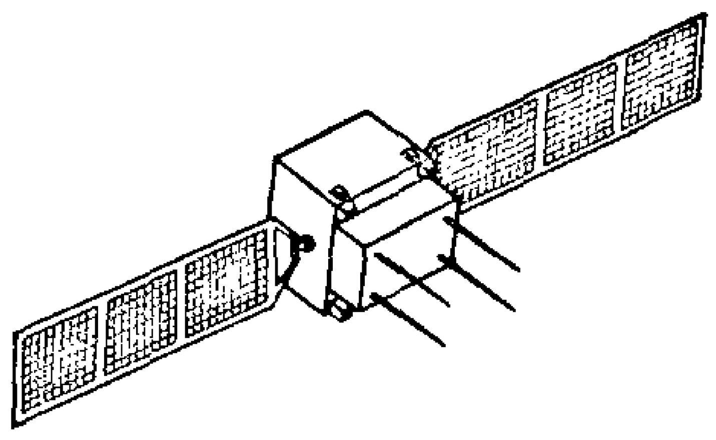

Special Issue on:
Remote Sensing for National Development

IRS-1A Applications in Geology and Mineral Resources

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Abstract: *The data from IRS-1A, ever since its launch in March 1988, has been extensively used in different geological and geomorphological applications. Various case studies carried out in different geological terrains have clearly indicated that IRS-1A LISS-I and LISS-II data are comparable to Landsat MSS and TM data (comparable bands only), respectively, and the digitally enhanced images give significantly more information as compared to normal false colour composites. Case examples from Shimla and Nahan-Paonta areas in Himachal Pradesh have shown the utility of IRS-1A data, in geological mapping of inaccessible areas like Himalayas. To highlight the utility of IRS-1A data, a few case studies have been discussed in this paper.*

Introduction

The IRS-1A satellite has two CCD cameras with a resolution of 72m and 36m, which helps in looking at features simultaneously at two different scales under uniform conditions. This is of particular significance in geological studies, as it helps in providing detailed information and at the same time helps in the identifying and mapping of regional structural features as well as correlation of lithological units.

Mineral deposits are the end products of the geological processes whereby anomalus concentration of minerals get localised in small areas in a particular geological environment. Therefore, the most vital factor in any exploration programme is the geologic information and knowledge. The most fundamental geological information is provided by the geological map which gives the spatial distribution of various rock types, their structural relationships and stratigraphic position, which together enable understanding the different controls of mineralisation in favourable areas.

Geological mapping methods have been undergoing continuous changes alongwith the technological and scientific advances in the relevant fields. Remote sensing techniques are now being increasingly used to prepare geological maps, and has provided a new capability for preparing better lithological and structural maps[1]. Also, these methods which enable extrapolation, provide continuity of geological observations which is not possible in ground surveys. It is worth noting, that even in areas of good rock exposures, nearly 30 to 40 per cent ground is covered by soil or vegetation, and to a great extent geological maps based on ground surveys are prepared on the basis of inferences drawn from random observations or observations during traverses[2].

Trends in Geologic Remote Sensing

It has been proved beyond any doubt that the space-borne data could be used efficiently for mapping the earth's surface at small, medium and large scales. The synopticity of the space-borne data gave a wealth of information on structural lineaments and resulted in the discovery of numerous unmapped ones, even in areas considered to be reasonably well mapped. Attempts were also made to correlate such lineaments with aeromagnetic data[3]. The study of structural lineaments assumed greater significance because of their correlation with known mineral deposits all over the world and in establishing the control of mineralisation in many areas. In Khetri and Singhbhum, it has been postulated that the intersection of different sets of lineaments are the most favourable zones of localisation of mineral deposits[4].

Subsequently, after the first rush of lineament mapping was over, attention was paid to the other features on the space-borne data, particularly the tonal variations and anomalous tonal areas, which were directly related to mineralisation such as gossans, blooms and alteration zones, etc. Digital image processing techniques were applied to further enhance such anomalous tonal areas. The study of Rowan *et al*[5] showed, that the combination of ratioing and stretching offers a powerful means for discriminating some rock types, exposed iron-oxide enriched gossans and alteration zones. Further discrimination may be possible by applying different stretch formulas to ratio values. Many such techniques have been tried in various mineralised belts of India under a joint experiment programme betweeen the Space Applications Centre and the Geological Survey of India[6]. These experiments in fact have helped to a great extent the identification of the spectral bands for the IRS-1A satellite.

Now attempts are being made to integrate and correlate remotely sensed data with airborne, surface and sub-surface geological, geochemical and geophysical data for better delineation of lithological and structural features as has been done in the case of Project Vasundhara.

Applications

Geological Mapping

In the hilly terrain of Shimla - Solan - Sarahan and Nahan - Paonta areas of Himachal Pradesh, digitally enhanced IRS-1A LISS-I data was used for geological and structural interpretation[7]. In Shimla area, a clear delineation of the lithological units of upper and lower Siwaliks, Subathu-Murree, Krols, Shimla and Jaunsar formations, granites and gneisses could be done using these enhanced images (Figure 1). The Main Boundary Fault (MBF) separating the younger Siwaliks from the older rocks and the Krol thrust are clearly demarcated.

In another case study, digital enhancement of IRS LISS-II data proved very useful in the inaccessible terrain of the south-eastern part of Doon Valley for interpretation of various lithological units of Palaeozoic (Damtas, Chandpurs and Nagthats), Mesozoic (Blainis, Krols and Tals), Tertiary (Siwaliks) and Quarternary. Within Mesozoic the Krol formation could be separated from the Tals, and within Tertiaries the middle and upper Siwaliks could be separated from each other[8]. Moreover, the synclinal fold with NW-SE axis could be interpreted from the trend lines and repetition of the Krols further north-east. The Narendranagar anticline is traceable by the subtle trend lines. The MBF which marks the south-western edge of the Pre-Tertiaries shows dextural shifts along transverse faults trending

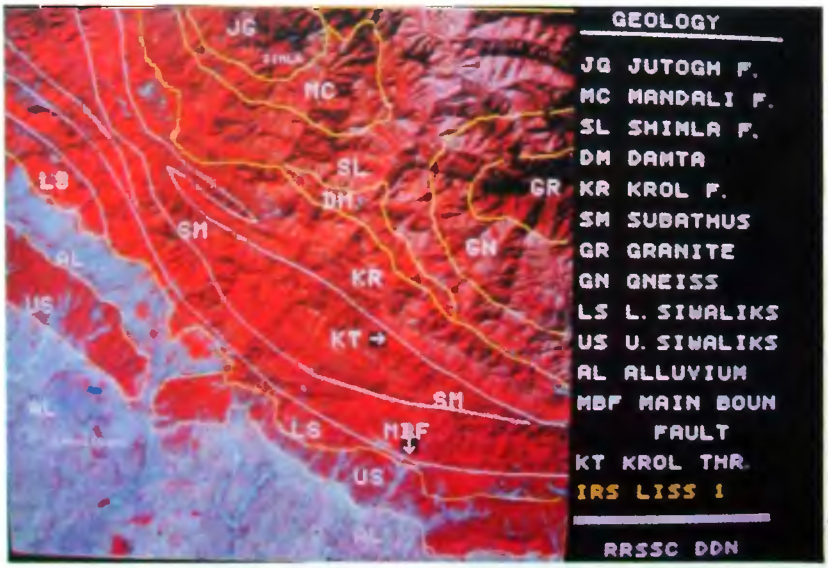

Figure 1. Geology of Shimla area, Himachal Pradesh.

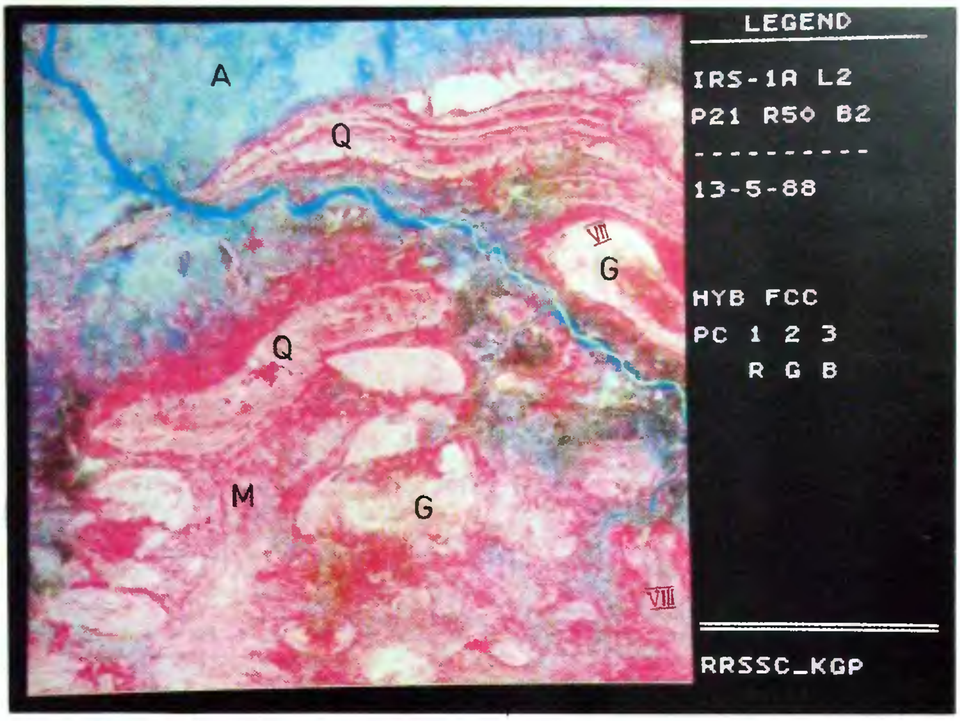

Figure 2. Hybrid FCC of PC1, PC2 and PC3 (G-Granite; Q-Quartzite; M-Mica-schist, and A-Alluvium of Bihar Mica belt.

NE-SW; some of which could be traced right across the Doon Valley into the Siwalik hills.

In another study over the central part of the Bihar Mica Belt, granitic plutons were found to be better defined in ratioed image (NIR/S) of IRS-1A LISS-II data compared to individual band images[9]. Principal Component Analysis using 4 band data revealed that the PC-2 image is better that PC-1 image for identification and mapping of granitic plutons of the porphyritic type. Hybrid colour composite prepared from 3 Principal Component images (PC-1, PC-2 and PC-3) proved to be the best single image for identification and mapping of the granitic plutons (Figure 2).

Geomorphological Mapping

The analysis of landforms and drainage helps in the lithological discrimination, and thereby facilitates indirectly the geological mapping and further understanding of the geological processes.

In a case study of the Doon Valley[8], digitally enhanced IRS-1A LISS-II data has been found very useful in differentiating various geomorphological units such as highly rugged and deeply dissected denudational hills formed on the Pre-Tertiaries in the outer Lesser Himalayas, the less dissected but high denudational mountains on the Mesozoic formations in the inner Lesser Himalayas, the linear structural hills of the Tertiary formations in the Siwalik ranges and the broad synclinal valley between the Siwalik ranges and the Lesser Himalayas. A similar interpretation of geomorphological features from digitally enhanced IRS-1A images have been done in Kalka-Narayangarh area of Haryana (Figure 3).

Geomorphologic study of the Gaula catchment in Nainital area of the Himalayas using digitally enhanced IRS-1A and Landsat TM data revealed slope instability and concentration of landslides along the fault controlled valleys which follow the Main Boundary Thrust and Ramgarh Thrust.

Mineral Exploration

Significant amount of work has been done with space-borne data in mineral exploration[6]. The remote sensing data has been used in two ways – delineation of features favourable for localisation of mineralisation such as folds, faults and fractures and secondly identifying features directly related to mineralisation, such as alteration zones, gossans and specific host rock association.

Application of IRS data in mineral exploration have been carried out in the lead-zinc mineralised belt of Rajpura-Dariba areas of Udaipur district, Rajasthan. The area forms a part of the peneplaned Mewar-Bhilwara plateau which is mostly covered with soil/alluvium.

The lead-zinc mineralised belt extends over a strike length of 17 km from Dariba in south to Bethumni in the north, forming part of the western

Figure 3. Geomorphology of Kalka - Narayanagarh area, Haryana.

limb of the north-easterly plunging Banera-Bhinder macrosyncline of Pre-Aravalli Bhilwara group of rocks. The mineralisation is syngenetic and confined to mica schist, graphite schist, dolomitic marble and chert. Limonite, fault breccia, chert and gossan with a zone of oxidation upto 40m are the main guides for the exploration of mineralisation in this area.

Visual interpretation of IRS data has resulted in detailed analysis of lineament pattern, structural trends and demarcation of major lithological units. A well defined fault zone with conspicuous and diagnostic residual gossan is delineated between Dariba and Rajpura. Just East of Dariba village, a thin fault zone containing abundant barytes is also found. During the course of geological and geomorphological interpretation, mesoscopic folds developed during the different stages of deformation have been clearly observed in the Sindesar-Kalan quartzite ridge, the only prominent outcrop in the western part of the area.

Detailed geological and geomorphological studies show that the mesoscopic folds, observed in the Sindesar-Kalan quartzite ridge, are extending with less intensity in the eastern part of the area, and are noticed in the Jasma quartzite ridge. The expressions of these mesoscopic folds are clearly manifested in the entire area which is covered with thick soil. Geomorphic expressions in the form of annular drainage developed in the area substantiates the regional structural trends.

Compilation and extrapolation of the geological and geomorphological information interpreted from IRS data, particularly for the eastern part of the area led to delineation of favourable zones for lead-zinc mineralisation around Lunera-Bari villages.

In Project Vasundhara, IRS-1A and Landsat TM data covering an area of 400,000 sq. km in the southern Peninsular Shield, south of 16° N latitude, has been interpreted and integrated with air-borne geophysical and ground survey data for identification of mineral prognostic zones. Six different thematic maps — geology; structural trends, lineaments and circular features; aeromagnetic Bouguer gravity interpretation; synoptic geology; geophysics, and mineral distribution were generated on 1:500,000 scale. From the basic knowledge, six derivative maps – electromagnetic and radiometric maps, igneous intrusion, dykes and sills, isotopic age map, metamorphic map, and epicentre map were generated.

On the basis of the conjunctive analysis of thematic and derivative maps, reconnaissance investigations were carried out in 10 random areas by the Geological Survey of India. Further work is being done in development of prognostic models (maps) and through geostatistical methods to determine potential target areas of mineralisation.

Apart from these maps, remote sensing data of a few selected locations were enhanced and studied for possible correlation between mineral localisation and reflectance values of the data.

CONCLUSIONS

The work done with IRS-1A LISS-I and LISS-II data in geological and geomorphological studies has clearly indicated that data from IRS-1A is comparable with Landsat MSS and TM data in geological studies. Significantly more information can be derived from the data by digital enhancement techniques as were followed in the case of Himalayas and in Bihar Mica Belt.

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