Advances and Applications of Geospatial Technology in Earth Science

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Abstract: Geospatial technology is a multidisciplinary field that includes disciplines such as remote sensing, geographic information systems (GIS), surveying, photogrammetry, mapping, geodesy and global navigation satellite system (GNSS). Geospatial technology is emerged as an innovative and cost effective tool for earth science applications. Numerous specific relevant applications of geospatial tools to earth science are presented in the perspective of a recent advancement. Applications have included mapping minerals, lithology, geological structures and water resource management using remote sensing and GIS.

IndexTerms **- Geospatial technology, earth science, GIS, remote sensing, hyperspectral.**

I. Introduction

Geospatial technology is widely used as a tool for earth science mapping. Recent advancement of satellite imaging technology, the application of this technology has improved manifold. Earth science application based on traditional methods i.e., field-based surveys, is laborious, time-consuming and very expensive, which has necessitated the application of geographic information systems (GIS) and remote sensing (RS) for earth science studies, these being more time-saving and less expensive approaches. Geospatial technology is useful for geological, geomorpholocical, structural mapping and discriminating minerals, rocks types, etc. Recently to increase accuracy of mineral and rock type mapping the hyperspectral remote sensing technology is used worldwide. It collect with narrow and continuous spectral bands can detect the spectral signature to characteristic the minerals and therefore help immensely in lithological mapping based on mineralogy. RADAR and LiDAR technologies are another emerging technology in earth science application

II. Geospatial technology in earth science application

Geospatial technology is effectively used for identification of landforms, rock types and rock structures (folds, faults, and fractures), etc. This technology playing a tremendous role for understanding the mechanism of earth's surface and subsurface process for example groundwater movement, hydrocarbon alteration zone, mineral deposits, stratigraphy, etc. Natural resource and geological mapping using remotely sensed data are required standard procedures. Conventional methods are challenge task due to earth complex topography. Therefore, researchers and scientists have developed computer tools to acquire precisely geological related thematic information from satellite data. Computer based visual image interpretation techniques are most user-friendly method for geologic feature extractions from satellite data. Visual image interpretation techniques are considering following elements of image characteristic such as, tone, texture, pattern, shape, size, shadows, site and association. Geologic information extractions based on visual image interpretation techniques for satellite images can be divided broadly into three categories: (i) feature enhancement for characterization of geologic structures; (ii) image classification to perform geologic mapping or to locate spectrally anomalous zones attributable to mineralization and (iii) superposition of satellite images and multiple data such as geological, geochemical and geophysical data in a GIS. Hyperspectral remote sensing based geological mapping is advanced techniques where image reflectance spectra is collected and match with spectral library spectra and identified minerals on the surface of the planet.

III. Ease of Use Lithological Mapping

In the last few decades, satellite data have been used extensively for lithological mapping and mineral exploration [1] (Figure. 1). Satellite images processed for extracting geological features like faults, folds, and fracture zones and topographic ridges and drainage segments and lineaments. Geologic lineaments are important for mineral exploration as they are the potential locations for hosting ore bodies that are deposited by ascending hydrothermal fluids. Mapping geologic units consists primarily of identifying physiographic units and determining the rock lithology or coarse stratigraphy of exposed units. These units or formations are generally described by their age, lithology and thickness. Remote sensing can be used to describe lithology by the colour, weathering and erosion characteristics (whether the rock is resistant or recessive), drainage patterns, and thickness of bedding. Lithological unit mapping is useful in mineral exploration, since these resources mineral) are often associated with specific lithologies. Structures below the ground, which may be conducive to trapping oil or hosting specific minerals, often manifest themselves on the Earth's surface. By delineating the structures and identifying the associated lithologies, geologists can identify locations that would most likely contain geological resources (mineral, oil, etc), and target them for exploration.

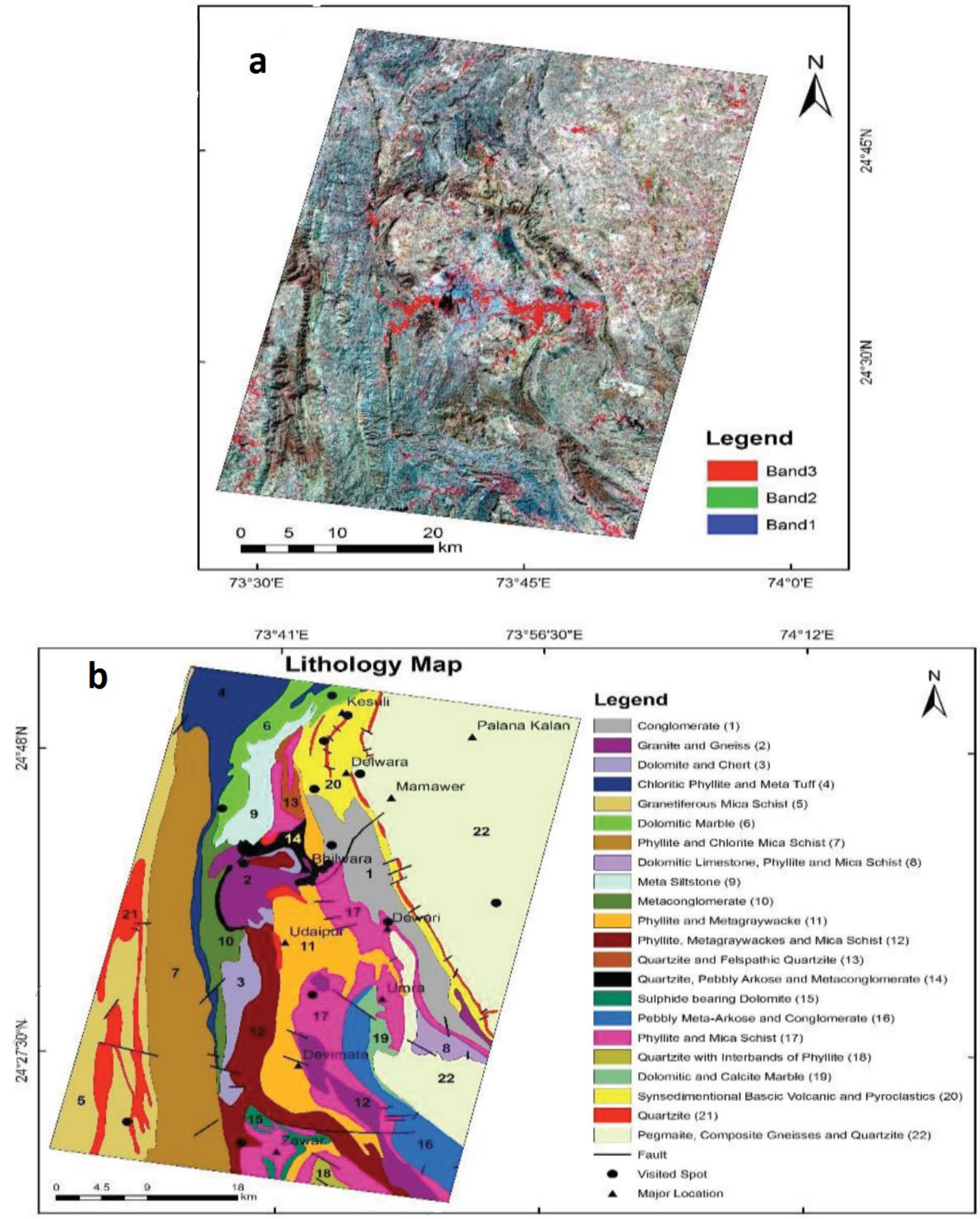

Figure 1. Lithology mapping using satellite data (modified after Kumar, et al, 2015 [2]). a-ASTER satellite image; b-Lithological map (prepared using satellite image and after GSI map)

IV. GEOMORPHOLOGICAL MAPPING

Geomorphology as a science developed much later than geology although several aspects of geomorphology are embedded in geological processes. It is the scientific study of landforms and processes, is not limited to an understanding of the landscapes of earth and other planets. Geomorphology deals with the genesis of relief forms of the surface of the earth's crust. Certain natural processes are responsible for the forms of the surface of the earth. A thorough understanding of various processes leading to landforms is necessary to understand the environment. Remote sensing observations from aerial and space platforms which are currently in operation provide a synoptic view of terrain features in images which are interpreted by thematic specialists to understand and extract information of specific interest from the images. It is also considered an effective tool in this understanding, as satellite images contain integrated information of all that is on the ground, the landform, the ecology, the resources contained in the area and the impact of human actions on the natural landscape. The dynamism with which changes occur in the landscape is brought out effectively by repeated coverage of images of the same area at different times. Images convey many things even to the untrained eye and for a professional it conveys much more including many features previously unknown or unseen on the ground (Figure 2).

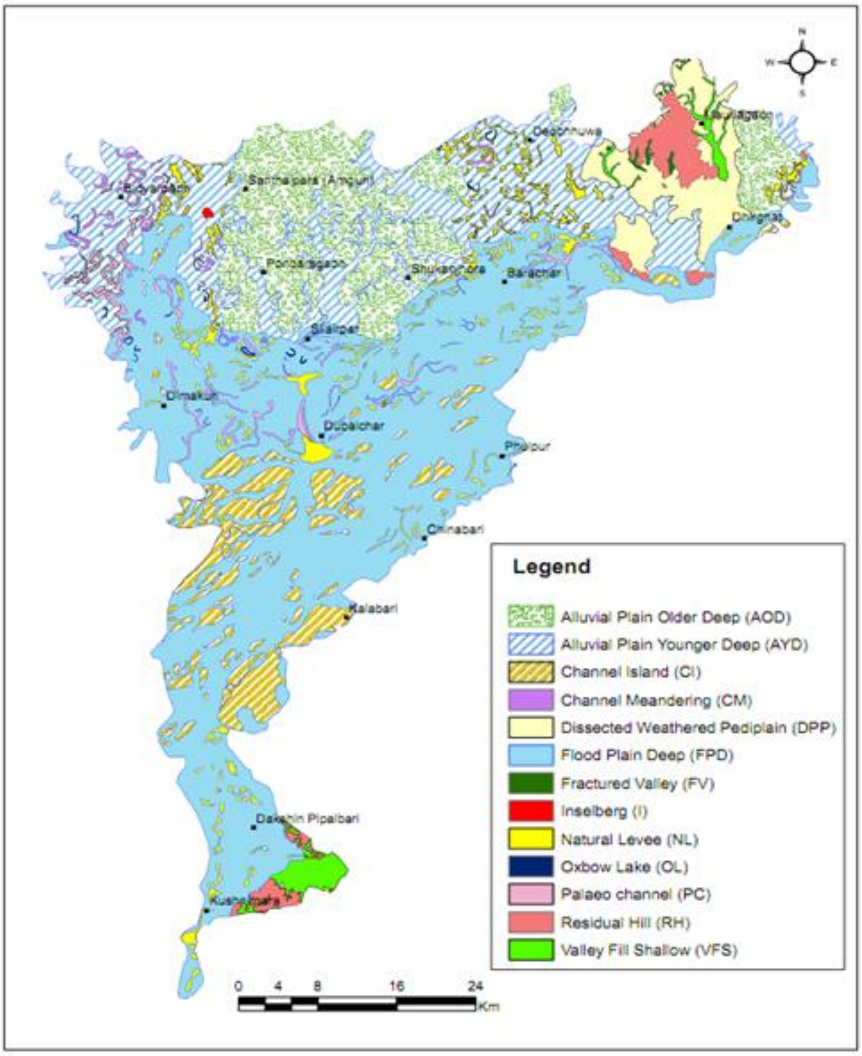

Figure 2. Geomorphology map derived from satellite imagery (After Sivakumar, et al, 2013 [3])

V. MINERAL MAPPING

Geospatial technologies have led the way for the development of hyperspectral sensors. Hyperspectral remote sensing, also known as imaging spectroscopy, is a relatively new technology that is currently being investigated by researchers and scientists with regard to the detection and identification of minerals, terrestrial vegetation, and man-made materials. Hyperspectral remote sensing provides high spatial/spectral resolution data from a distance, with the aim of providing near-laboratory-quality radiance (and subsequent related information) for each picture element (pixel) from a distance. Imaging spectrometry is defined as the simultaneous acquisition of images in many narrow, contiguous spectral bands. Analysis of imaging spectrometer data allows extraction of a detailed spectrum for each picture element (pixel) of the image. High spectral resolution reflectance spectra collected by imaging spectrometers allow direct identification of individual minerals based upon their reflectance characteristics. Figure-3 shows concept of Hyperspectral remote sensing technology.

Hyperspectral technology is a powerful tool for mapping minerals, soil types and for a range of environmental applications. The spectral signatures of land surface derived from imagery can be used to identify and even quantify mineralogical entities of exploration significance. The spatial analysis of imagery can lead to improved mapping by more precise Identification and subdivision of soil units. Environmental processes can be identified and monitored with high spatial resolution. The visible and near infrared wavelength region is potentially useful for mapping gossans, rich in iron oxides and associated with weathered sulphide occurrences as well as regolith characterization. The short wave infrared wavelength region is potentially useful for mapping alteration haloes that comprise minerals like chlorites and white micas in epithermal/porphyry styles of Cu-Au mineralization as well as regolith characterization. The thermal infrared wavelength region is potentially useful for mapping a range of exploration targets. For example, in more weathered environments, mapping silicification associated with epithermal/porphyry alteration may be useful for some of the Proterozoic and Archaean deposits. With the aid of hyperspectral remote sensing, an extensive range of minerals can be remotely mapped including: iron oxides, clays, micas, chlorites, amphiboles, talc, serpentines,carbonates, quartz garnets, pyroxenes, feldspars and sulphates, as well as their physicochemistries. Figure 4 shows sample mineral spectra of goethite, hematite, kaolinite, alunite and montmorillonite.

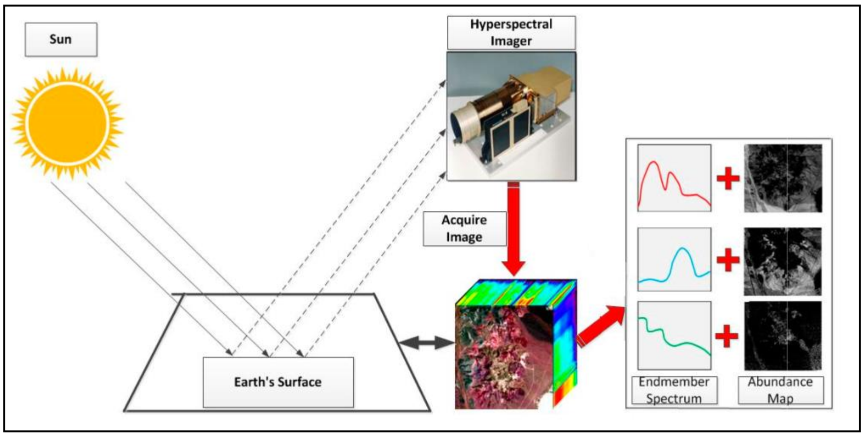

Figure 3. Concept of hyperspectral remote sensing (After Shao, et al., 2018 [4])

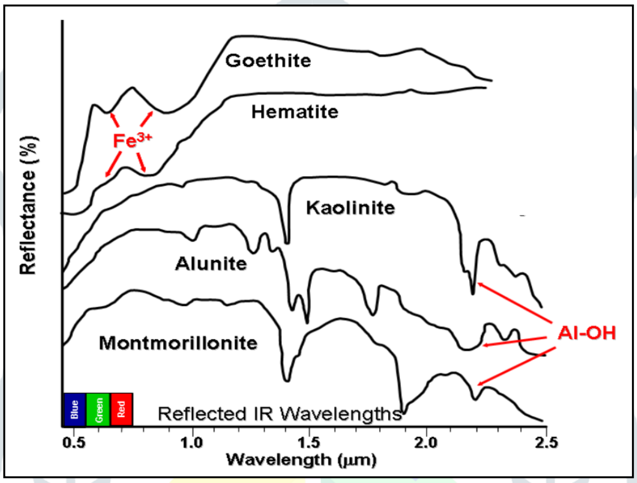

Figure 4. Mineral reflectance spectra of hyperspectral data (Source: NRCAN)

VI. Geological Structural Mapping

The mapping of geologic structure is important in mineral resources studies because many ore deposits are located for instance along zones of geological structures (fracture, fault, fold, linear-curvilinear features). Geological structures and lithological characters, mineralization and alteration as well as bio-geochemical anomalies are the three types of information features that have normally considered in the procedure of mineral deposit using remotely sensed data. By structural analysis, geologists can get some supplementary information for mineral exploration from satellite images. On geological studies using remote sensing technique, researchers have recognized various kinds of liner and circular phenomenon existed in the satellite images. This caused an extensive study on the relationship about minerogenetic geological background and the statistical information of liner-circular structures, and results in people's high attention to the ore-controlling function of these structures. Figure-5 shows structural feature on remote sensing image.

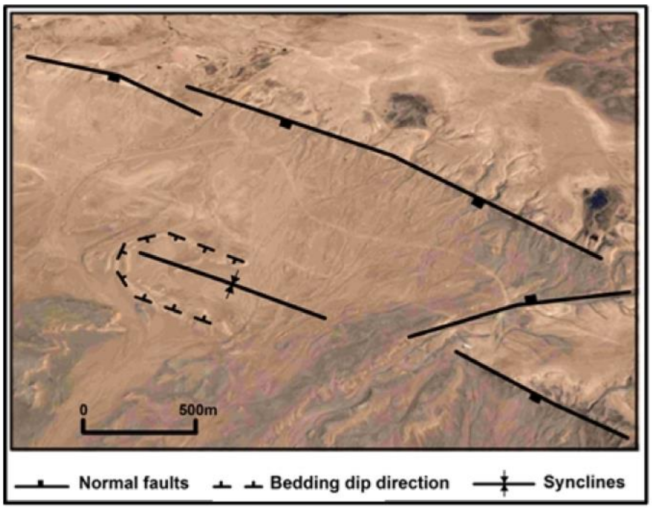

Figure 5. Geological structure on sensing image (after Abdunaser, 2015 [5])

VII. WATER RESOURCE MANAGEMENT

In the recent years, the requirements of geospatial technology applications have been constantly increased in the whole world and its applications are relatively advanced. Remote sensing with its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within short time has become a very handy tool in mapping, monitoring and conserving groundwater resources. Satellite data provides quick and useful baseline information on the parameters controlling the occurrence and movement of groundwater like lithology/structural, geomorphology, soils, landuse / landcover, lineaments etc. The controlling parameters have rarely been studied together because of non-availability of data, integrating tools and modeling techniques. Hence a systematic study of these factors leads to better delineation-of groundwater prospective zones in an area, which is then followed up on the ground through detailed hydro-geological investigations. Visual interpretation has been the main tool for evaluation of groundwater prospective zones for over two decades. It has also been found that remote sensing besides helping in targeting potential zones for groundwater exploration provides inputs towards estimation of the total groundwater resources in an area, the selection of appropriate sites for artificial recharge and the depth of the weathering area. By combining the remote sensing information with adequate field data, particularly well inventory and yield data, it is possible to arrive at prognostic models to predict the ranges of depth, the yield, the success rate and the types of wells suited to various terrains under different hydro-geological domains. Based on the status of groundwater development and groundwater irrigated areas (though remote sensing), artificial recharge structures such as percolation tanks, check dams and subsurface dykes can be recommended upstream of groundwater irrigated areas to recharge the wells in the downstream areas so as to augment groundwater resources.

VIII. GEOSPATIAL TECHNOLOGY WATERSHED MANAGEMENT

Geospatial technology has played critic al roles in all aspects of watershed management, from assessing watershed conditions through modeling impacts of human activities on water quality and to visualizing impacts of alternative management scenarios. The field and science of GIS have been transformed over the last two decades. GIS has grown quite rapidly to become a multi-billion industry and a major player in the broader field of the ubiquitous information technology. Advancements in computer hardware and software, availability of large volumes of digital data, the standardization of GIS formats and languages, the increasing interoperability of software environments, the sophistication of geo-processing functions, and the increasing use of real-time analysis and mapping on the Internet have increased the utility and demands for the GIS technology. In turn, GIS application in watershed management has changed from operational support (e.g., inventory management and descriptive mapping) to prescriptive modeling and tactical or strategic decision support system. Increasingly, researchers, resource planners and policy makers are realizing the power of GIS and its unique ability to enhance watershed management [6].

IX. CONCLUSION

Geospatial technology provides user friendly tools and methods to mapping minerals, rock types, landform, geological structure and water resource and watershed management. Multispectral remote sensing has provides an effective method for geological mapping (fault, lineaments, fold, etc.,) and mineral recognition surveying. The hyperspectral sensors represent one of the most important technological trends in remote sensing for earth surface material mapping. Spatial technology is immensely useful for spatial data collection, processing and analysis, and providing access to spatial information in various development sectors such as mining, petroleum exploration, transport, tourism, hydroelectric power, disaster managing, environmental management, etc.

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