Remote Sensing Applications to Mineral Exploration

Remote Sensing as a supplement to field lithologic and structural mapping, has played an important role in the study of mineralized areas, since aerial photography became available in early 1950's. Satellite imagery can be successfully used for mineral reconnaissance. It is simply a search for examination and evaluation of features that may indicate a mineral deposit. It is fairly general in scope, being followed in favorable areas by detailed mapping, sampling, essay and possible development. The features that indicate mineralization are known as localizer or indicators or guides. If these indicators can be identified on satellite data/ imagery then the mineral explorations can be much faster with increased efficiency.

Satellite imagery have proved valuable for mineral exploration in three ways:

1. Mapping of regional and local fracture systems that controlled ore deposits.
2. Detection of surface alteration effects associated with ore deposits.
3. Providing basic data for geologic mapping.

Mineral deposits can be broadly distinguished into two basic types, primary and secondary. These deposits are frequently marked by certain surface indicators, some of which could be observed on the remote sensing data.

Main types of Mineral Deposits and their surface indicators observable on remote sensing data (Gupta 1991)

Genetic type and Form/mode	Minerals (examples)	Salient Surface indicators
Primary Syngenetic		
Magamatic segregation & differentation, volcanic pipes, pegmatites	Chromite, magnetite, ilmenite, platinum, diamond, gemstones, rare earths, mica etc.	Intrusive bodies, host rocks concordant / discordant relations, vegetation, drainage etc.
Sedimentary / Metamorphic Bedded/ Layered	Banded Iron formations, phosphorites, Syngenetic sulphides, manganese, coal	Banded layered terrain, stratigraphic aspects and vegetation characters
Primary Epigenetic		
Hydrothermal veins and disseminations	Base metal sulphides, precious metals	Gossan, alteration zone, structural and lithological controls, vegetation anomaly etc.
Secondary		
Placers mechanically concentrated by fluvial, aeolian and marine action	Diamond, monazite gold, platinum etc.	Terrain and provenance of sediments, suitable landforms of deposition
Supergene enrichment Chemical leaching and deposition	Base metal sulphides	alteration zone, oxidation and leaching and vegetation anomaly
Residual enrichment lateralization	Bauxite, laterite, manganese minerals	Terrain, chemical leaching etc.

A number of principal geological guides have been distinguished from mineral prospecting (McKinstry 1948, Peters 1978, Kreiter 1968) of all these, those that can be observed on remotely sensed data are

1) Stratigraphical-lithological
2) Geomorphological
3) Structural
4) Rock alteration
5) Geobotanical

Besides these criteria such as geochemical and geophysical anomalies can also be additional inputs at different stages during prospecting.

1. **Stratigraphical - lithological guides :**

   Stratigraphic (age) criteria refer to the geological setting and the stratigraphical position of the geological unit (e.g. beds or intrusives), since some types of mineral deposits are confined to certain age groups e.g. deposits of coal, iron manganese, phosphorites. The syngenetic igneous deposits are relatively less regular and occur in differentiated intrusives e.g. chromite, magnetite. The lithologically bound epigenetic deposits are formed due to strong preference of host rocks e.g. carbonatites, volcanic flows metapelites etc. By the migrating mineralising fluids. Remote sensing data of adequate spatial resolution can help to identify and locate the occurrence of lithological guides under suitable conditions, by virtue of synoptic overview and the multispectral approach.

2. **Geomorphological guides :**

   Geomorphological guides particularly important in prospecting of secondary type's deposits, i.e. products of sustained weathering and erosion, like the deposits of diamond, monazite, gold etc. The placer deposits are formed as a result of the mechanical concentration of fluvial, aeolian, eluvial and marine processes. Suitable sites for their deposition and occurrence can be better located on the satellite imagery, e.g. in the case of fluvial placers, by delineating buried channels, abandoned meander scars etc. Deposits formed by the process of residual and supergene enrichment can be indicated by geomorphological criteria e.g. hills, ridges, plateau and valleys in areas of weathering and leaching.

3. **Structural guides :**

   The epigenetic mineral deposits are formed by deposition of mineral bearing solutions in voids/fracture spaces and replacement of host rocks and therefore commonly exhibit strong structural control. Information regarding localisation of mineral deposits by certain types of geological structural belts, shear zones, faults, fractures, contacts, folds, joints or intersection of some specific structural features can be obtained from satellite imagery and is vital for planning exploration strategy.

   The Singhbhum shear zone in Bihar is major tectonic feature, separating the Iron ore and Singhbhum group of rocks. It localises mineral deposits of copper, uranium, nickel, chromite, molybdenum, gold and titanium-vanadium. The localization of minerals within a shear zone forms a major guide for exploration in this area.

   The Khetri copper belt in Rajasthan in another interesting example of polymetallic sulphide deposit localised along longitudinal NNE-SSW to NE-SW trending lineament. Field data shows that this lineament is a manifestation of sheared contact between quartzites and metapellites (Roy Choudhary and Das Gupta, 1965 Bharkatya and Gupta 1981) and thus the sulphide deposits are controlled by regional structural and stratigraphical factor.

Within a mineral province areas numerous fractures and fracture intersections are good prospecting targets because fractures are conduits for ore forming solutions. Local fracture patterns are mappable on enlarged satellite imagery especially those acquired at low sun angles and those that have been digitally enhanced to emphasize fractures.

4. Rock alteration as guide :

Many ore bodies are deposited by hot aqueous fluids called hydrothermal solutions that invade the country rock. During the formation of ore minerals, these solutions also interact chemically with the country rock and alter the mineral composition for considerable distances beyond the site of ore deposition. The hydrothermally altered country rocks contain distinctive assemblages of secondary minerals, called alteration minerals that replace the original minerals. These alteration minerals can be broadly categorised into four groups:

i) Tectosilicates (quartz and feldspar) – These minerals have absorption features in the thermal infrared and multispectral data in thermal infrared can be used for locating and differentiating between different types of silicates.

ii) Carbonates have absorption features in the SWIR (1.9μm, 2.3μm, 2.5μm) and TIR(7μm). Though present day space imaging sensors do not provide data in these spectral bands, the possibilities are obvious.

iii) Hydroxyl-bearing minerals – The abundance of clays and sheet silicates which contain Al-OH and Mg-OH bearing minerals and hydroxides implies that absorption bands in the 2.1- 2.4 μm range are very significant.

iv) Limonite: the presence of iron oxide (limonite) leads to strong absorption in the blue end. The ration of blue/green (TM band 1 / 2) or green/red (MSS 4/5) yields very low values for limonite bearing zones and hence extensively applied for limonite mapping. The technique of limonite mapping has been applied for exploration of several mineral deposits, chiefly sulphides of Cu, Pb, Zn, Mo, Hg etc.

5. Geobotanical guides :

In temperate and humid climates, where mineral deposits are obscured by soil and vegetation, geochemical exploration techniques are used. The major geobotanical criteria for recognising concealed ore deposits are as follows:

i) Lack of vegetation: This may be caused by concentration of metals in the soil that are toxic to plants – may be seen on imagery

ii) Indicator elements: These are species that grow preferentially on outcrops and soil enriched in a certain elements e.g. in the Katanga (South Zaire) region, a small blue-flowered mint, Acrocephalus robertii is restricted to Cu bearing outcrops.

iii) Physiological changes: High metal concentrations in the soil may cause abnormal spectral reflectance characteristics of leaves, flowers, fruits ot entire plants. A relationship between spectral properties of plants and metal content of the soils could form the basis for remote sensing of mineral deposits in vegetated terrain.

Thus remote sensing techniques play an extremely significant role in effectively locating mineral deposits and identifying mineral targets, thereby reducing the cost of prospecting and exploration.