COMPREHENSIVE SOLUTIONS FOR MODERN COAL MINING THROUGH APPLIED REMOTE SENSING AND INTEGRATED GIS

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Abstract

Globally the rising demand of coal from energy as well as steel sectors has enforced the need for massive coal exploration. Increased coal mining and exploitation of coal deposits has heightened the need for development of dependable technological solutions in order to identify coal deposits. To comply with the existing and future demand for coal, new technological development in the form of applied remote sensing and integrated geographic information system (GIS) need to be adopted. GIS has emerged as powerful tool which has the potential to organize complex spatial environment. This system supports analysis of geological evidences including structural, lithological, compositional, and elevation aspects that helps in preparing a comprehensive model based solution for the coal mining industry. It will help in overcoming current challenges to define world's remaining resources of coal deposits. Successful application of Landsat TM and/or ETM+ data together with Radar satellite data either in the shallow or deep regions were attempted. This helped in confirming the spatial modeling to be used as a trial data set for prospecting possible underground coal bodies which were further validated during field observations. Several relative band depth variation studies were applied in order to get the best possible response from shale and organic rich clay signatures of the surface under which coal bearing formations are hidden depending on the region's lithological association and structural compositions. Previous study to discover underground coal deposits using remote sensing were carried out in eastern China (Long, Sun-xin, et. all; 2008). Current approach together with geologic evidences in a systematic platform of ESRI ArcGIS suites of software through spatial and 3D analyst extension in ArcMap and image processing software using ENVI, enables to identify coal prospecting regions. A proper understanding of this model would also facilitate spatial assessment of laterite or bauxite extents.

About the Author

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Introduction

Coal continues to be the central focus to the global energy system, accounting for around 40% of global electricity production. As per 2013, World Energy Council survey report, it is currently world's second largest source of primary energy after oil. Coal's dominant position in the global energy mix is largely due to the fact it is abundant, widely distributed across the globe and affordable. Coal mining activities have increased globally in order to meet the huge demand. Continued exploitation of surface coal exposures has resulted in depletion of such coal resources. Increased coal exploration demand for underground coal resources has laid the emphasis on developing digital spatial databases, using the data sets derived from precise navigation and imaging satellites, digitization of maps and transactional databases. With such application of geospatial intelligence, it is expedient to identify underground coal seams and coal bearing formations. This paper aims to discuss how remote sensing and integrated geographic information systems (GIS) assimilate geological propositions, facilitating identification of possible coal seams within a known deposit. This is achieved through joint application of Landsat TM and/or ETM+ satellite data and Radar satellite data. Previous efforts were made to understand similar approaches in geospatial research. However practical applications in order to recognize predictive areas for coal prospecting with spatial data from public domain in a GIS platform were not widely applied. Current study attempts to augment the approach towards exploration of coal deposits. As of 2011, the global coal reserve estimates stood at 891,530 Mt. The five major coal reserves of the world viz. United States of America, Russia, China, Australia, and India respectively account for almost 70% of the total reserves. However, active investigations for coal exploration continue in several developing countries including Indonesia, Thailand, Mozambique, Mongolia, and many other countries of the world within known coal bearing formations through the application of remote sensing and integrated GIS technology.

Methods

Data engagement:

(i) RADAR Data

The National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA) jointly operated radio acting detecting and ranging (RADAR) data to collect earth's surface including its elevation with space borne imaging radar-C (SIR-C) and X-Band synthetic aperture radar (X-SAR) by Shuttle Radar Topography Mission (SRTM) imaging. These datasets were used not only for DEM analysis and know the elevation aspects of the targeted zones but also their structural compositions at regional scale. Current study used C and X-Band combined finished SRTM data with wavelength of 5.8cm and with 3 arc-second horizontal spatial resolutions, and more precisely SRTM derived DEMs with orthometric heights and relief models were created in order to find extended depression surfaces spread over inland mass and contours were also generated at desired intervals to see elevation trends. Mapping structural association coupled with realizing location of outcrops or possible surface exposures if any were another reason to use Radar of this investigation.

(ii) Landsat Data

This study utilized the US Geological Survey provided Landsat sensors with thematic mapper (TM) which is a multi-spectral scanning radiometer that records reflected and emitted energy from earth surface in various wavelength of the electromagnetic spectrum (Global Land Cover Facility). Level-1 products of Landsat TM 5 with 6 spectral bands derived high resolution visible (color composite) and infrared imageries (panchromatic) in 30m were used and the results were coupled with 8 banded thermal data Landsat 7 and enhanced thematic mapper plus (ETM+) in 15m resolution. These multi-spectral datasets were used for mapping lithological variations, discriminate litho-boundaries, disintegrate volcanic and sedimentary and metamorphic rock units, identify host rock, which were achieved by high precision remote sensing aided geology mapping, finding anomalies in spectral signature, possible hydrothermal alterations related to coal bearing lithology.

Data processing:

This approach was initiated from the close study of hypsographic image of earth surface which provides general spatial arrangement of sedimentary basins of the world. The remotely sensed data were processed using EXELIS Visual Information

Solution's ENVI, the image processing software which successfully accomplished desired results followed by series of correction and pre-processing of spatial data including some raster processing using data management tools but not limited to mosaic, clip, buffer, etc. as well as pan-sharpening of the data, or image fusion and synthesis. ENVI integrated with ArcGIS 10.2 provided the suitable environment for the comprehensive data analysis while projection and datum issues were handled with much smoother way. The study broadly engaged TM 5 data where the results were sometimes incorporated with results from ETM+ 7 to complete routine analysis of spectral signature study of associated minerals by relative band depth algorithms. Deco-relation Stretch and transformations were processed in order to get the enhanced lithological information of the region while feature based directed principal component analysis were mapped with key findings of possible mineral associations. All these results in multi-vectors as ESRI shape-files were finally assimilated in a systematic platform of elevation model derivative relief, contours, lithology, and mapped geologic structural complexities to see the co-relations.

Observations

The proposed model was tested in the following regions: Western Mozambique, Eastern Kalimantan, Northern Mozambique, Bangladesh, central Myanmar, eastern region of India, and southern Laos. The locations were randomly selected spread over the globe with the assumptions of having elongated lowlands bounding uplands neighboring coastal environment to relate popular coal seams deposition history with marine environment. The outcomes show significant association of possible coal seams in these regions. The results further can be more accurate with the collation of data from geophysical well logging which was beyond the scope of this investigation.

Case study – western Mozambique:

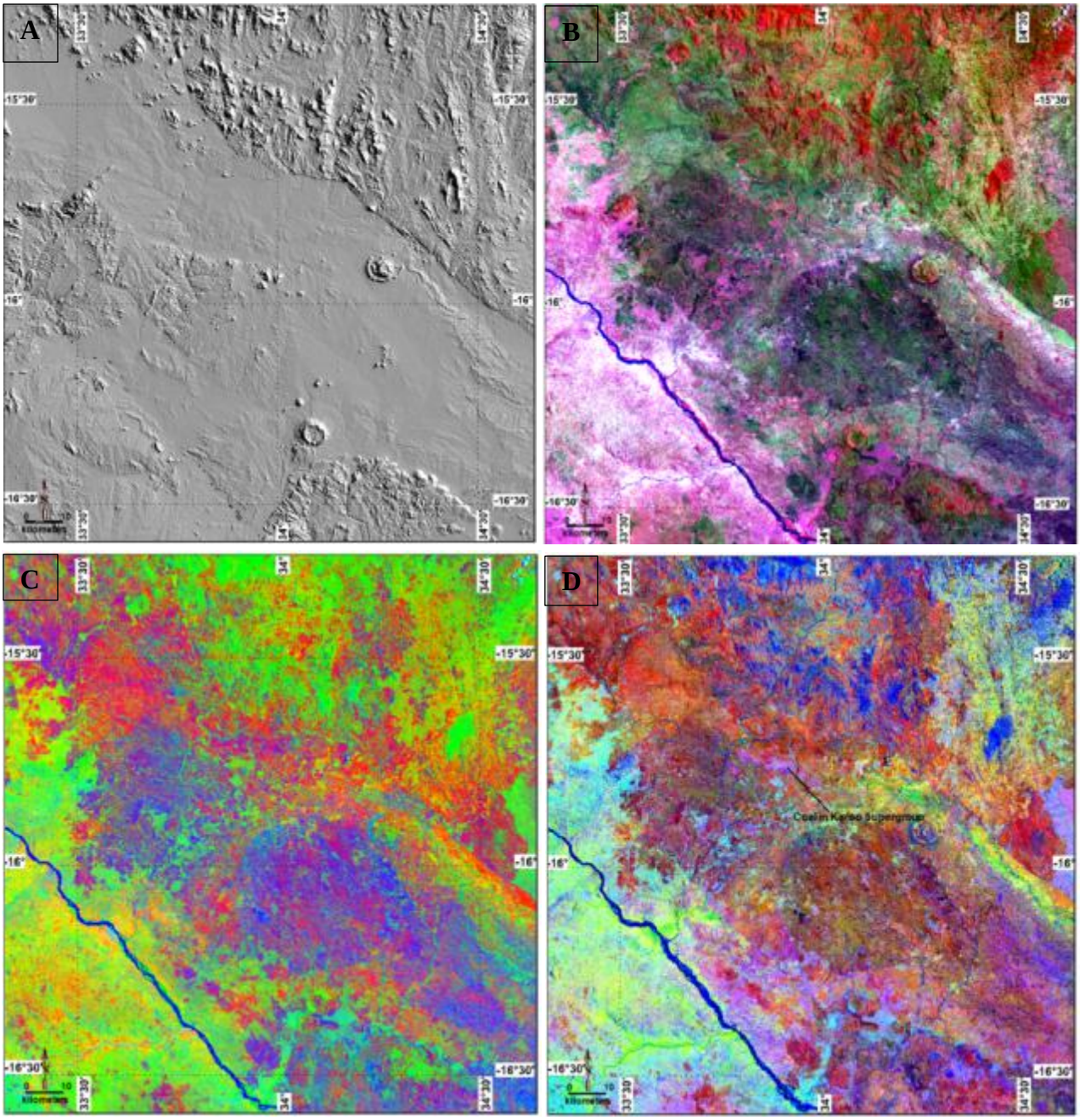

Fig. 1: Terrain showing elongated continuous lowland with surrounding uplands together with structural components in western Mozambique (A); Landsat TM 5 satellite data covering the region with suitable band combinations where green is vegetation, blue indicates presence of moisture, clay and Al(OH) compounds, and other colors show similar lithological variations. The Landsat 5 Thematic Mapper 4-7-2 stretch combines high-resolution VNIR data with SWIR to extract geologic information appropriately at larger scale (B). Decorrelation stretch of bands 7-4-2 from Landsat TM 5 data to show oxide dispersion as red to orange color, vegetation as red-pink color and water & moisture in soils as deep blue to purple color. The oxide traces are suspected for presence of Fe2+ rich minerals and other Fe-oxides (C). Relative Band Depth image maps moist regions with shale and organic rich clay signatures to depict the spectral features of clay rich residual soil enriched with organic matter and shale which are potentially coal bearing zones. The obtained image has mapped the alteration zone in red correspondent for the case of western Mozambique and the targeted zone with coal in Karoo Supergroup is shown with mauve (light purple) hue (D).

Conclusion

As discussed earlier, this model has been tested in various regions with similar physical settings. The subsequent outcome would explain why northeastern regions of Bangladesh, central Myanmar, and southern Laos have good prospects in underground coal seams. It is not certain at this point whether Indian deposits of Gondwana coal can be described with this model but tertiary coal deposits in northern lands of Meghalaya were tested and failed to explain with the help of proposed model due to different geological complexities. As this model predicts coal deposits in regions nearing the coasts the spatial data from public domain might have some issues with scattered cloud concentration or with land cover of thick vegetation as it appeared in the case of east Kalimantan. In such case prediction of the models may show some redundancy. The extension of this study would see the validity of the results in more locations globally as well as see how Landsat 8 with its OLI Band can expose more ground details for this investigation. From the other publicly available spatial data MrSid data which is actually Landsat geo-cover mosaic is the next approach to add up in this model for more structural explanations. In the exploration of bauxite reverse version of this model can significantly contribute to predict the extent of bauxite spread with identification of continuous surface on elevation with well drainage facilities where instead of continuous low lands; flat continuous uplands to identify bauxite contours were of more interests.

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