Application of imaging radar technology to uranium exploration

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Abstract. The history of imaging radar technology development, technical advantages, current technology research status of lithologic identification with remote sensing have been comprehensively evaluated on this thesis. Radar technology applied in structure recognition, rock identification, and uranium exploration research are discussed in this paper. Examples of microwave-optical fusion technology have been given in part 3, and the results demonstrate that imaging radar technology, as one of the most frontier observation techniques, has extensive application prospect in uranium exploration.

1. Introduction
Radar remote sensing technique is a method which uses microwave to observe ground target. According to working principle, radar remote sensing can be classified as active observation and passive observation. Active observation uses transmitter inside the sensor to launch microwave pulse and receive reflection wave. Passive observation receives ground reflection wave without launching microwave pulse.

Since radar was invented, many countries have developed air bone radar system, after conducting amount of experiments. Radar technology has achieved significant achievement. In early 1980s, the spacebone imaging radar research gradually increased in the field of geological applications, topographic mapping and cartography. Owing to its large-area rapid mapping and small geometric distortion technical characteristics, radar technique has been playing an extremely significant role in lithology identification and structural identification, especially in areas which are perennially covered by fog and clouds. Besides identifying lithology distribution, Radar image was also used to identify underground geological bodies, and it is a complementary method of optical remote sensing.

With the development of radar technology, radar becomes increasingly important than ever before. The radar information acquiring methods and data processing means are improved nowadays so this technology superiority makes radar remote sensing more and more useful in crustal deformation and deposit exploration.

2. Geological application status of Radar technology
Unlike optical remote sensing microwave remote sensing due to its unique mechanism, have rapid develop in recent years, are widely used in disaster monitoring, and geological mapping exploration and other fields. And have made a series of achievements.
2.1. Structure recognition

Side looking characteristic can enhance specific direction of geological structure in radar image when the radar beam direction are perpendicular to major lineaments in observe area. Therefore, radar data have unique advantages of detect linear structures.

Egypt ministry of Remote Sensing and Space Sciences, University of Texas lithosphere research center used Landsat TM image data and SIR-C/X image to study Allaqi structure alteration zone in Sahara Desert in southwest of Egypt, with density segmentation method, to map iron and clay alteration index of structural alteration zone, and successfully identify new mineralization areas.

Chinese Academy of Sciences Center for Earth Observation, discovered a gold-bearing structural belt in Yulin Inner Mongolia with SIR-A data, which shows abnormal high brightness linear spread on the radar image. Researcher of The Chinese Academy of Sciences Institute of remote sensing application used SIR-C synthetic aperture radar to enhance linear structure information, because the synthetic image, with strong stereoscopic feel, have better effect to identify linear tectonic[1]. U.S. Geological Survey, used radar technology discover the ancient river and ancient human remains, and alluvial fan, buried dyke in the Sahara desert.

Indonesia Department of Energy, ChiBa University combined ASTER data and JERS-1 radar data to get geological structure of Cepu area, researchers had interpret 11 anticline, including a fault anticline structure with JERS-1 data after radiometric calibration, geometric correction, image sharpening, combined with ASTER images.

2.2. Rock identification

Microwave remote sensing depend on tone, landforms, microwave scattering intensity to recognition feature. Different objects have different surface roughness and complex permittivity and therefore have different microwave backscatter intensity. In general, the tone depends on the radar echo intensity. Target complex permittivity, surface roughness, topographical features are the main factors to affect microwave back-scatter, the larger the dielectric constant the stronger echo effect is the smaller the ability to penetrate subsequent scattering, the color tone of the image is more shallow, whereas the deeper. The surface roughness is apparent displayed on characteristic of the rock material composition, it an important factor to determine the tone display such lithology on the radar image, the rock type and physical parameters of microwave plays a control role, affecting fault structure and development of the water system distribution and vegetation development, thus forming a unique texture of the radar image of the study area[2]. Therefore, according to the gray scale, texture and other characteristics of the radar images, can accurately identify different lithologies by combining optical remote sensing and geosciences information.

Staffs in the BRIUG used the Radarsat data, aerial radiometric data and ETM sixth band thermal infrared data to study the tectonic development characteristics of sandstone-type uranium deposits of the northern part of the Ordos basin, with ore-bearing strata spatial distribution characteristics. Fused image, northeast and south of the 2081 mine preselected area, ore-forming target strata Jurassic Zhiluo formation sandstone tones prominent in the image(red tones), the southern boundary of the 2081 mine ore-controlling fault zone shows green strip of nearly east-west direction, and the surrounding object texture features characteristics, spectrum feature, thermal characteristics are significantly different[3].

The Chinese Academy of Sciences Center for Earth Observation used radar data of Hunan Tao Ling to identify lithology, which interprets six kinds of rock unit, that match results 1:200000 geological map. Researcher of The Chinese Academy of Sciences Institute of remote sensing application used multi-polarization synthetic image successfully identify the coverage in the hybrid rock edge of Pleistocene loess-like sand deposition in Zhangjiakou[4].

2.3. Uranium exploration research

Researchers of BRIUG used the radar data to carry out a series of geological exploration research in the Yili Basin, Jiangxi uranium ore field, Xuemisitan, Namibia betel Lake area. In Yili Basin,
comprehensive utilization of various means of remote sensing technology, including radar data, successfully identified local discharge zone related to uranium mineralization in study area by comparing both sides of the tectonic zone\cite{5-6}. ETM multi-band remote sensing data and Radarsat fine mode data were used in Taoshan, Jiangxi, through the analysis of texture characteristics and optical and microwave fusion technology, the main ore-controlling fault zone has discovered on the remote sensing image for analysis granite type uranium ore field in Taoshan. Radarsat2 fine mode data and ASTER data were also used in Namibia betel lake, comprehensive study on regional ore-controlling structure, space distribution of ancient river and calcrete, have provide geological maps in this area, which played an important role in uranium metallogenic environment analysis.

3. Key techniques of microwave remote sensing for uranium exploration

As previous mentioned. The radar technology is active remote sensing. To a certain extent it can work under all climatic regions. Meanwhile the radar receiver have reflected geometry and dielectric properties information of geological body. It beneficial to structure and lithology interpretation\cite{7}. Besides, microwave can penetrate the earth’s surface. When the transmitter launch microwave pulse, part of pulse signal penetrate ground object. Pulse signal is proportional to microwave wavelength, and closely related to target moisture content electromagnetic. And this feature is very effective to detect underground substances, especially aqueous fault structure\cite{8}. Therefore radar technology have a brilliant future in uranium exploration. According to the advantages mention above, the key technique in uranium exploration including:

3.1. Radar data characteristic processing technology

Distortion is inevitable during data acquiring processing. Distortion lead to decline image quality, seriously affect data application effect(figure1). Figure 1 (a) presents raw data of Rossing uranium mine. Due to the salt and pepper noise it hard to recognize useful information from this picture, by applying lee filter, figure 1 (b) shows obvious structure information, that very useful for uranium geological prospecting. Therefore research on filter for different polarization mode features is key and foundation to realize precision calibration and efficient extract metallogenic-geological.

![Raw radar data](image1)

![Process by Lee filter](image2)

(a) Raw radar data  
(b) Process by Lee filter

**Figure 1.** Comparison of filter result

3.2. Microwave-optical fusion technology

Due to the band range and data obtaining method, radar and optical remote sensing have a great difference of expression electromagnetic waves of the surface features(figure2). The purpose of fusion is to clearly integration texture and polarization of the radar data and spectrometer information, display electromagneticspectrum characteristics of ground target, and accurately identify the different
geological bodies, such as ore-controlling structure, mineralized alteration zone and so on. Figure 3 (a) (c) (e) are ASTER data, (b) (d) (f) are fusion image of ASTER data and Radarsat-2 data. Compare figure 3 (a) and (b), fusion image have abundant texture information, a fault structure (red arrows) is very obvious, and on the contrary, the structure is not very clear in aster image. Figure 3 (c) (d) shows data of Rossing south, the yellow frames in (d) it is Nkb group biotite schist it shows black in aster image but in fusion image we can found lots texture information. Figure 3 (e) (f) presents west parts of Valencia uranium mine, the syn-tectonic granite (yellow arrows) shows white in ASTER data, after fusion with radar data it can distinguish from surrounding formation.

(a) Radarsat-2 data  
(b) Aster data  
(c) Fusion data

Figure 2. Comparison map of fusion image of optical image and radar data

(a) Aster data  
(b) Fusion data  
(c) Aster data  
(d) Fusion data
3.3. Metallogenic essential factor extraction technique

Based on radar data characteristics and radar-optical fusion technology, to analysis regional metallogenetatic condition and metallogenic essential factor, can provide the necessary remote sensing information and technical support for the study of the temporal and spatial distribution of uranium deposits, uranium mineralization forecast.

4. Conclusion and prospect

As one of the frontier technology of remote sensing for land observe, Radar technology have a brilliant future in uranium exploration. As the develop of uranium resource prospecting, the identity of shallow hidden geological bodies have attracted more attention than before. Because restrict of wavelength range, optical remote sensing have limit to detect buried structure. Therefore, how to give full play to microwave remote sensing technology is one important developing direction in remote sensing of uranium exploration.

At the present time, Radar technology had used in resource explore, but relative than the remarkable results achieved by visible-thermal infrared remote sensing in structure, rock mass, stratum, altered identification, high-precision data processing and quantitative geosciences application need further research. Therefore innovation of new technique and new method to fundamental research of microwave remote sensing are of significance to detect shallow hidden geological bodies, buried structure identification, exploration of concealed uranium deposits.

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