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Remote sensing, SWIR, Raman and XRD applications in Pesovets epithermal system mapping, Panagyurishte ore district, Bulgaria

Дистанционни, SWIR, Raman и XRD приложения при картиране на епитермалната система Песовец, Панагюрски руден район, България

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Abstract. Remote sensing UAV based study combined with field mapping, SWIR, XRD Raman and XRF tests for mineral detection outlined advanced argillic alteration domains in the Pesovets silica cap to demonstrate quick approach for epithermal gold exploration targeting and evaluation. As and Ti increasing trend toward epithermal high-sulphidation Cu-Au mineralization could be employed as a proximal path finder.

Keywords: mineral exploration, remote sensing, UAV, alteration mapping, HS epithermal Au deposits.

Introduction

Remote sensing study of mineral alterations is an important tool for mineral exploration (Sabine, 1999). When distal sensing is combined with field mapping and modern mineral detection methods such as SWIR (1300–2500 nm), Raman spectroscopy, XRD and ore petrography are more capable for recognizing hydrothermally altered minerals and zones by their diagnostic spectral signatures. Recent technological advances based on UAV (Drone) supported study provide high resolution efficiency for a real-time georeferencing and acquiring VIS (390–750 nm), NIR (750–1300 nm) and multispectral SWIR data (ASTER, Sentinel-3, InSAR sensors) for mineral alterations mapping and fault control of Cu-Au epithermal and porphyry-copper deposits and ore occurrences in Panagyurishte ore region, Central Srednogorie, Bulgaria (Bakardjiev, Popov, 2015; Filipov et al., 2020).

Advanced argillic (AAA), argillic (AA) and propylitic alteration styles overprinting rocks of dominated andesitic composition rocks have been recognized and sampled across Pesovets volcanic cone, that also have been mapped by UAV-supported survey (Fig. 1A).

Samples and study methods

Twenty-five samples collected during the field work have also been examined by means of XRD analyses

with X-ray diffractometer D8 Advance Brucker, Fe-filtrated Co X-ray, 35 kV and 40 mA. The phase identification is based on International Powder Diffraction File, ICDD (Fig. 1B). Raman tests were performed by means of handheld Labao LATR 6500 Raman spectrometer with a super-fluorescence suppression effect based on the 1064 nm excitation light (Fig. 1C). SWIR spectra were obtained using NanoQuest (1300–2500 nm, spectral resolution 10 nm) spectrometer (Fig. 1D). In situ measurements with portable XRF Skyray 6000 on the sampled rock outcrops have also been provided (Fig. 1E). All the mineral detection studies have been done at Sofia University, Department of Mineralogy, Petrology and Economic Geology.

Geological background

Pesovets ore occurrence is located 2 km NW of Popintsi village, Panagyurishte ore region in the Pesovets anticline with a core of Upper Cretaceous (89.61–80.21 Ma; von Quadt et al., 2005) andesite to basaltic andesite dominated volcanic rocks and limbs of red calcareous marls, limestones, and tuffs (Radonova, 1966; Popov et al., 2012). The observed volcanic rocks are presented by agglomerate tuffs, tuffaceous breccias and conglomerates and coherent andesitic lava flows as part of the Pesovets volcanic complex (Popov et al., 2012).

Fig. 1. *A*, alteration zoning around Pesovets silica cap outlined by UAV survey, field mapping and mineral detection study; *B*, XRD mineral detection data; *C*, Raman pattern for kaolinite (462; 922 cm⁻¹) and alunite (488; 1026 cm⁻¹); *D*, SWIR spectra for chlorite and alunite; *E*, XRF data plot for Cu and As. *Abb.*: *Q*, quartz; *Kaol*, kaolinite; *Alu*, alunite; *APS*, alumino-phosphato-sulphate minerals; *Phy*, phyllic; *Prop*, pyritic alterations.

According to previous geological exploration in the area propylitic, phyllic (quartz-sericitic), propylitic (albite-chlorite-epidote), argillic and advance argillic (secondary quartzite) were described (Radonova, 1966; Hikov, 2001, 2005; Velinov et al., 2007). The propylitic rocks have limited distribution affecting mainly volcanoclastic rock types and outlining a halo around the AAA and AA domains (Fig. 1A). Commonly observed minerals in the propylitic halo include albite, chlorite, epidote, and pyrite. The phyllic (quartz-sericitic) rocks are less abundant and form horseshoe-like zone in the western periphery of the AAA, tracing ring fault structures. Hikov (2001) described quartz, sericite, pyrophyllite, zunyite, diaspore, illite, topaz, smectite, jarosite, K-feldspar, rutile, and pyrite found in AA and AAA around Pesovets hill.

The massive and vuggy silica topaz-bearing outcrop on the SW slope of Pesovets volcanic cone

(Fig. 1A). They are white or light gray and composed of quartz, topaz and rutile, with wide development of kaolinite. The alunite-bearing massive silica occupies the highest parts of Pesovets volcanic neck (Fig. 1A). The AAA rocks are white or pale pink with brecciated texture and relict porphyritic. The rocks are composed of quartz and alunite, and minor rutile, pyrite, goethite and hematite. (Fig. 1A–D). The silicified zones are sub-horizontal lense-like and range from a few to several tens of meters in thickness.

Results and discussion

3D UAV supported remote sensing mapping of Pesovets silica cap outlined the AAA and AA domains in addition to fault control ring and radial structures. In combination with mineral detection methods and field mapping (Fig. 1A) we demonstrate a combined quick

distal and proximal approach for area selection, discriminating the mineralized zones and mineral exploration targeting.

Alunite, Na-alunite-1c, APS minerals (svanbergite), dickite, kaolinite, topaz, rutile in addition to albite, analcime, muscovite, phlogopite, montmorillonite, magnetite, pyrolusite, hematite, goethite, and anatase were detected by their spectral signature by means of XRD, Raman and SWIR spectroscopy in the sulphatic AAA and AA zone around Pesovets peak in the pervasively silicified andesitic tuffs and breccias (Fig. 1B–D). The Cu in the Qz-topaz rich zone based on pXRF test varies from 6.48 to 11.82 ppm, while in the AAA part it is increasing from 17.38 to 50.03 ppm in good correlation trend with As (Fig. 1E) which may assist in defining the geochemical signature of different alterations and mineralized zones. Rutile enrichment in the AAA has also been recognized by increasing of Ti concentrations from 295 to 2481 ppm as possible geochemical vector. Although the Co (0.28–6.99 ppm) and V (4.74–50.92 ppm) variations are not high both also have an increasing trend towards AAA.

Natroalunite-2c (Bayliss et al., 2010) has been rarely found in association with kaolinite, while goyazite $\text{SrAl}_3(\text{PO}_4)_2(\text{OH})_5\text{H}_2\text{O}$ was detected for first time by means of XRD. The latter in addition to svanbergite seems to be a possible reason for Sr enrichment in AAA zones indicating also epithermal paleosurface (Sillitoe, 2015), feature described also for Petelovo silica cap (Hikov, 2005). Kaolinite-rich zones could also be detected by the extremely high reflectance patterns displayed on the Sentinel-3 and ASTER images around the Petelovo silica cap.

The mineral spectral signatures obtained by SWIR spectroscopy of the field samples (Fig. 1D) could be used to verify and calibrate further multispectral ASTER, Sentinel-3 and UAV based mineral mapping for more efficient mineral targeting approach.

Our data verify the mineral alteration zoning described in the previous studies (Radonova, 1966; Hikov, 2001; Velinov et al., 2007). Recognizing hydrothermally altered rocks by their spectral signature will help to evaluate and outline spatial distribution of alteration mineral assemblages to overcome exploration challenges in Panagyurishte ore district.

Conclusions

Our preliminary UAV supported remote sensing and field mapping of Pesovets volcanic cone outlined the AAA and AA domains in addition to fault-controlled ring and radial structures in combination with spectral mineral detection methods demonstrate quick approach for mineral exploration area selection.

Mineral alteration mapping of Pesovets silica cap outlined overlapping AAA and AA fault controlled proximal and more distal intermediate argillic (illite-smectite) and propylitic domains (Fig. 1A) as potential high-sulphidation gold mineral exploration target for further evaluation.

Increasing of As (~20–50 ppm) and Ti (~570–2480 ppm) concentrations when approaching AA and AAA alteration domains could also help as trace path finders for targeting of epithermal Cu-Au mineralization.

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