International Symposium on Uranium Raw Material for the Nuclear Fuel Cycle: Exploration, Mining, Production, Supply and Demand, Economics and Environmental Issues (URAM-2018)

Contribution ID: **62**

Type: **ORAL**

ADVANCES IN HYPERSPECTRAL REMOTE SENSING TECHNOLOGY FOR THE EXPLORATION OF HYDROTHERMAL TYPE URANIUM DEPOSITS IN CHINA: A CASE STUDY IN THE XUEMISITAN AND LONGSHOUSHAN AREAS

Tuesday, 26 June 2018 14:20 (20 minutes)

1 INTRODUCTION

Hyperspectral remote sensing technology has unique technical advantages in mineral identification[1], by which the obvious effects in metal mineral exploration have been made at home and abroad[2,3].Since 2008, With the introduction of the internationally advanced CASI(Compact Airborne Spectrometer Imager)/ SASI(Shortwave Airborne Spectrometer Imager)/TASI (Thermal Airborne Spectrometer Imager) airborne hyperspectral measurement system to Beijing Research Institute of Uranium Geology,CNNC,China, the researches and application to uranium exploration using hyperspectral remote sensing technology had entered a new stage of rapid development [3]. Xuemisitan area in Xinjiang, is an important Cu-Fe-Au-W-Mo-U-Be metallogenic belt in northern Xinjiang, China. The mineralizations are mainly related to volcanic and magmatic hydrothermal activities. In the belt, a volcanic type U-Be-Mo polymetallic deposit named Baiyanghe Deposit and a series of uranium mineralizing dots, anomalies had been discovered before. Therefore, there are good uranium polymetallic ore-forming conditions and high prospecting potential in Xuemisitan area. In Baiyanghe uranium deposit and its surrounding area, there mainly developed Devonian and Carboniferous volcanic rocks, granite, granite porphyry, diabase vein and so on. The uranium ore bodies were mainly located within the 50 meters zone of the contact zone between microcrystalline granite porphyry called Yangzhuang body and the underlying intermediate and acid volcanic rock of upper Devonian Talbahaitai Formation (D3t). Main hydrothermal alteration minerals are hematite, hydro muscovite, carbonate, fluorite, silicitization and so on[4].The Longshoushan uranium polymetal metallogenic belt is located in Gansu province, China, where the U, Th, Cu, Ni, Fe, Au, Ag and other minerlizations had been discovered before. There existed good metallogenic conditions and great prospecting potential. The main strata were Proterozoic metamorphic rock and upper Paleozoic Devonian, Carboniferous, and Permian system. The magmatic activity in Caledonian period was strong, and there were many intrusive rock bodies, such as ultrabasic rocks, intermediate rocks, acid rocks and alkaline rocks. Hydrothermal activity was strong in the area, and the main hydrothermal alterations related to uranium mineralization were albitization, carbonation, chloritization, hematitization, silicification, sericitazation. The alkaline metasomatic type uranium deposits, such as Jiling, and the siliceous belt type uranium deposits named Gemigou, and the uranium deposits related to the alkaline body named Luchaogou had been discovered in this zone before. Above two areas are well exposed and suitable for the research and application of hyperspectral remote sensing technology to uranium exploration, which can promote new breakthrough in uranium exploration.

2 HYPERSPECRAL DATA AND PROCESSING METHODS

The hyperspectral remote sensing data used in this study include CASI/SASI/TASI airborne hyperspectral data acquired in 2011 and 2017 respectively, ground-based spectrometric data and borehole core spectrometric data. The spatial resolution of CASI data was 1.0 m, and its spectral resolution was 20 nm, the spectral coverage was 404˜1047nm. For SASI data, the spatial resolution, spectral resolution and spectral coverage was 2.0 m, 15 nm, and 950˜2450 nm respectively.For TASI data, they were 2.0 meter, 125 nm, and 8000˜11500 nm respectively. The ground and borehole core hyperspectral data were obtained by using Field Spec Pro FR portable spectrometer of ASD Company of the United States. The spectrum of ASD data ranged from 350 to 2,500 nm, with spectral resolution of 3 nm in 350 to 1,050 nm and 8 nm in 1050 to 2500 nm respectively. In order to extract the altered mineral information from the obtained airborne hyperspectral data, the processes of radiation correction, geometric correction, atmospheric correction, spectral reconstruction, separation of temperature and emissivity and mineral mapping were performed. For ground and borehole core spectrometric data, the main processes were spectral curve analysis, mineral identification and statistical analysis. After extraction of mineral information, the field verification and chemical analysis of samples were needed to be carried out to ensure the accuracy of hyperspectral mineral mapping.

3 MAIN ADVANCES

Through the researches and application of the hyperspectral technique to uranium exploration in China, recent years some new advances on hyperspectral remote sensing technology of uranium exploration and its application have made as the following.

3.1 Hyperspectral remote sensing technology suitable of hydrothermal type uranium exploration

Through introducing the CASI/SASI/TASI airborne hyperspectral remote sensing technology into uranium exploration domain systematically, a set of airborne hyperspectral detection technology for uranium exploration, which combining data acquisition, mineral mapping, information analysis, model construction and exploration prospecting, were established. The detection technology specifically include CASI/SASI/TASI hyperspectral data acquisition technology, CASI/SASI airborne hyperspectral data processing and mineral mapping technology, TASI airborne thermal infrared hyperspectral data processing and identification technology of quartz-silicon zone, information analysis technology for airborne hyperspectral mineral mapping, model construction technology for uranium deposit using hyperspectral information, and prediction technology for uranium exploration using hyperspectral information. Among them, the information analysis technology for airborne hyperspectral mineral mapping, model construction technology for uranium deposit using hyperspectral information, and prediction technology for uranium exploration using hyperspectral information are the most important new advances. The information analysis technology mainly include the genesis analysis technology of Al-high sericite, Al-medium sericite and Al-low sericite identified by airborne hyperspectral, the mineral assemblage analysis technology based on the concept of favourable metallogenic geochemical barrier, and metallogenic environment analysis technology. Through researches, a new idea about the genesis of Al-high sericite, Al-medium sericite and Al-low sericite Al- sericite was proposed systematically. Namely, Al-high sericite was considered to be formed in the relatively high temperature and acid hydrothermal fluid environment, while Al-low sericite was formed in relatively low temperature and alkaline hydrothermal fluid environment. In the same time, 3 kinds of new mineral assemblage of hyperspectral altered minerals were proposed to predict the favorable volcanic rock type uranium prospecting area. The uranium prediction technology for uranium exploration using hyperspectral information includes the method based on above 3 kinds of mineral assemblage, method based on uranium deposit location model and the method by integrating mineral mapping information and airborne radioactive information.

3.2 Analysis on hyperspectral characteristics in Baiyanghe volcanic type uranium deposit

Using different scale of hyperspectral remote sensing data from airborne, ground, drillhole, the hydrothermal alteration types in surface and depth of Baiyanghe uranium deposit and its surrounding area were identified. After that, the hyperspectral characteristics of uranium deposit and their hydrothermal fluid activities in surface and deep of uranium deposit were analyzed and studied.

(1) There existed alteration minerals such as pyrophyllite , dickite, alunite, kaolinite, Al-high sericite, Al-medium sericite, Al-low sericite, hematite, silicification, and so on, in deposit and its around area. According to the spatial distribution of these minerals, they can be divided into three alteration areas: northern alteration area, deposit alteration area and southern alteration area. In northern alteration area, a set of acidic hydrothermal alteration groups composed of pyrophyllite, dickite, alunite and Al-high sericite were developed. Al-high sericite, Al-medium sericite, hematite and silicitization were mainly developed in deposit alteration area, while Al-low sericite and Al-medium sericite were developed in southern alteration area. Analysis showed that the northern alteration area was a set of mineral assemblage of advanced argillic belt formed by volcanic gas and liquid boiling [5], and it formed from an ascending magma hydrothermal fluid [6] and indicating that the metallogenic fluid may have risen to a shallow hydrothermal depth. Therefore, the northern alteration area is a possible volcanic structure and regional hydrothermal fluid activities centre in Baiyanghe and its surrounding area. Baiyang uranium deposit alteration area was characterized by the strong development of Al-high sericite, Al-medium sericite, and was the obvious fluid activity area located in the side of the fluid activity center in the regional hydrothermal system. The southern alteration zone also was an obvious hydrothermal fluid activity area with more decreasing temperature farther from the fluid activity centre.

(2) In uranium deposit area, the hydrothermal alteration temperature was considered to be higher in the middle and west than in the east, higher in the northern margin than in the southern margin.The northern margin was the contact zone between Yangzhuang sub-volcanic body and Devonian intermediate and basic volcanic rock, the alteration temperature was higher in the middle and west part than in the east. This idea was based

on the following hyperspectral mineral information and the genesis analysis of Al-high sericite, Al-medium sericite and Al-low sericite above mentioned. The SiO2 content extracted from airborne thermal hyperspectral data was comparatively lower in the central and western part than that in the eastern part. In the northern margin contact zone, there developed Al-high sericite and Al-medium sericite. While in the southern edge there developed Al-low sericite and Al-medium sericite. Moreover, in the northern margin contact zone, the alteration minerals varied from Al-high sericite to mixture of Al-high sericite and Al-medium sericite, the Al-OH absorption wavelength of sericite altered mineral changed from the relatively short wavelength in central and western regions to the relatively long wavelength in the east. In vertical profile from the contact zone, the Al-OH absorption wavelength of sericite had the same change from near contact zone to far from contact zone.

(3)There were at least two typical ways of hydrothermal fluid activity in the deep of Baiyanghe uranium deposit. Based on the minerals characteristics and sericite Al-OH absorption wavelength change identified from drillhole core hyperspectral data, two typical ways of hydrothermal fluid activity in deep of BaiYanghe uranium deposit were discovered. They are called Direct-flow type and Separate- flow type. The former had the characteristics of continuous and directional Al-OH absorption wavelength change from 2195nm to 2208nm to 2215nm. It reflected the temperature of the hydrothermal fluid varied gradually from the relative high in the deep to the relative middle in the vicinity of the contact zone and then to the relative low into granite porphyry. Two drillholes of ZK5432 and ZK5630-1 located in the main mineralized area in the central and western region were characterized by this type. It may be related with diabase vein, which were more developed there. The latter had the characteristic of changing Al-OH wavelength from 2200 nm in contact zone to 2210nm in the deep and to 2215 nm in the shallow, respectively. It reflected the relative high temperature of the hydrothermal fluid in the vicinity of the contact zone, decreased toward two sides of the deep and upper respectively. ZK 3310 and ZK2710 located in the eastern part of deposit were belonged to the type. This type of temperature change of hydrothermal alteration was also consistent with that existed in northern margin of deposit above mentioned. They were the same fluid activity patterns appeared in different horizontal and vertical profiles respectively.

(4) Relationship between uranium mineralization and hydrothermal fluid activity. From the spatial distribution of uranium mineralization and anomalies in Baiyanghe deposit and its surrounding area, it can be found uranium mineralization had good relationship with hydrothermal fluid activity. First, uranium mineralization has certain relationship with regional hydrothermal activity centre. The identification of hydrothermal activity centre is very important to predict the regional uranium exploration area with benefit ore-forming condition. Second, uranium mineralization was closely related to the relatively high temperature of hydrothermal fluid. ZK5432 and ZK5630-1 with good mineralization had the direct-flow type of fluid activity way, and it may be related to the invasion of basic rock vein and diabase vein. Therefore, this provides new evidence to prove the close relationship between uranium mineralization and basic vein in the Baiyanghe uranium deposit area. Thirdly, the uranium mineralization and enrichment in borehole core were mainly in the transitional zone between Al-high sericite and Al-low sericite alteration, where the hydrothermal activity was from relatively high temperature to relative middle temperature, hydrothermal properties from acid to neutral and weak alkaline. Therefore, uranium mineralization may be closely related to the change zone of hydrothermal fluid temperature and acidity and alkalinity.

3.3 Analysis of hyperspectral characteristics of alkalic metasomatic and siliceous belt uranium deposits

By analyzing the characteristics of different types of uranium deposits in Longshoushan area using airborne hyperspectral information, the preliminary ore-forming features were found. (1)The hydrothermal alteration characteristics in Longqiangshan area was strong in the east and weak in the west, strong in the Southeast and weak in northwest. Hydrothermal alteration was closely related to faults with north-west trend, north-north-west trend and east-west trend. The hydrothermal alteration strength was relatively weak in the main uranium prospecting area. Hydrothermal alteration mainly distributed in the outer of the contact zone between granite, alkali rock bodies and old Metamorphic rock. Alteration was relatively weak in the interior of granite bodies. (2) The Jiling alkalic metasomatic type uranium deposit was located in the contact zone between granite and diorite, and the ore body is located in the red alaklic metasomatic alteration bodies albllized. The main alteration minerals in and around Jiling uranium deposit are hematite, Al-medium sericite, Al-low sericite, chlorite, carbonate, serpentine and silicification. Among them, chlorite, carbonate and serpentine mainly distributed along the ore-controlled reoinal big fault named Malugou. The secondary faults mainly developed some Al-medium sericite and Al-low sericite alteration. The hydrothermal alteration generally was weak in surface of deposit and strong in outer of deposit. Along the north-west trend Maligou fault, SiO2 content decreased obviously in the norwest part. (3) Gemigou deposit and Lucaogou deposit were considerated to be in the same hydrothermal activity system. The former is located in the contact zone between granite body and metamorphic rock, and the fault structure named Gemigou ore-controlled fault. while the latter is located on the interior side of contact zone between alkaline rock body and metamorphic rock. The former is remarkalbely characterized by silicification, kaoliniztion, Al-high sericite and carbonate, while the latter is characterized by the obvious alkaline rock body with alkaline feldspar identified by thermal infrared hyperspectral. From the margin of alkaline body in the south to granite to metamorphic rocks in north, there existed different alteration zone of fe-rich chlorite, carbonate and Al-low sericite, Al-high sericite and kaolinite and silicification.

3.4 Uranium exploration prediction

According to the hyperspectral characteristics of volcanic type uranium deposit in Xuemisitan area and different type uranium deposits in Longshoushan area, the favourable uranium prospecting area were predicted. In the Xuemisitan area, the hydrothermal activity centre was selected in regional scale at first. Then, these areas developed Al-high sericite and Al-medium sericite, especially further existed hematization, acidic rock, basic rock vein were outlined as the target areas. Based on this new idea, several new uranium mineralization anomalies were discovered. It had been proved that there are good uranium mineralization and obvious ore-controlled fault in the deep in one predicting area by trenching. In Longshoushan area, the favorable areas were also predicted, which still need to be verified next. In addition, using hyperspectral remote sensing technique, the prediction results for Cu-Au prospecting in Xuemisitan are terrific obvious.

4 CONCLUSION

The hyperspectral remote sensing technology has made obvious achievements in identifying hydrothermal alteration minerals, analysing hydrothermal alteration and fluid activity law, judging ore-controlled structure in the Xuemisitan and Longshoushan area, which provided an important new technology for uranium exploration, and had promoted new breakthroughs in uranium and polymetallic mineral exploration. In the future, it is necessary to strengthen the comprehensive analysis of alteration minerals, structure and lithology identified by hyperspectral remote sensing. It is very important to combine hyperspectral information with fluid metallogensis and uranium ore-forming theory, so as to excavate the prospecting information underlied in hyperspectral remote sensing data deeply. Only do that, hyperspectral remote sensing technology can be server for uranium exploration more effectively.

REFERENCES

[1] Kruse, F. A., Use of Airborne Imaging Spectrometer data to map minerals associated with hydrothermally altered rocks in the northern Grapevine Mountains, Nevada and California, Remote Sensing of Environment. 24, 1(1988)31-51.
[2] Phil,B., David,H.,et al., Hyperspectral Mapping of Mineral Assemblages Associated with Gold Mineralization in the Central Pilbara, Western Australia, Economic Geology.97(2002) 819-826.
[3] Liu,D.C.,Tian,F.,et al., Application of hyperspectral remote sensing in solid ore exploration in the Liuyuan-Fangshankou area. Acta Geologica Sinaca, 91,12(2017)2795-2812(in Chinese).
[4] Ye,F.W.,Zhang,J.L., et al., Application of airborne hyperspectral remote sensing technique to uranium prospecting: A case study of Baiyanghe area, Xingjiang. Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS), 4th Workshop (2012)1-5.
[5] Hu,S.X.,Ye,Y., Petrology of the metasomatically altered rocks and its significance in prospecting. Beijing: Geological Publishing House(2004)1-214(in Chinese).
[6] Je,F.W.H.E., Antonio,A.J.,T.J.R., Evolution of an intrusion-centered hydrothermal system: FarSoutheast-Lep-anto porphyry and epithermal Cu-Au deposit, Philippines. Economic Geology, 93,4(1998)373-404.

Country or International Organization

China

Primary author: Dr YE, Fawang (Beijing Research Institute of Uranium Geology)

Co-authors: Mr ZHANG, Chuan (Beijing Research Institute of Uranium Geology); Mr LIU, Hongcheng (Beijing Research Institute of Uranium Geology); Mr MENG, Shu (Beijing Research Institute of Uranium Geology)

Presenter: Dr YE, Fawang (Beijing Research Institute of Uranium Geology)

Session Classification: Advances in Exploration

Track Classification: Track 4. Advances in exploration