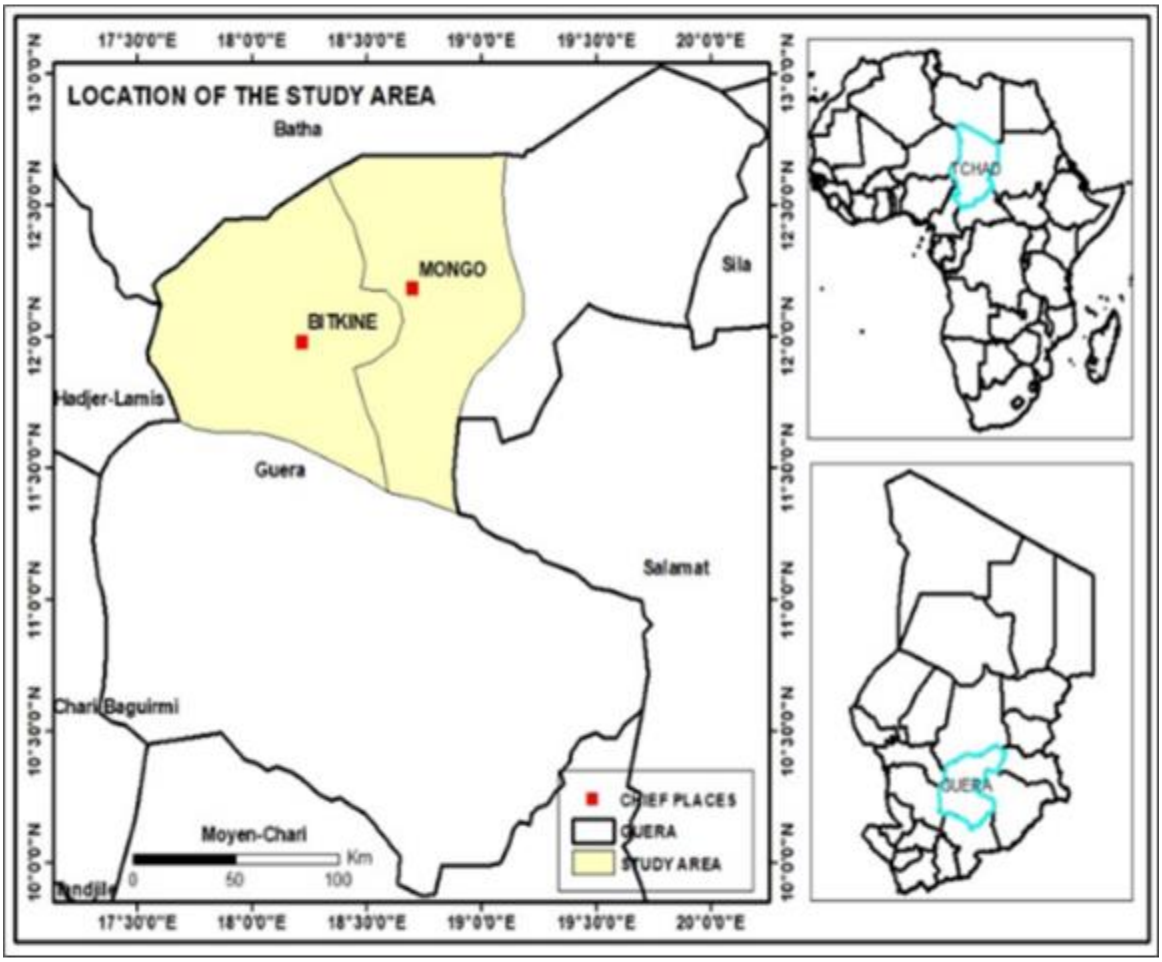

Figure 1 localisation de la zone d'étude

1.2. Regional Geological Framework

Geologically, Chad belongs to the Pan-African mobile zone, limited to the south by the Congo craton, to the west by the West African craton and to the northeast by the Nilotic craton [1] and includes the Uweinat craton. The northern boundary with the Nilotic craton is very poorly defined and its southern boundary with the Congo craton is materialized by the Sanaga shear zone in Cameroon. But the concept of Nilotic craton and Uweinat has been questioned, because the geological formations of these cratons have different ages proving that some formations were remobilized by the Pan-African orogeny [2] proposed the concept of metacraton, the arguments put forward of which convinced the scientific community and helped to dispel concerns about the ages of the formations. Consequently, the Tibesti, Ouaddaï and Massif Central formations belong to the Sahara metacraton, while the Mayo Kebbi and Baibokoum massifs belong to the Central African mobile zone. The Pan-African orogeny is at the origin of the formation of sedimentary basins (Doba basin, Lake Chad basin, Ennedi basin and Tibesti basin) formed by recent sedimentary formations [3].

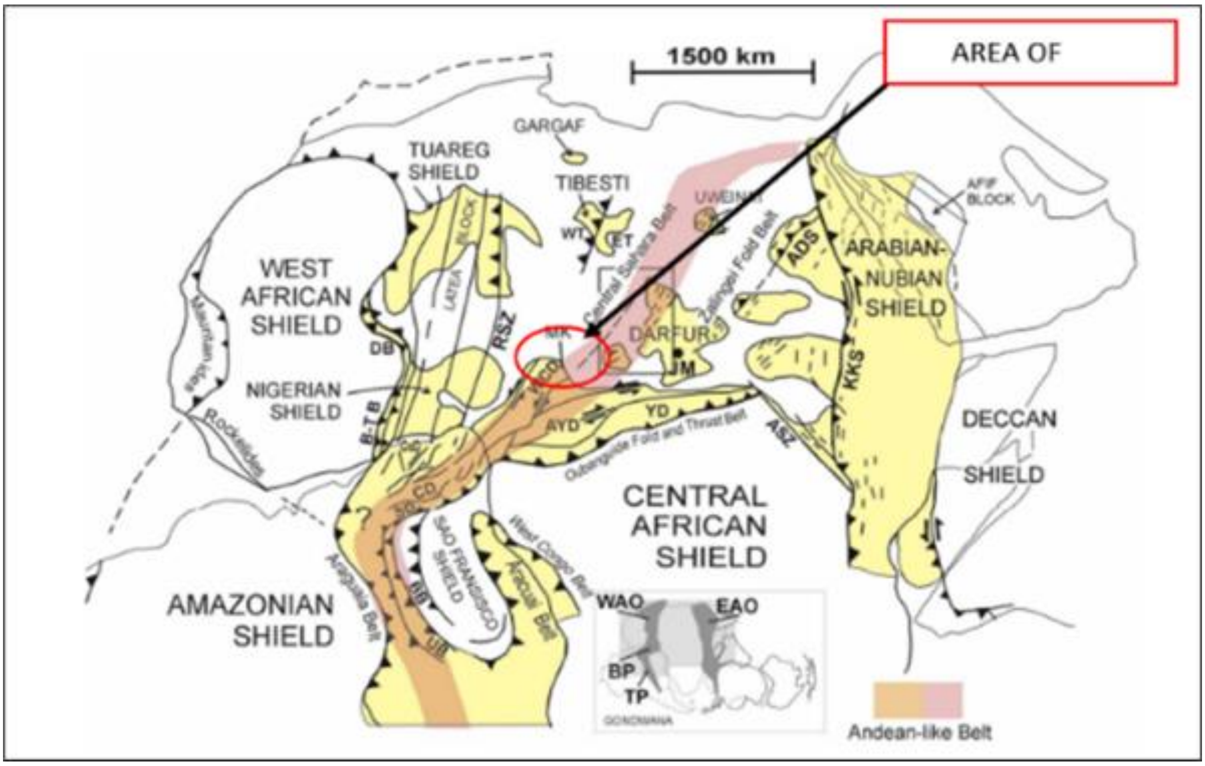

Figure 2 Location of cratonic and mobile zones in Central Africa

1.3. Geological Framework of the Guéra province

The Guéra province is part of the Sahara metacraton constituting the central Chadian massif, formed mainly by the Guéra and Aboutelfan massifs and some smaller outcrops. These massifs are the result of the collision between the Congo craton and the Saharan metacraton [2][5].

The Guéra massif is one of the smallest massifs of the Sahara metacraton, comprising Neoproterozoic magmatic and metamorphic rocks covered by Quaternary sediments. The granitoids of the province are grouped into two: those that are old, metalluminous to peralluminous, magnesian and alkaline, collisional and those that are young, peralluminous, ferrous and calc-alkaline and post-collisional. Overall, the province is composed petrographically of granites, granodiorites, diorites and gneisses with basaltic enclaves and cut by pegmatitic, aplitic and dolerite dykes. Between these formations are recent sedimentary covers.

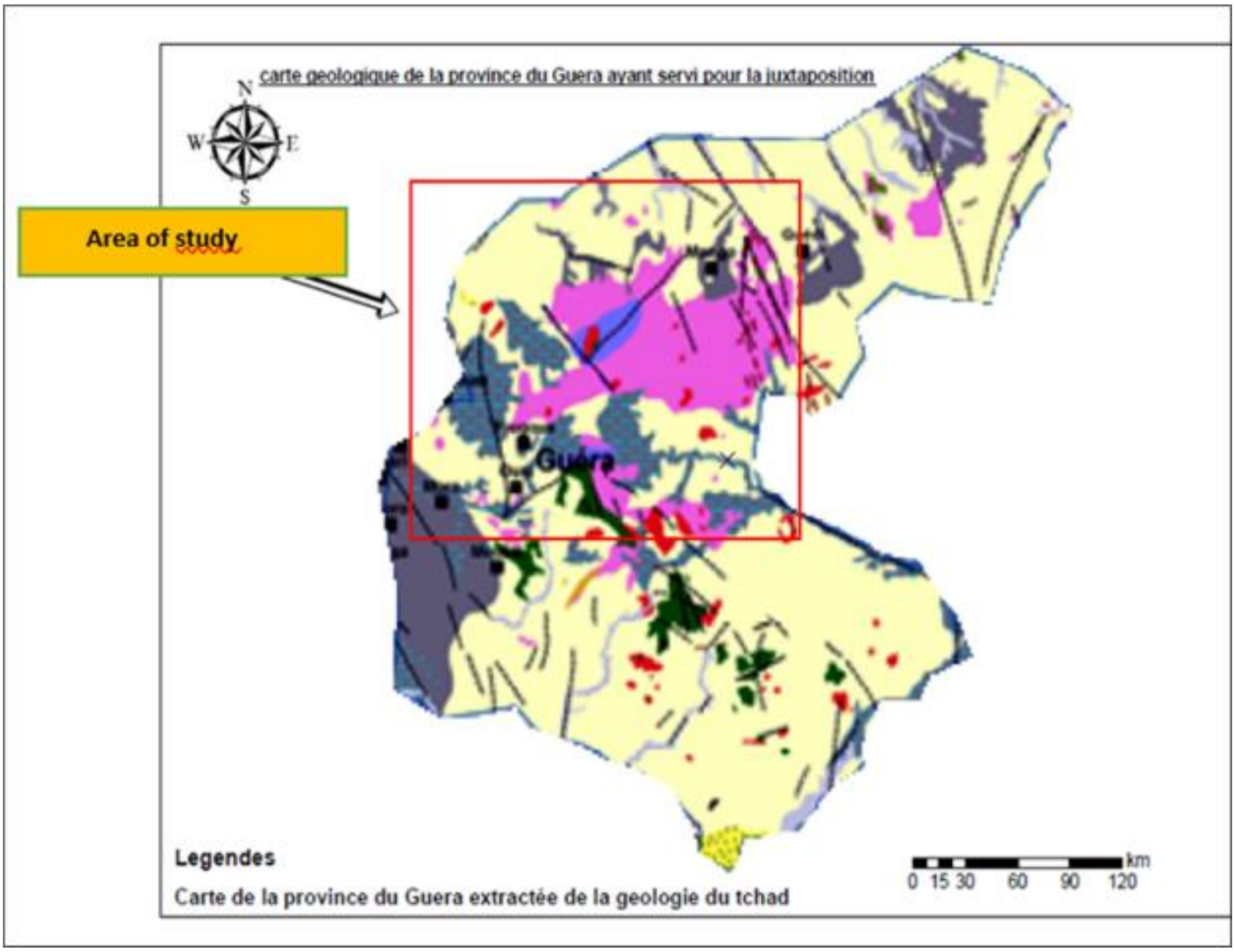

Figure 3 Geological map of Guéra province [6] modified by Podo Mahamat Matar illustrating the lineaments in the NNW and NNE

2. Materials, Data and Method

2.1. Materials and Data

As part of this work, equipment and data were used to map the alteration zones.

The materials used include:

- The Lenovo T46OS ThinkPad branded computer that serves as a platform for software installation;
- GPS (Global Position System) for taking coordinates and identifying points on the ground;
- A geologist's hammer and a sledgehammer for taking samples;
- A clinometer compass for measuring the direction and dip of outcrops, veins, faults, fractures and fractures.

2.2. Data

The data used to map the weathering zones are mainly based on Aster and Landsat 9 image data from the study area. The potential of these images for mapping alteration zones has been successfully demonstrated by numerous studies [7][5][8] For the proper use of the Aster and Landsat 9 data, the information relating to these images is summarized in the table below (Table 1).

Bande	Résolution (m)	(µm)	Résolution (m)	(µm)	Bande
Bande 1	30 Costal/Aérosol	0.435–0.451	15	0.52–0.6	Bande1
Bande 2	30 Bleu	0.452–0.512	15	0.63–0.69	Bande 2
Bande 3	30 Vert	0.533–0.590	15	0.76–0.86	Bande 3
Bande 4	30 Rouge	0.636–0.673	30	1.60–1.70	Bande 4
Bande 5	30 NIR	0.851–0.879	30	2.145–2.185	Bande 5
Bande 6	30 SWIR-1	1.566–1.651	30	2.185–2.225	Bande 6
Bande 7	30 SWIR-2	2.107–2.294	30	2.235–2.285	Bande 7
Bande 8	15 Casserole	0.503–0.676	30	2.295–2.365	Bande 8
Bande 9	30 Cirque	1.363–1.384	30	2.360–2.430	Bande 9
bande10	100 TIR-1	10.60–11.19	90	8.125–8.475	Bande 10
bande11	100 TIR-2	11.50–12.51	90	8.475–8.825	Bande 11
-	-	-	90	8.925–8.275	Bande 12
-	-	-	90	10.25–10.95	Bande 13
-	-	-	90	10.95–11.65	Bande 14

Figure 4 The Aster Landsat bands and their characteristics

2.3. Methodology

The Methodology used for the extraction of alteration zones is based on the calculation of directed component analyses (DCPA), band ratios (BR) and relative band depth (RBD).

2.3.1. Simple Principal Component Analysis (PCA) and Directed Principal Component Analysis (APCD)

Principal Component Analysis (PCA) is a highly effective image-enhancing approach for geological and mining mapping. PCAs will be carried out on the Landsat 9 and Aster bands and will surely allow a good lithological differentiation to be made. The PCAs performed on the OLI and Aster bands provided good results for the lithological characterization of the study area.

Directed component analysis (DCPA) is a very powerful enhancement technique, based on the selection of bands in relation to the target studied and allowing to extract a specific alteration. To generate DCPA, Aster and Landsa bands

The methodology used for the extraction of alteration zones is based on the calculation of directed component analyses (DCPA), band ratios (BR) and relative band depth (RBD).

2.3.2. The PCAs performed on the OLI and Aster bands provided good results for the lithological characterization of the study area

Directed component analysis (DCPA) is a very powerful enhancement technique, based on the selection of bands in relation to the target studied and allowing to extract a specific alteration. To generate the DCPA, Aster and Landsat 9 bands are used in this study. The input Landsat bands for BCAH are bands 2, 5, 6, and 7. In addition, the Landsat 8 ratio bands (4:2, 6:4, 6:5 and 6:7) were used for the ACSI to highlight rocks enriched in ferric/ferrous iron oxides and Fe-OH, ferrous oxides, ferric oxides and hydroxylated minerals (Al–OH and Fe, Mg–OH).

2.3.3. Band ratios (BR), relative band depth (RBD), and false-color compositions (FCC)

Ratio bands are enhancement techniques used in geology to distinguish lithological or mineral information. It is a technique based on mathematical operations manipulating the digital data of images.

The ratios of the calculated bands 7/6, 7/3 and 1/5 of the OLI2 sensor and the color composition (red:7/6, green: 7/3 and blue:1/5) gave a good result (Abdelnasser et al., 2023), (Banerjee et al., 2019). It effectively enhances the different facies of the granitoids.

Other reports of the processed Landsat-9 bands, (a) Abrams (RGB-6/7, 4/3, 5/4); (b) Chica-Olma (RGB-6/7, 6/5, 4/2) and (c) Kaufmann report (RGB-7/5, 5/4, 6/7) are used for lithological discrimination and the identification of important contacts of rocks considered to be favorable zones for mineralization (For the Aster data, the band ratios combined with the false-colour colour compositions (4/7, 2/1, 4/3), comparted effectiveness of RBD in mining mapping has been demonstrated by numerous previous studies: This parameter has made it possible to discover mining areas in operation around the world and to locate new mining areas that will be the subject of future research. As part of this work, the RBD has made it possible to localize

2.3.4. RBD1 for the alunite-kaolinite-pyrophyllite group of minerals

- RBD2 for the mineral group sericite-muscovite-illite-smectite;
- RBD3 for the chlorite epidote mineral group; and
- RBD4 for the Si-OH-rich mineral group.

2.3.5. Minimum Noise Factor (MNF)

The minimum noise fraction is a mathematical approach, based on orthogonal rotation, to generate components with increasing noise percentages as opposed to PCR which produces components with decreasing variance. Numerous studies have used MNF for the detection of alteration zones associated with mineralization [13].

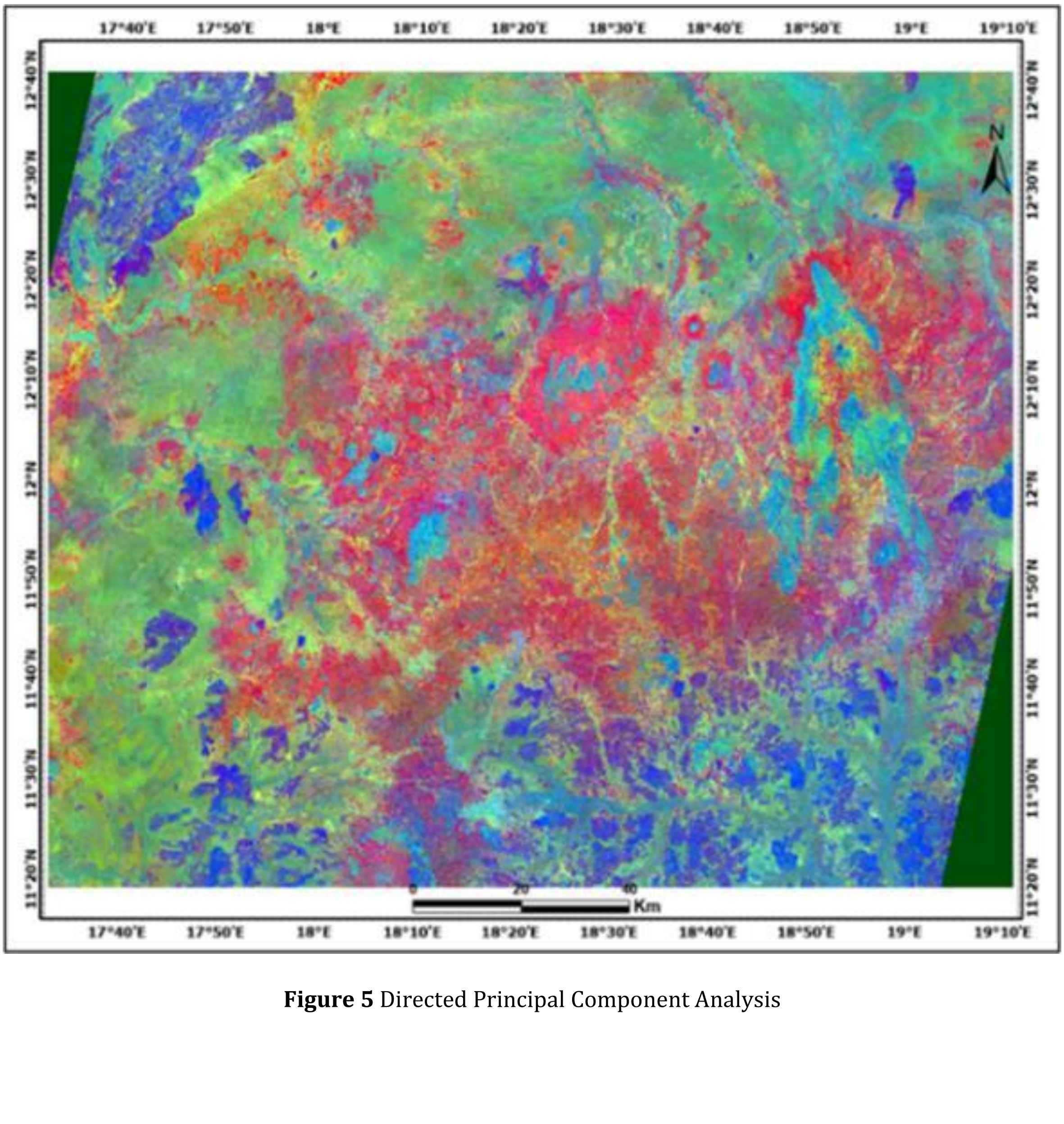

Figure 5 Directed Principal Component Analysis

2.3.6. Presentation of Relative Band Depth (RBD) Parameters

Figure 6 shows the distribution of the alteration mineral group (alunite-kaolinite-pyrophyllite), determined by the RBD1 parameter, this mineral group is expressed by the yellow-brown color. This mineral complex occupies only a small part, representing 15% of the portion studied. It is poorly distributed, located in the extreme east (near the locality of Golonti) and west of the study area.

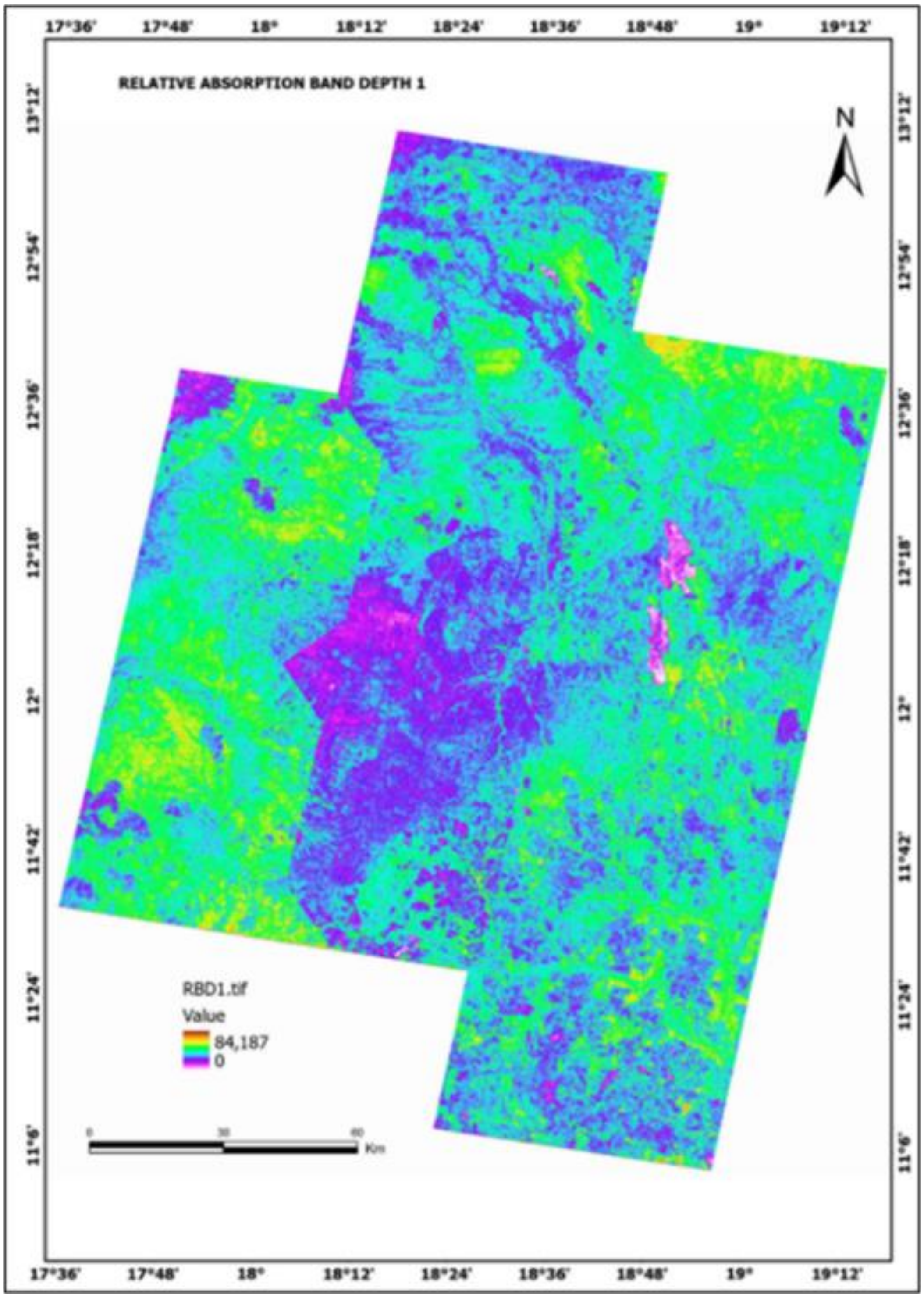

Figure 6 The RBD1 relative band depth showing a group of alteration minerals (alunite-kaolinite-pyrophyllite) in dark blue and purple

RBD2 was used to highlight the minerals sericite-muscovite-illite-smectite, expressed on the imaging in Figure 6 in brown and yellow. In terms of distribution in the area studied, this mineral complex is larger than the previous one and is very well expressed in the department of Abtouyour and identified in the localities of Dabakalamar, Tialo-Ideba, Sara-Arabe and Toumka.

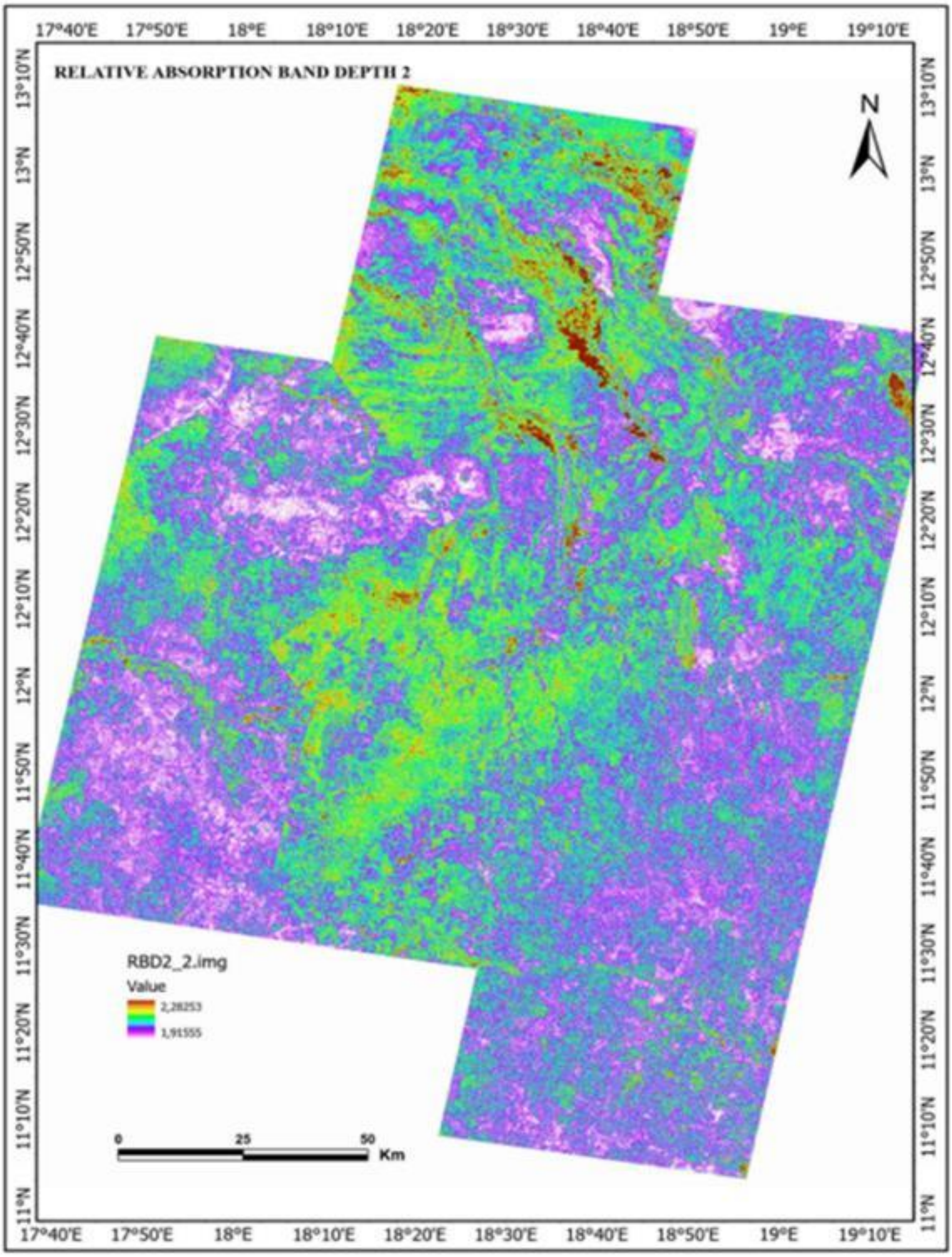

Figure 7 RBD2 relative band depth highlighting the sericity-muscovite-illite-smectite mineral complex, appearing yellowish-brown

.

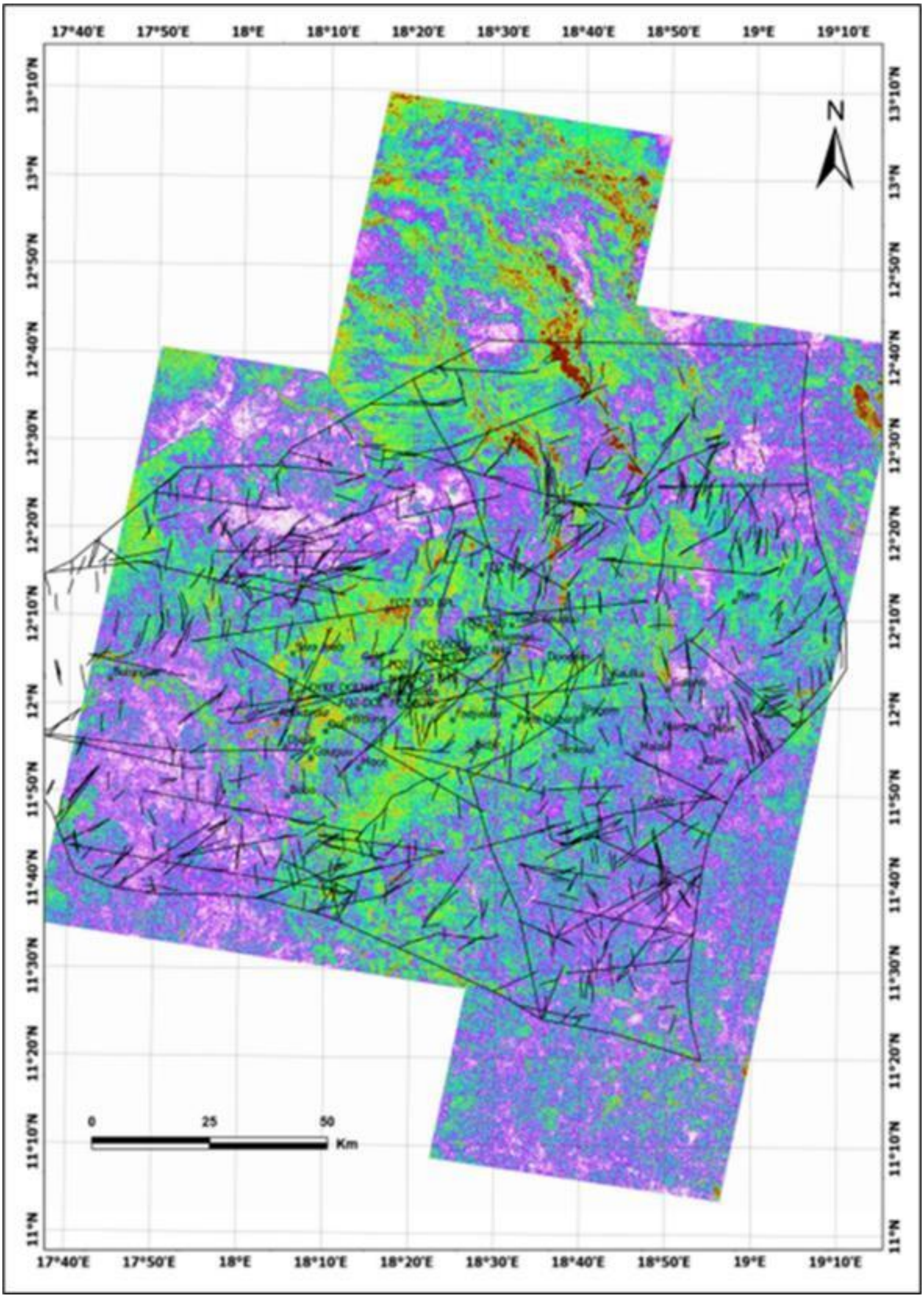

Figure 8 The RBD3 parameter, expressing two chlorite-epidote minerals, appearing in this figure in brown and yellowish. They are identified in the area of Tialo-Ideba and Dabakal-amar

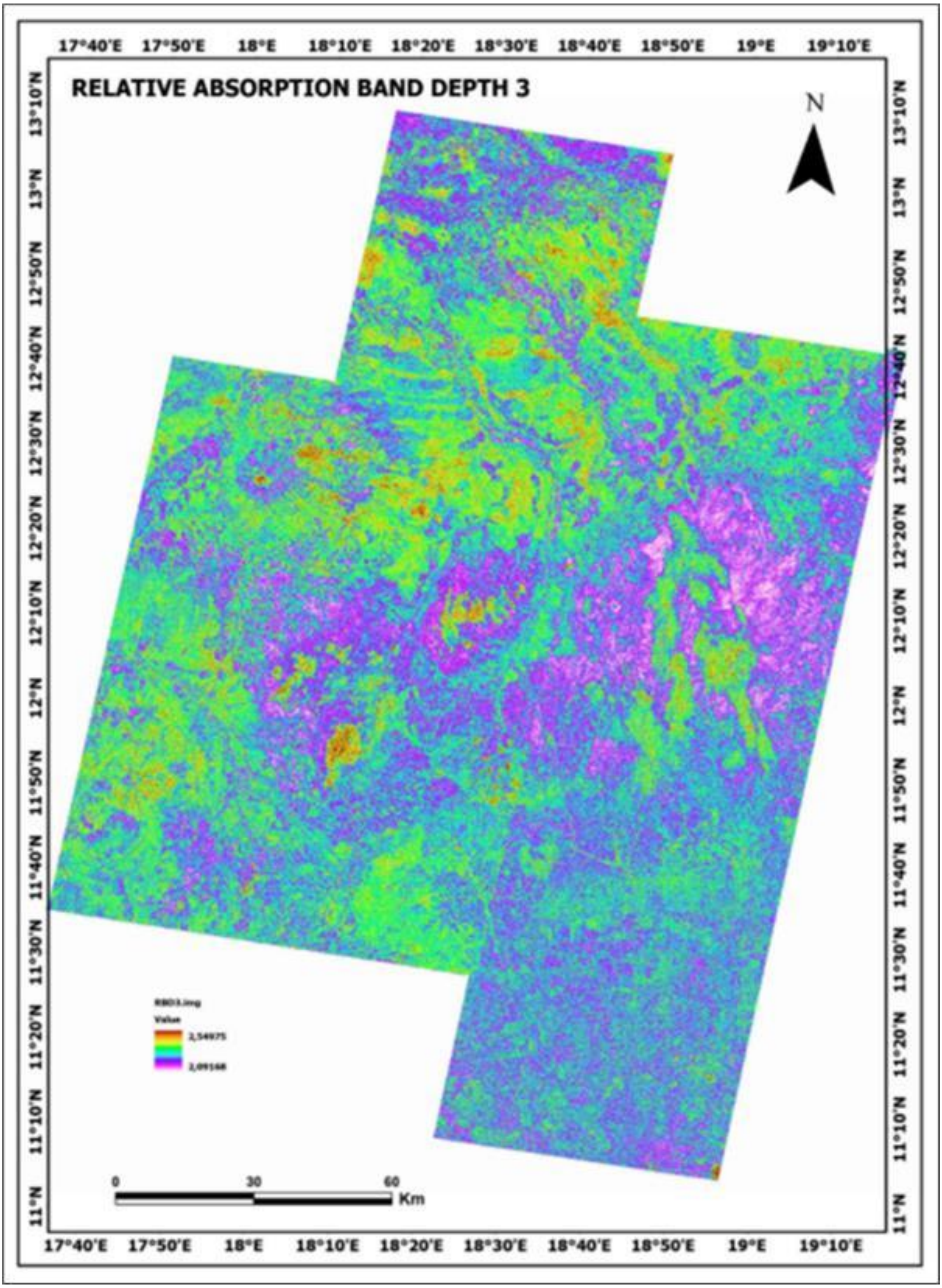

Figure 9 The relative band depth RBD3 highlighting the chlorite-epidote mineral complex

The Si-OH-rich rocks are highlighted by the RBD4, appearing in yellowish-green in Figure 7. They are identified and very concentrated in the north of the Sara-arabe and Toumka area in the department of Abtouyour.

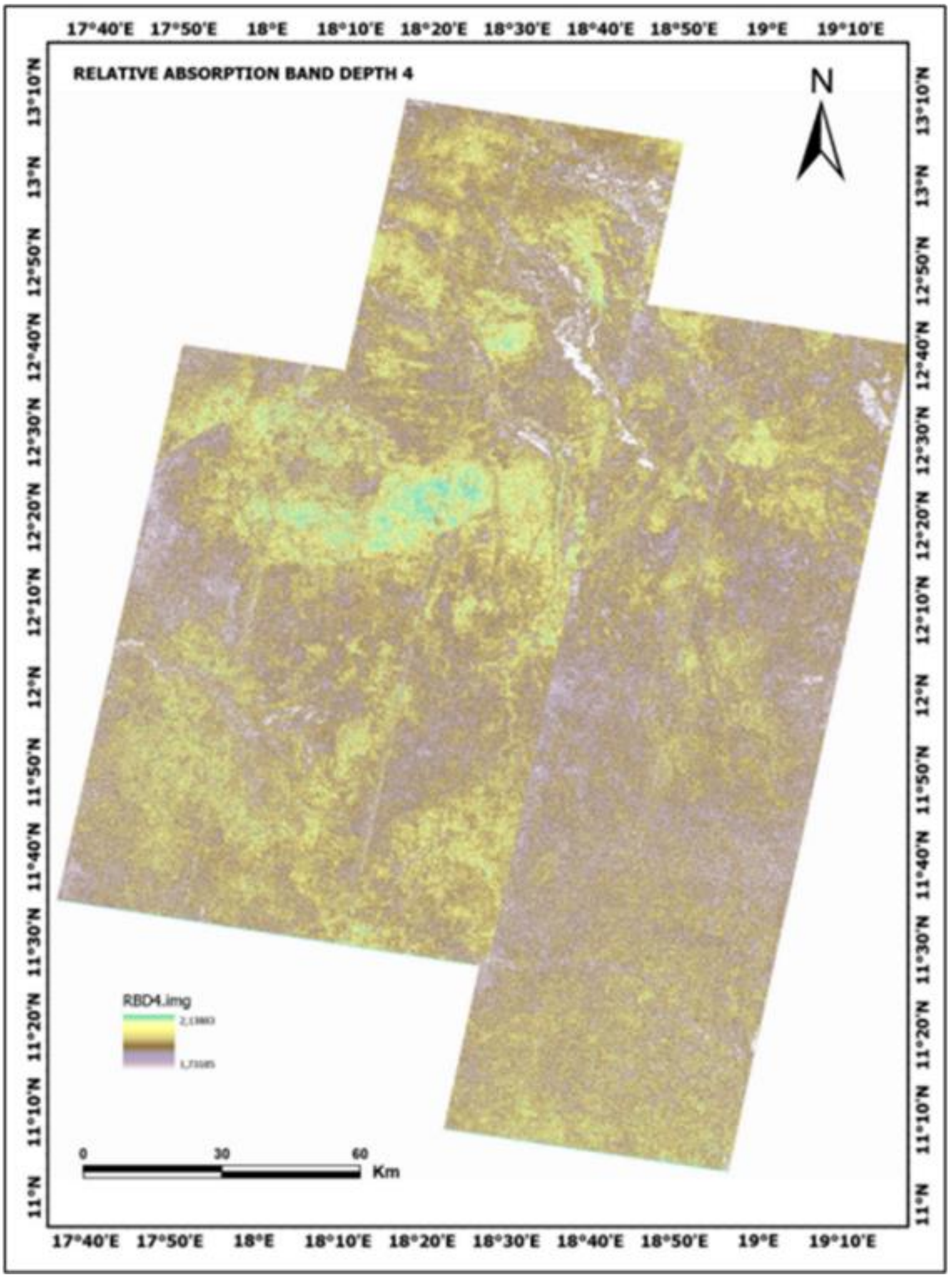

Figure 10 RBD4 relative band depth highlighting the Si-OH-rich mineral complex

3. Results, analysis and interpretation

3.1. Presentation of results

Presentation of Directed Principal Component Analysis

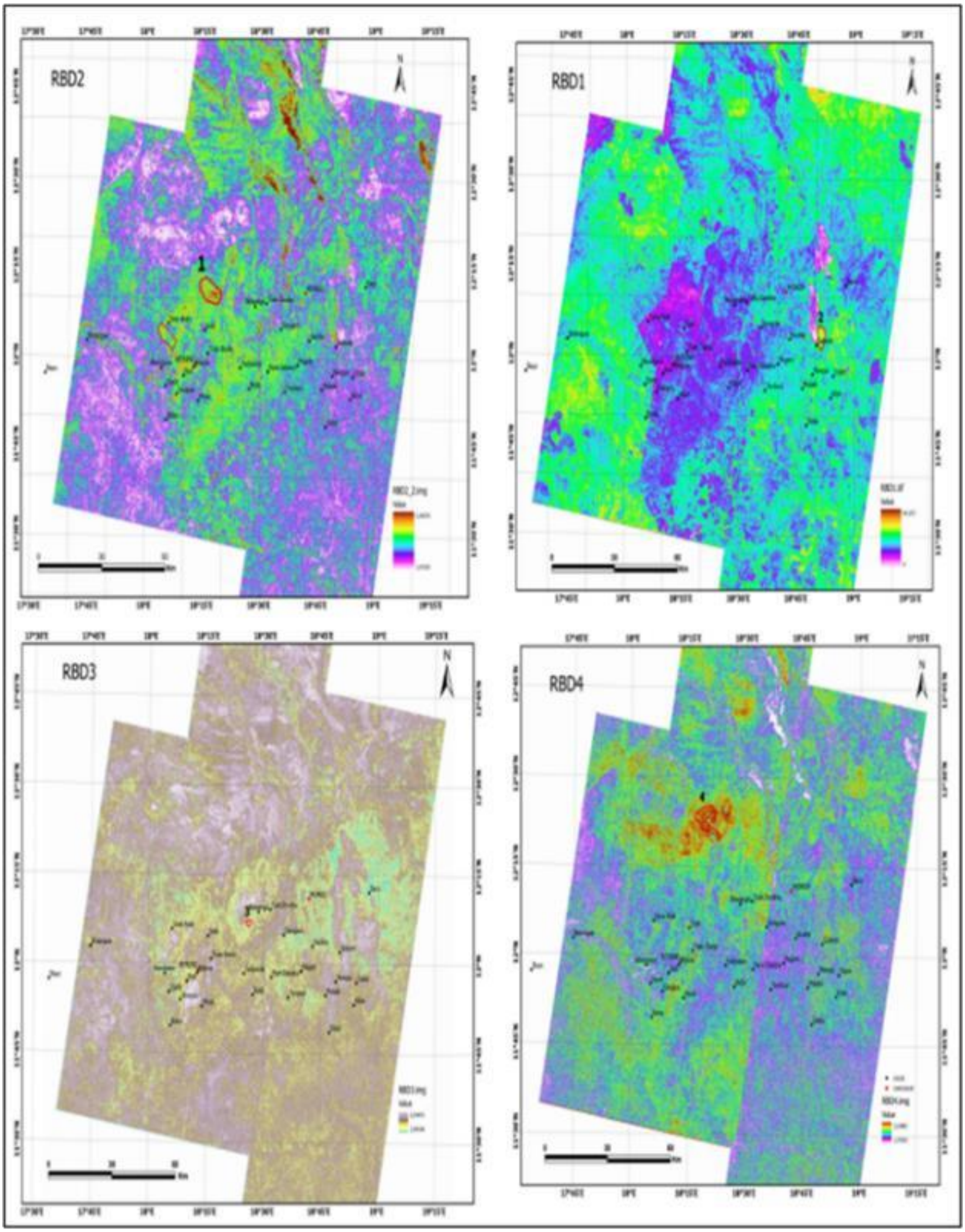

Figure 11 Synthesis of RBDs, 1 (muscovite-sericite-illite), 2 (alunite-kaolinite-pyrophyllite), 3 (chlorite-epidote) and 4 (SiOH-containing rocks)

3.2. Introduction of Iron Oxides

Figure 12 illustrates the spatial distribution of iron oxides, appearing in a reddish-yellow colour. These oxides are generally expressed in the areas near the granitic massifs.

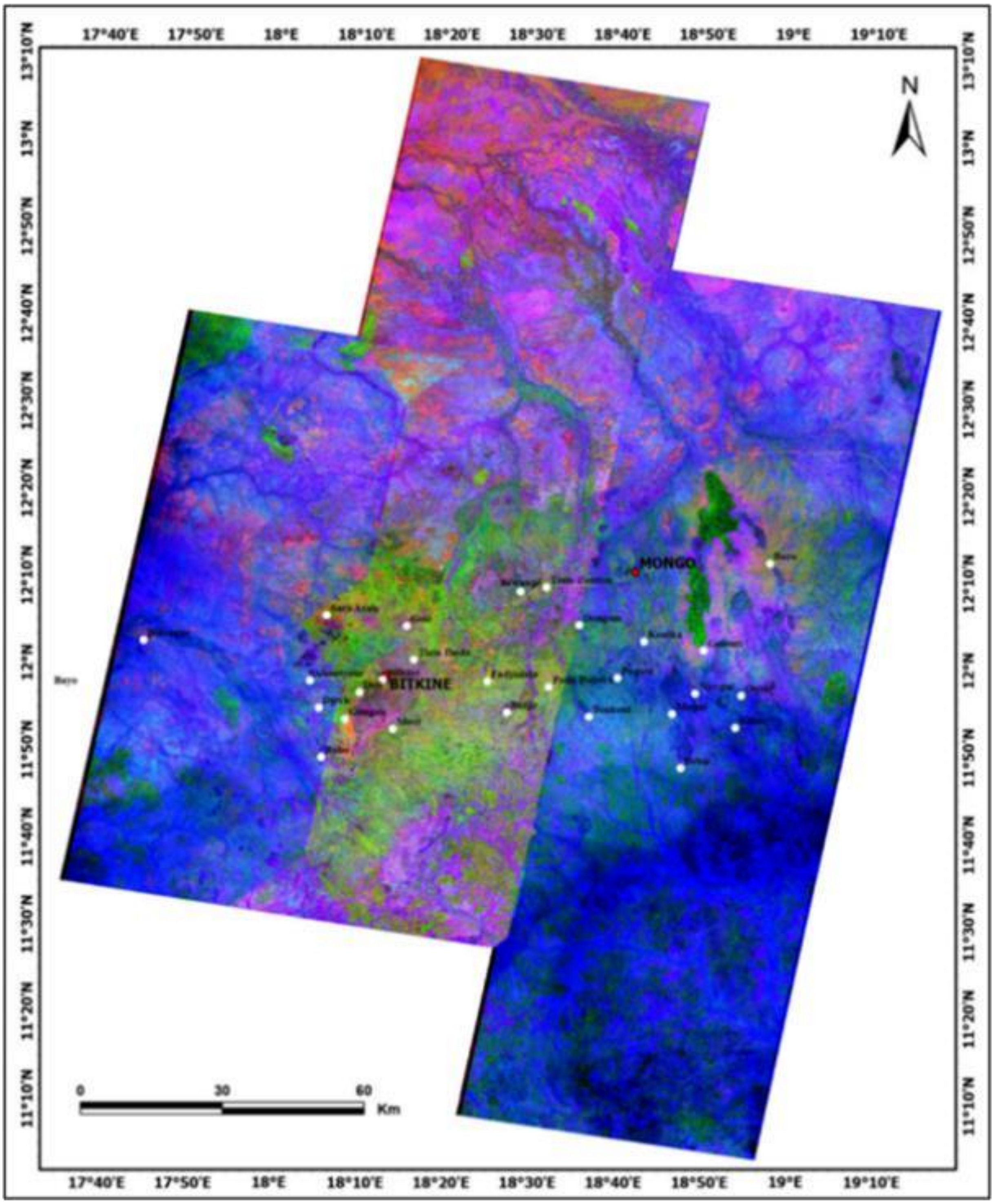

Figure 12 Iron oxide zones are highlighted by the RGB colour composition of the 2:1, 4:3 and 4:5 ratios. Iron oxides appear yellow to reddish

3.3. Presentation of the BR Aster 4/5

The BR is used for the determination of the lithological units and has made it possible to distinguish six (6) units distributed over the entire portion studied.

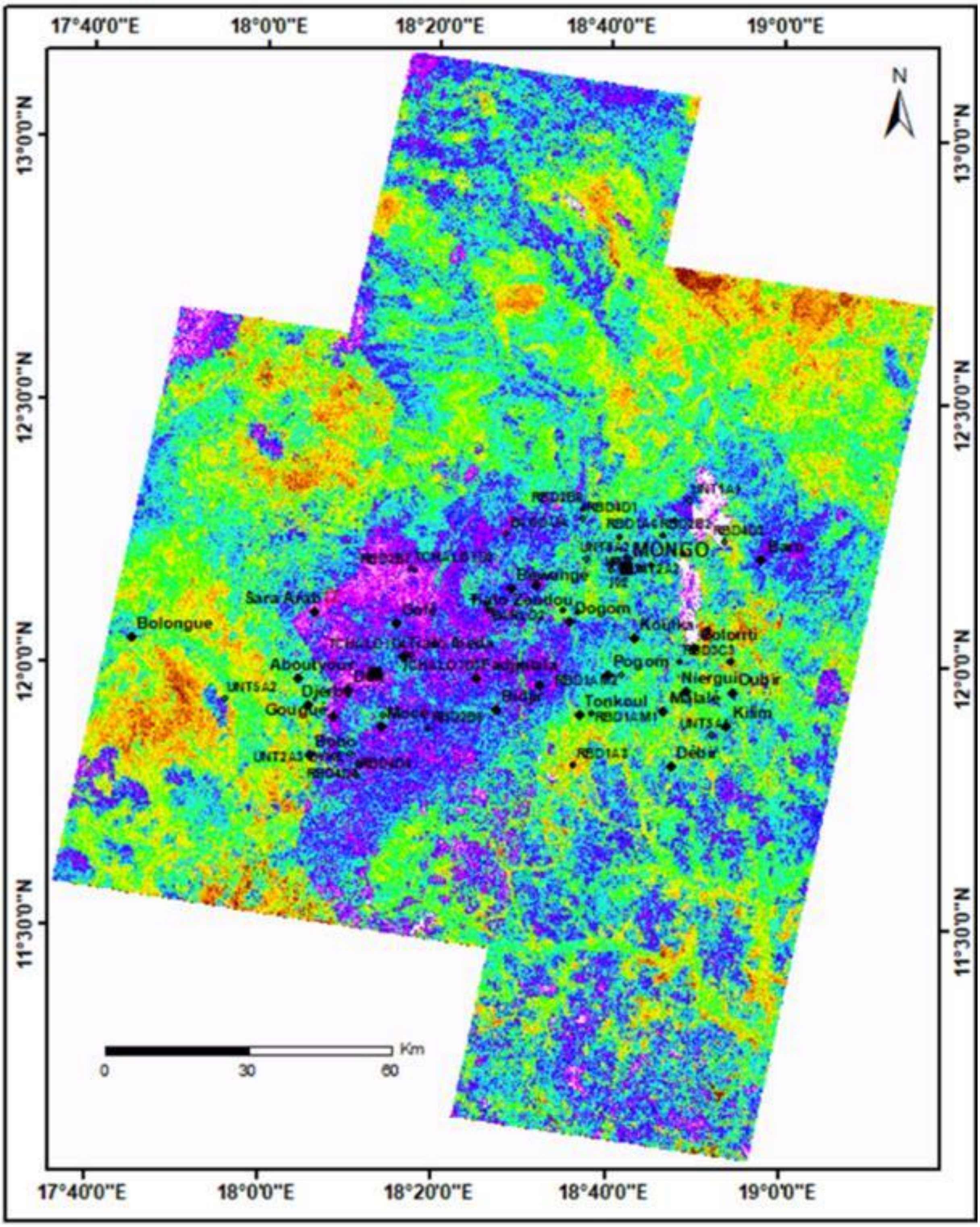

Figure 13 The Aster 4/5 ratio band ensuring good lithological discrimination

3.4. Analysis and Interpretation

The Aster and Landsat 9 images made it possible to carry out geological and mining mapping in record time, given the advantages offered by this new technology, which has been tested around the world with satisfactory results. RBDs, very effective parameters in the mapping of alteration minerals in relation to mineralization, have made it possible to locate hydrothermal alteration zones. The results obtained through imaging were validated by an incursion into the field. These different minerals have been recognized in the field, it has been found that these areas with alteration minerals coincide with the gold panning sites of Toumka and Lellé in the department of Abtouyour.

4. Conclusion

The potential of Aster and Landsat 9 imagery is highly effective in mapping hydrothermal alteration zones and iron oxides and hydroxides, in relation to mineralization. The parameter, the relative band depth made it possible to map the hydrothermal alteration minerals of the study area. Four (4) RBDs (RBD1, RBD2, RBD3 and RBD4) were determined, and respectively highlighted the kaolinite-alunite-pyrophyllite groups, the smectite-muscovite-sericite-illite groups, the chlorite-epidote groups and the SiOH-rich mineral groups. RBD3 is observed in the field next to the dolerites from which the minerals identified are derived. The other RBDs are globally associated with granitoids. The results obtained show that the mapped hydrothermal alteration zones coincide well with the gold panning sites of Toumka and Lellé. These results make it possible to know the areas of interest for the barrels

Compliance with ethical standards

Acknowledgments

Our thanks to the University of Mongo, which allowed us to carry out this work thanks to its laboratory and its President Professor MACKAYE HASS TAÏSSO for his guidance and availability and to the CDIG (Center for Documentation and Geographic Information) for the data, it provided us and the documentation.

Disclosure of conflict of interest

We affirm on our honor that all the authors who contributed to the writing of this article have no conflict of interest.

References

[1] B. Bessoles et R. Trompette, "geology of Africa, the pan-African chain" mobile zone of central Africa (southern part) and Sudanese mobile zone"», 1980.

[2] M. G. Abdelsalam, J.-P. Liégeois, et R. J. Stern, « The saharan metacraton », *J. Afr. Earth Sci.*, vol. 34, nº 3-4, p. 119-136, 2002.

[3] I. Kusnir et J.-L. Schneider, Geology, Mineral Resources and Water Resources of Chad, No. 1. National Research Support Centre, 1993.

[4] M. G. Abdelsalam, J.-P. Liégeois, et R. J. Stern, « The saharan metacraton », *J. Afr. Earth Sci.*, vol. 34, nº 3-4, p. 119-136, 2002.

[5] F. Djerossem, A. Zeh, M. Isseini, O. Vanderhaeghe, J. Berger, et J. Ganne, « U-Pb-Hf isotopic systematics of zircons from granites and metasediments of southern Ouaddaï (Chad), implications for crustal evolution and provenance in the Central Africa Orogenic Belt », *Precambrian Res.*, vol. 361, p. 106233, 2021.

[6] J.-P. Wolff, Geological map of the Republic of Chad. Bureau of Geological and Mining Research (BRGM), 1964.

[7] I. Naouadir *et al.*, « Coupling Field Investigations with the Contribution of Remote Sensing and GIS for the Moroccan Middle Atlas Karst: A Case Study of the El Menzel Causse », *Iraqi Geol. J.*, p. 19-35, 2023.

[8] M. El-Mimouni, A. Aarab, A. Lakhloufi, A. Hamzaoui, A. Akhssas, et K. Benyas, « Contribution of multispectral remote sensing to mining exploration in the Rehamna Massif, Moroccan Meseta », ", presented at E3S Web of Conferences, EDP Sciences, 2020, p. 03018.

[9] H. El-Desoky, A. Shebl, H. El-Awny, M. El-Rahmany, et O. Soliman, « Detecting Oxides Mineralization Utilizing Remote Sensing and Comprehensive Mineralogical Analysis: A Case Study Around Mikbi-Zayatit District, South Eastern Desert, Egypt », *Iraqi Geol. J.*, p. 97-130, 2023.

[10] M. El-Mimouni, A. Aarab, A. Lakhloufi, A. Hamzaoui, A. Akhssas, et K. Benyas, « Contribution of multispectral remote sensing to mining exploration in the Rehamna Massif, Moroccan Meseta », ", presented at E3S Web of Conferences, EDP Sciences, 2020, p. 03018.

[11] A. Shebl et M. Hamdy, « Multiscale (microscopic to remote sensing) preliminary exploration of auriferous-uraniferous marbles: A case study from the Egyptian Nubian Shield », *Sci. Rep.*, vol. 13, nº 1, p. 9173, 2023.

[12] M. A. Abdelkader, Y. Watanabe, A. Shebl, H. A. El-Dokouny, M. Dawoud, et Á. Csámer, « Effective delineation of rare metal-bearing granites from remote sensing data using machine learning methods: A case study from the Umm Naggat Area, Central Eastern Desert, Egypt », *Ore Geol. Rev.*, vol. 150, p. 105184, 2022.

[13] S. Peyghambari et Y. Zhang, « Hyperspectral remote sensing in lithological mapping, mineral exploration, and environmental geology: an updated review », *J. Appl. Remote Sens.*, vol. 15, nº 3, p. 031501-031501, 2021.

[14] Y. Xi, A. M. Mohamed Taha, A. Hu, et X. Liu, « Accuracy comparison of various remote sensing data in lithological classification based on random forest algorithm », *Geocarto Int.*, vol. 37, nº 26, p. 14451-14479, 2022.