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Remote Sensing Studies for Mapping of Iron Oxide Regions in Keonjhor district, Odisha, India

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ABSTRACT

Odisha is known for having a bounty of mineral resources, which are required for the economic and industrial development of the state. Ore minerals such as hematite, magnetite, pyrolusite, psilomelane, chromite etc are richly available in Odisha. A lot work has been done on the mineral property, texture, behaviour of individual ions in different chemical conditions within the domain of the aforesaid minerals and a very few works has reportedly been done on the spectral behaviour of these ore minerals. For the development of human societies, economic and industrial demand of iron has been raised which resulted in search of new cost-effective techniques for the exploration of ore minerals containing Fe metal. Remote sensing methods are now considered as modern and cost effective highly dynamic techniques for exploration of economic ore minerals containing iron oxides. In this study, various digitalimage processing techniques of remote sensingsuch as False Colour Composites (FCCs), Band Ratios (BRs), and Principal Components Analysis (PCA) were used on satellite derived images for mapping iron oxide mineralization zone. The results were compared with the already published maps and also with the field inspection. From the results, it was found that various band combinations of BRs and PCA may be used for mapping of iron oxide ore regions.

Keywords: *Iron oxide ore minerals, Band ratioing, FCC, PCA, ASTER*

Introduction

Iron plays an important role in the development and economy of the country. Iron is mainly used as raw material in steel industry. The common iron ore used in steel industry are Hematite (Fe_2O_3), Magnetite (Fe_3O_4), Goethite (FeO(OH)), Limonite (FeO(OH)nH_2O) or Siderite ($FeCO_3$). The demand of Iron ore in steel industry is continuously increasing in recent decades. Therefore,researchers are searching for new cost-effective techniques for quick andaccurate identification of Iron ore depositional area. Mineral exploration is becoming very difficult in sensitive or remote areas. In these cases, the remote sensing methods may be used for speedy operation in exploration process which significantly reduces the cost of the finance as well.

Mapping of earth surface mineral deposits using remote sensing techniques add more opportunities at the reconnaissance stages of mineral exploration (Moghtaderi *et al.,* 2007; Gabr *et al.,* 2010, Pour and Hashim 2011, 2014; Raj *et al.*, 2015; Ducart *et al.* 2016). Many earth scientists have worked on the multispectral and hyperspectral data to delineate various mineral deposits present on the earth surfaces through Band Ratioing techniques, Principal Component Analysis (PCA), Image Enhancement techniques, Spectral Analysis of the end members (Pour and Hashim 2012). Digital image interpretation for identification and extraction of geological

([1]Ph.D. Research Scholar, [2]Associate Professor) features through band ratiomethodis widely used on Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data. The very near infrared bands of ASTER data sets are highly useful for the identification and mapping of iron oxides (Rajendra *et al.,* 2011). In present study, identification and mapping of iron oxiderich regions mainly in Jodablock of Keonjhor district, Odisha has been performed on ASTER data using Band Ratios, Principal Component Analysis and Spectral reflectance pattern of the materials present in the image. The resulted iron ore potential zone map has been validated using Google Earth image and Field studies.

Study Area and Geological Setting

This research work has been done on a part of Joda block of Keonjhor district, Odisha (Figure 1). The study area covers a small part of the famous 'horse shoe' shaped synclinorium of Precambrian Iron Ore Super Group of Odisha and Jharkhand. The area lies within toposheets 73F08 and 73G05. It is bordered by Mayurbhanj district in the East, Sundargarh district in the West, Singhbhum district of Jharkhand in the North and Jajpur district of Odisha in the South. The study area is considered as one of the important iron ore deposits of Odisha. The mineralization environment in Joda region can be easily identified from the False Colour Composite (FCC) image (Figure-2).

Banded iron ore formations (BIF) are mainly found in association of Singhbhum Shear Zone (SSZ) in northern part of Odisha. It is imposed periodically by the basic lavas in some places while and at other places it is brought down by the ultrabasic rocks (Banerjee 1982). The Iron Ore Super Group (IOSG) of Odisha constitute three prominent provinces of Banded Iron Formations (BIFs) such as Bonai-Keonjhor belt, Badampahar- Gorumahisani-Suleipat belt and Tomka-Daitari belt. These BIFs are found surrounding Archaean continental nucleus i.e., the North Odisha Iron Ore Craton (NOIOC (Satpathy and Beura2013, Deb 2014). The Archean Iron ore group of Singhbhum craton contains most of the high-grade iron ores (Fe % >60 wt.) of eastern India. The Iron Ore Groups are mainly found within the Singhbhum Granite (>3.1 Ga,). The major geological formations in the study area are BIFs, Kolhan group, Lower Bonai and Singhbhum Granite complex. The geology and lithology of the study area are given in Fig. 3 and . 4 respectively.

Methodology: The ASTER instrument, launched in December 1999 on NASA 's Terra satellite, has a unique combination of bands of high spatial resolution and wide spectral coverage. It has three sensors for recording the reflected and emitted Electromagnetic Radiation (EMR) energy from the surface of earth. The Visible and Near Infrared (VNIR), Short Wave Infrared (SWIR), Thermal Infrared (TIR) sensors work in 0.52 and 0.86 µm, 1.6 and 2.43 µm, and 8.125 µm and 11.65 µm wavelength regions respectively.

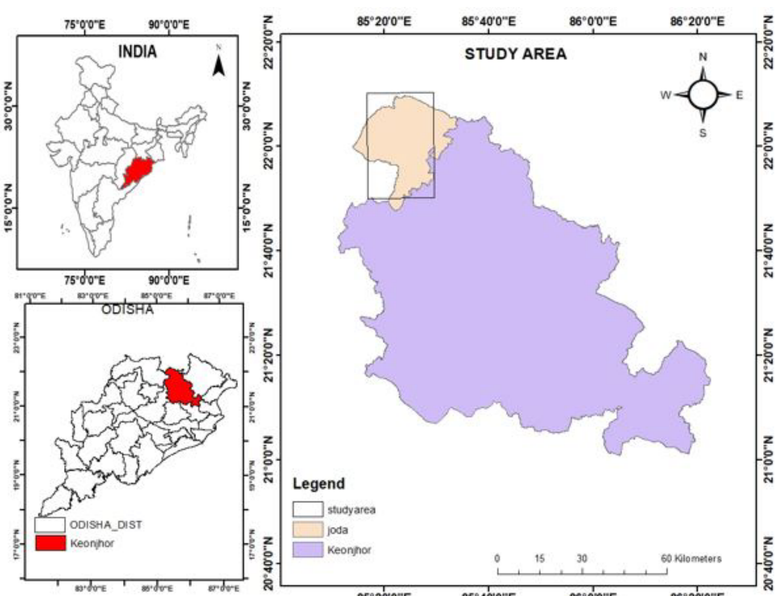

Fig. 1. Location map of study area.

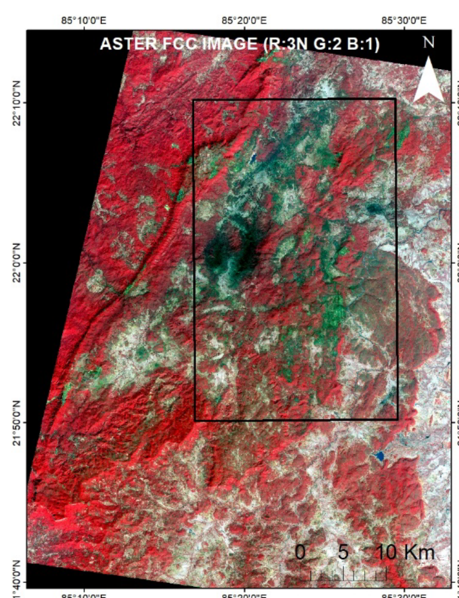

Fig. 2. FCC image of study area.

There is total 14 bands in ASTER image. 3 number of VNIR bands, 6 number of SWIR bands, and 5 number of TIR bands are present with 15, 30, and 90 m spatial resolution, respectively. The wavelength coverage of these bandsprovides a whole complete data about the earth surface for lithological mapping.In present work, ASTER level 1B image covering the study area (AST_L1B_00302062002050304_20180531035316_18486) acquired on 6th Feb 2002 Time 05:03:04.602000 containing 0% cloud cover is used. The methodology adopted in this study includes pre-processing of ASTER data, extraction of different band ratios, Principal Component analysis, and extraction of best band combinations for mapping iron oxide ore regions. ENVI 4.7 and ArcGIS 10.5 software packages were used for digital image processing of the ASTER satellite imagery and preparation of thematic layers respectively.

ASTER image processing and analysis

The VNIR and SWIR bands of geometrically and radiometrically corrected ASTER Level 1Bimage with 0% cloud coverage for the study area is processed for orthorectification using UTM projection for WGS-1984 ellipsoid. If cross track illumination effect is present in SWIR bands, it should be corrected before any processing for better results. TheFast Line of Sight Atmospheric Analysis Spectral Hypercubes (FLAASH) module available in ENVI 4.7 softwareis applied to the image for the removal the atmospheric effect, and the determination of surface reflectance data by taking into consideration the following parameters viz. (i) scene centre coordinates, (ii) data acquisition time, (iii) sensor altitude, (iv) aerosol modules (v) atmospheric modules, and (vi) water vapour content in the atmosphere etc. After pre-processing of ASTER image, noise reduction and image enhancement techniques are applied to it.

Band Ratio (BR) method

The earth surface materials, depending on its structure, absorb, emit or reflect electromagnetic radiation at a certain wavelength. So, the reflectance pattern of each object is unique at a particular wavelength. Band Ratio (BR) is a simple image processing method where the pixel location value/Digital Number (DN) of a band is divided by the pixel/DN value of another band for highlighting certain fea-

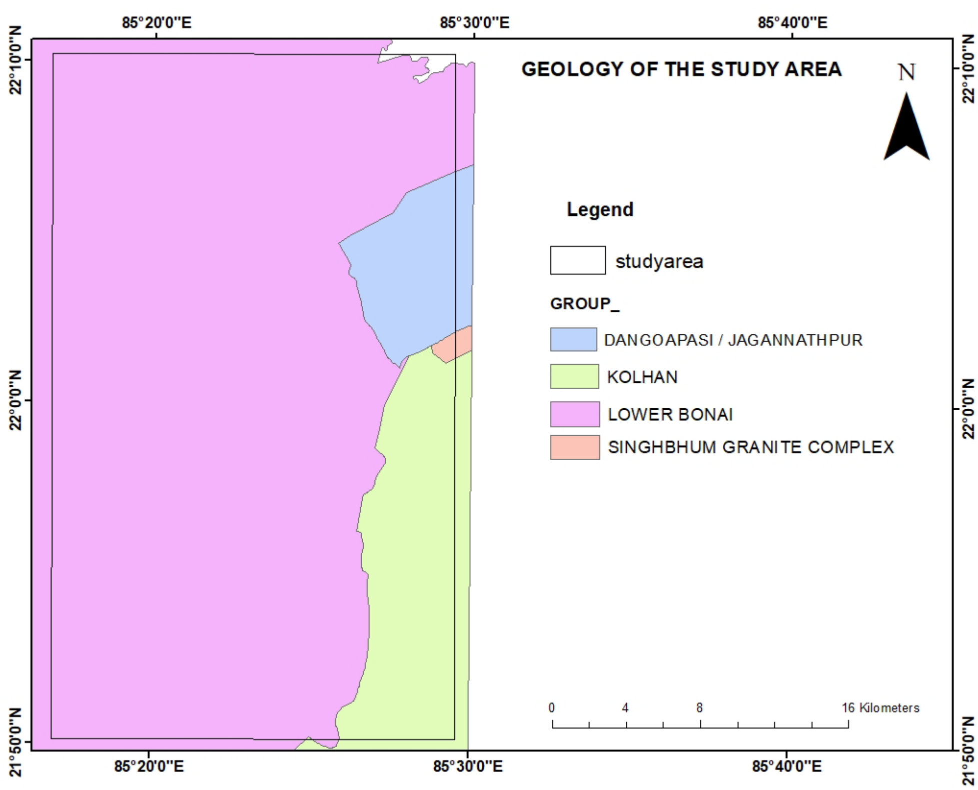

Fig. 3. Geology of the study area.

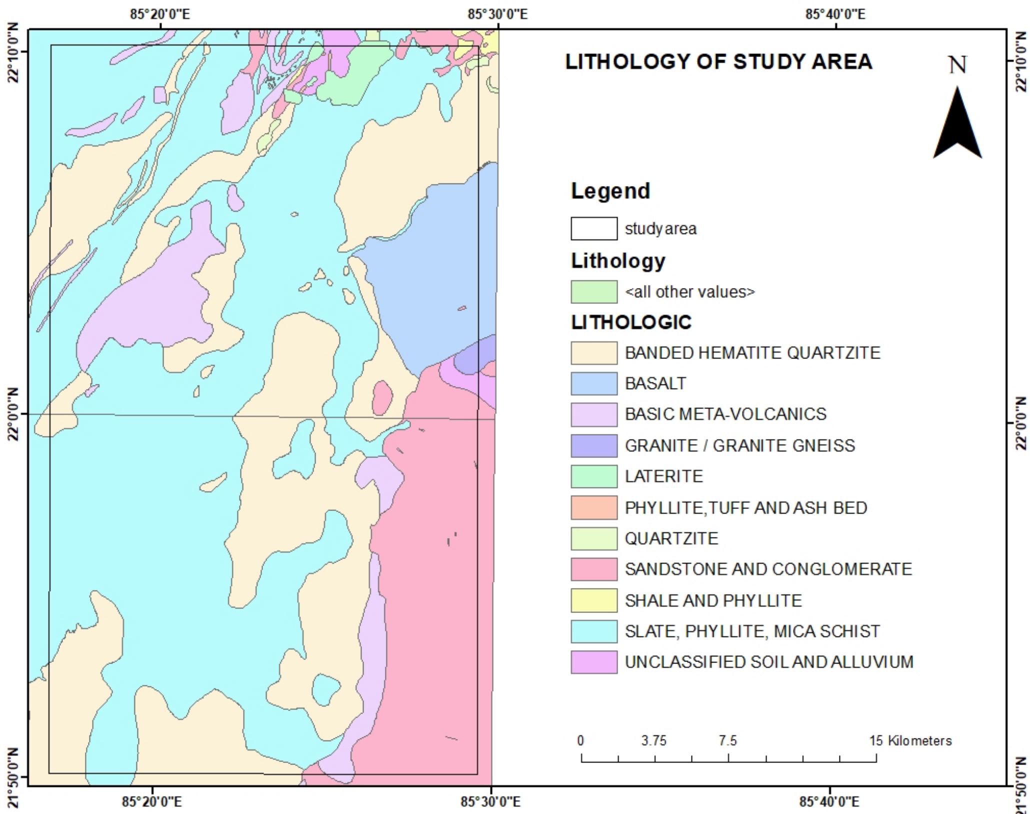

Fig. 4. Lithology of the study area.

tures on the surface of earth which the satellite's raw bands were unable to identify (Inzana *et al.*, 2003). In past decades, several researchers have widely accepted ASTER BR technique (Gad and Kusky, 2007, Khan *et al.*, 2007, Pour and Hashim, 2011) for geological mapping. Different mineral indices are also prepared by Kalinowski and Oliver (2004) using ASTER data. In this study, different indices for Ferric iron oxide minerals and Ferrous iron (Table 1) are used using ASTER bands to delineate Iron rich zones in Banded Iron Formations. The results are verified with the field observations.

False Colour Combination (FCC) Method

False colour combination (FCC) method is also used for identification and separation ofdifferent geologi-

Table 1. ASTER iron ore mineral index by Kalinowski and Oliver 2004

Commonly used ratios

Feature	Band or Ratio	Comments	Reference
Iron			
Ferric iron, Fe^{3+}	2/1		Rowan; CSIRO
Ferrous iron, Fe^{2+}	5/3 + 1/2		Rowan
Laterite	4/5		Bierwith
Gossan	4/2		Volesky
Ferrous silicates (biot, chl, amph)	5/4	Fe oxide Cu-Au alteration	CSIRO
Ferric oxides	4/3	Can be ambiguous*	CSIRO

cal features on the surface of earth. It is the combination of three different bands of same spatial resolution given to Red, Green, and Blue (RGB) color gun. Assigning red, green, and blue wavelength bands to the RGB colour gun will result a true colour combination. If other bands of electromagnetic spectrum are used to the RGB colour gun, a false colour composite image will be produced which is not similar to the actual colour of the surface of the earth. In false colour combinations, the bands with less correlation are used.

Principal Component Analysis

Principal Components Analysisis performed to reduce the correlation among variables to produce uncorrelated bands. It extracts noise components and reduces the data dimensionality in order to save time and money. In PCA new sets of orthogonal axes are produced whose origin is at the mean value of data and the axes are rotated in such a way that the data variance is maximized. In PCA result, the first principal component (PC)band contains the highestinformation and the second PC band contains the second highest and so on. The last PC bands appear noisy because they have no or very less information.

Results and Discussion

Band Ratio (BR) method

The above-mentioned ASTER iron ore mineral indices by Kalinowski in Table -1 are applied to enhance the spectral differences between bands. The band ratio b2/b1 (Fig. 5) highlights the ferric iron content in the image whereas the band ratio b5/b3+b1/b2 (Fig. 6) very clearly highlights the ferrous iron constituents. Band ratio b4/b3 (Fig. 7) of Kalinowski also able to delineates the ferric oxides accurately due to absorption in band number 3. Band combination RGB (2/1, 4/3, 4/5) (Fig 8) of ASTER image equivalent to (3/2, 5/4, 5/7) of Landsat TM (Kalin Rouskov *et al.,* 2005) is used for effective mapping of iron ores in Keonjhor district of Odisha. The above band combination has differentiated the iron ore deposits and iron rich soil surrounding the iron ore deposits over the study area by deep yellow to reddish yellow colour.

False Colour Composite (FCC) method

In the study area the False Colour Combination band 4, band 6 and band 8 as RGB is used. The FCC image is shown in Figure. 9. The Iron ore mineral-

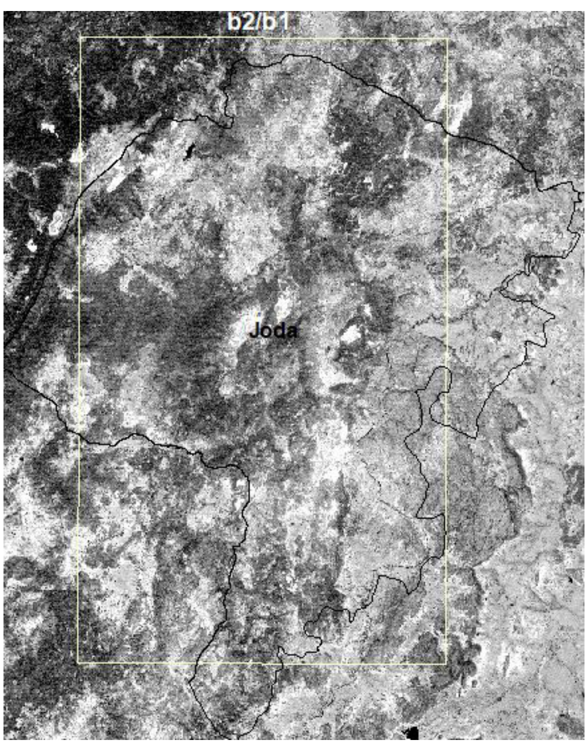

Fig. 5. Ferric iron Fe^{3+} Abundance (White= High, grey=Low)

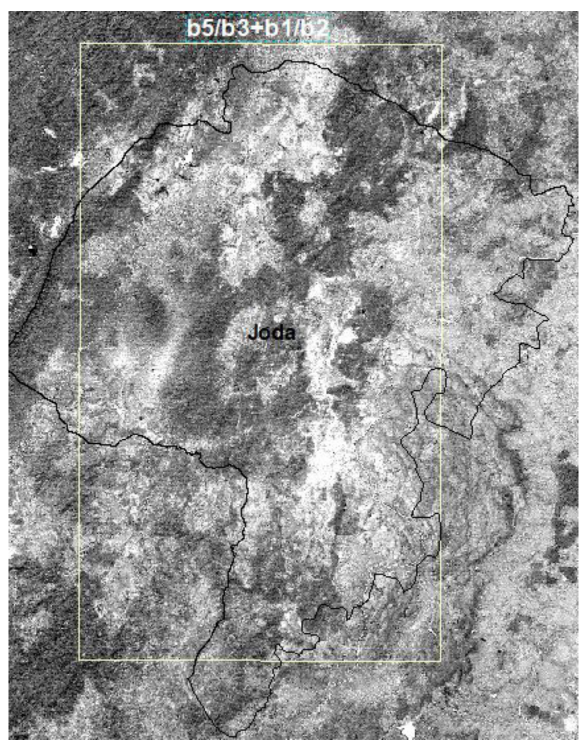

Fig. 6. Ferrous iron Fe^{2+} Abundance (White= High, grey=Low)

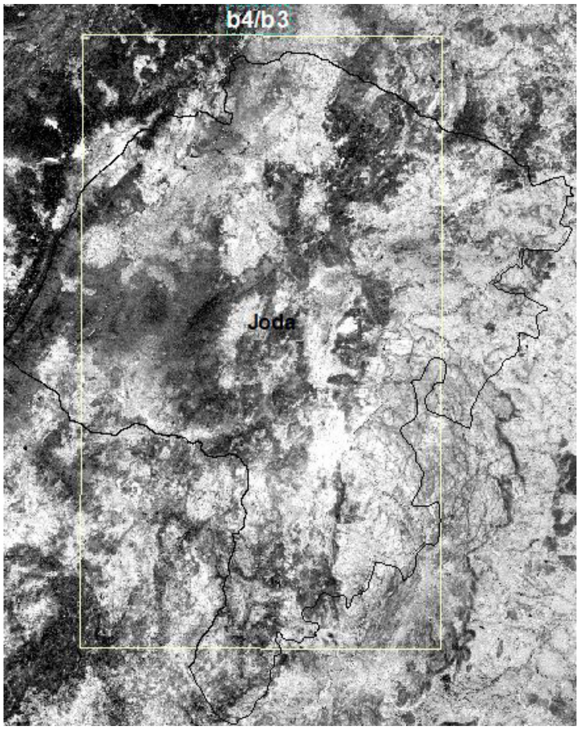

Fig. 7. ASTER interpreted ferric oxides abundance.

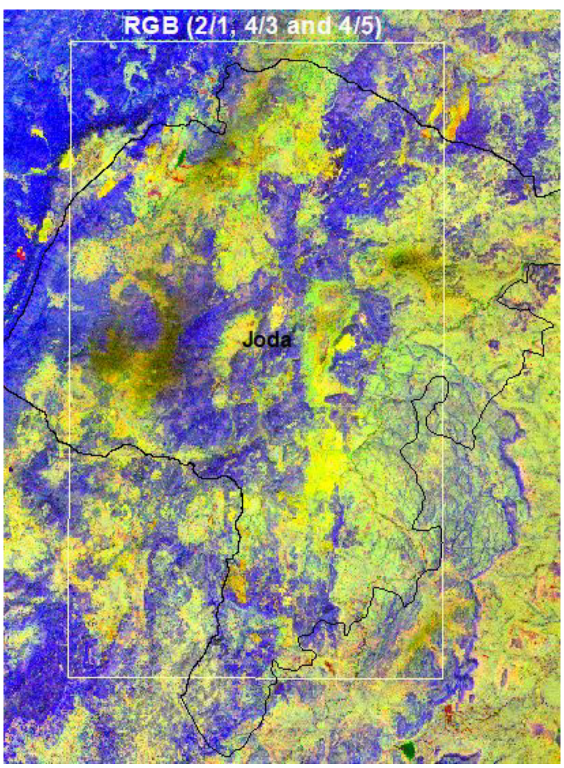

Fig. 8. Band combination 2/1, 4/3, & 4/5 (white = High abundance, grey = Low)

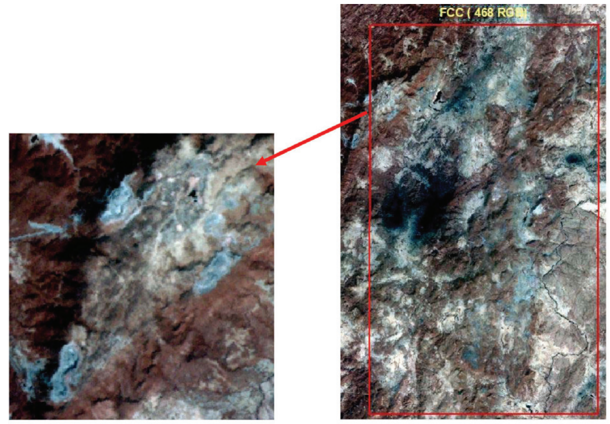

Fig. 9. False Colour Composite Image 468 in RGB. (Zoomed image scale 1:50000).

ization area is highlighted in 1:50,000 scale which appears as light blue colour region.

Principal Component Analysis

From the Principal Component eigen values, selected PC bands are taken into consideration for discriminating all the lithologies present in the study area. The best result is shown by PC band combination RGB (PC5, PC4, and PC3) in figure-10 where BIFs are mainly represented in deep blue colour.

Conclusion

Bands showing high reflectance or absorption features are used in band ratioing for iron ore discrimination.TheASTER mineral indices for Iron (Kalinowski and Oliver 2004) successfully highlight the iron oxide ore deposits in the study area. The result is again cross checked using principal Component Analysis (PCA) where the PC band combination 543 clearlydiscriminates the iron ore bodies from the surrounded land cover. All the results are cross checked and verified with the help of 1: 50000 geological maps downloaded from the BHUKOSH portal of Geological survey of India, google earth imagery and also with field area inspection in some places.

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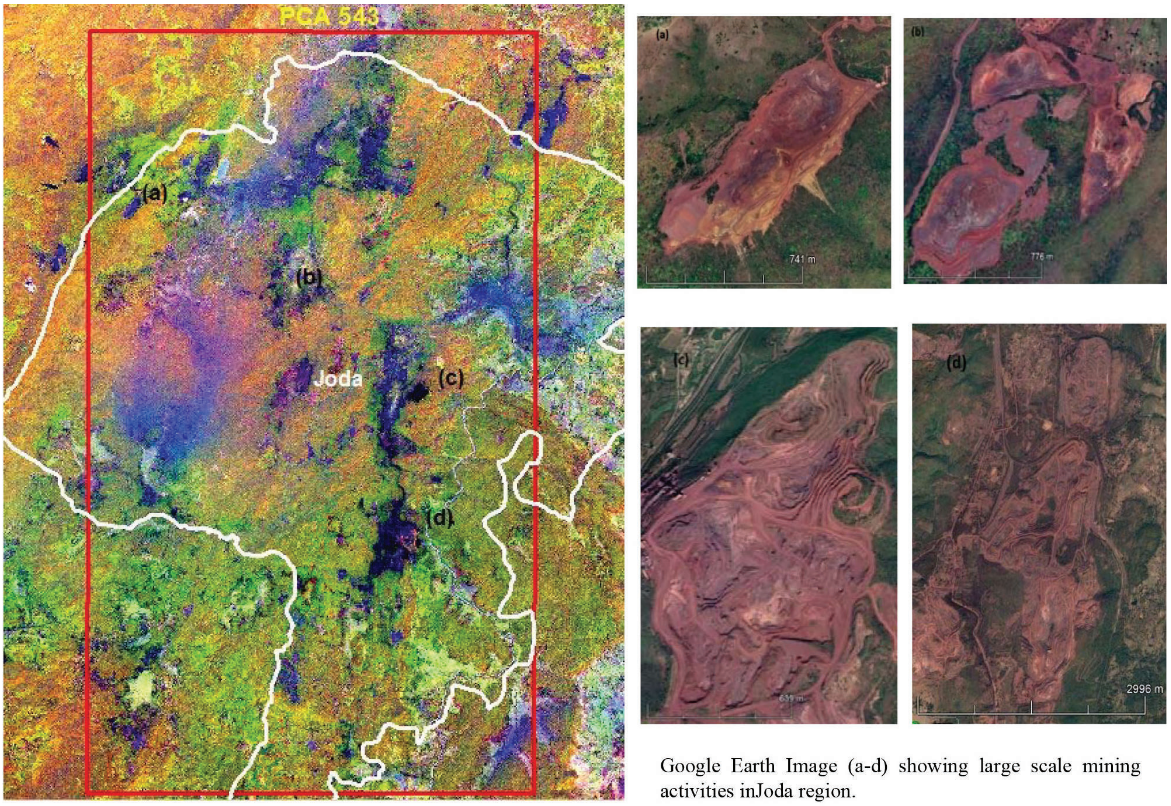

Google Earth Image (a-d) showing large scale mining activities inJoda region.

Fig. 10. Principal Component Analysis image (RGB 543) (Scale 1:50000)

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