Remote sensing and Unmanned Aerial System (UAS) application for geological exploration

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Introduction

During the recent decades, the unmanned aerial systems (UAS) in addition to the remote sensing in mineral exploration (Sabine,1999) have demonstrated significant potential for application in many areas. One of the significant scientific applications in particular is in the field of photogrammetry as a low-budget alternative to classical aerial orthophotography. Modern unmanned aerial vehicles are equipped with navigation equipment that allows you to follow a certain course of flight (altitude, direction and speed), maintaining two-way communication with the aircraft and sensor control. The integration of a GPS receiver allows correct georeferencing of images acquired from the aircraft's sensors. In case of need for particularly high accuracy (Eugster, Nebiker 2008) of the orthophoto-mosaic positioning it is envisaged to build a network of a sufficient number of ground control points or to use RTK (Real-Time Kinematic) equipment on board the aircraft.

Our studies of Panagyurishte ore district (Fig. 1) are based on satellite images (Sentinel-2, Aster) with several spectral channels in SWIR band (Fig. 2 a,b) in addition to pure spatial resolution and Drone images with high spatial resolution but limited number of spectral bands in VIS -NIR region (Fig. 2 c-g). Data fusion and feature classification at current research is performed manually because of complexity for automation in this approach. Challenge in this approach is need for good qualification in mineralogy and multi-spectral image processing, but relatively lower cost of image collection and good results sound as a good alternative for using multi-spectral technology in mineralogy exploration.

Combining satellite and UAS applications in geological surveys are the ever-expanding possibilities for using specific technical means to acquire spatial information such as multispectral (up to several spectral channels) and hyperspectral (several tens or even hundreds of spectral channels) radiometers and cameras and active scanning devices such as Lidar and Georadar. These capabilities of modern remote-sensing satellite-UAS approach is used in geological exploration in three directions: a) express geological survey for initial target selection and appraisal; b) detailed research through UAS with application of advanced technological solutions, aimed at acquiring specific characteristics such as spectral signatures of mineral alterations as a signatures for Cu and Au deposits; c) field geological activities documentation aimed at purchasing of time-related surveys for mineral exploration.

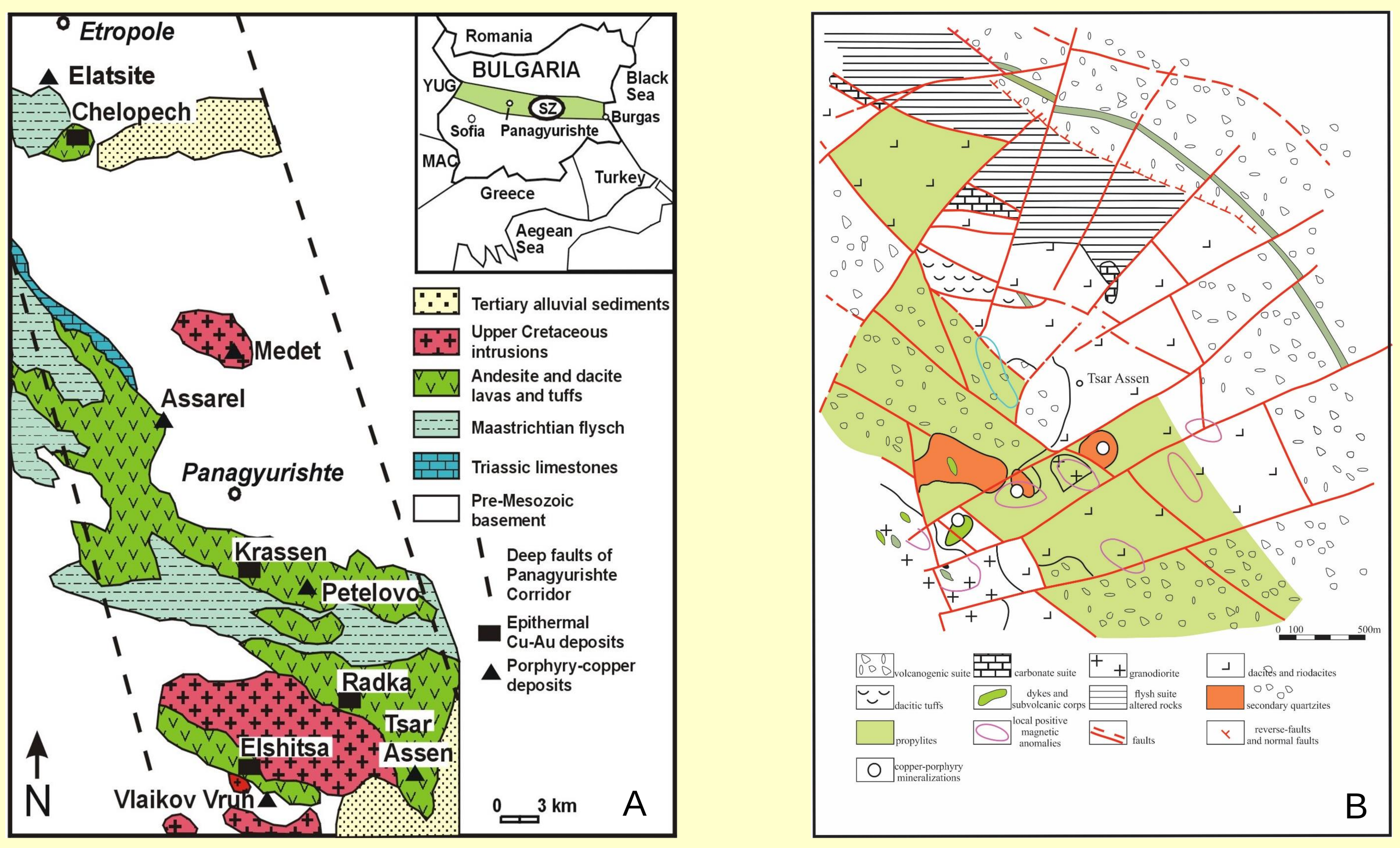

Figure 1. A- Map of the Panagyurishte ore region (after Bogdanov,1987, Bogdanov, Popov,2004); B- Map of Tsar Assen porphyry-copper deposit (Modified after Slavov et al., 1978;Velinov et al.,2007).

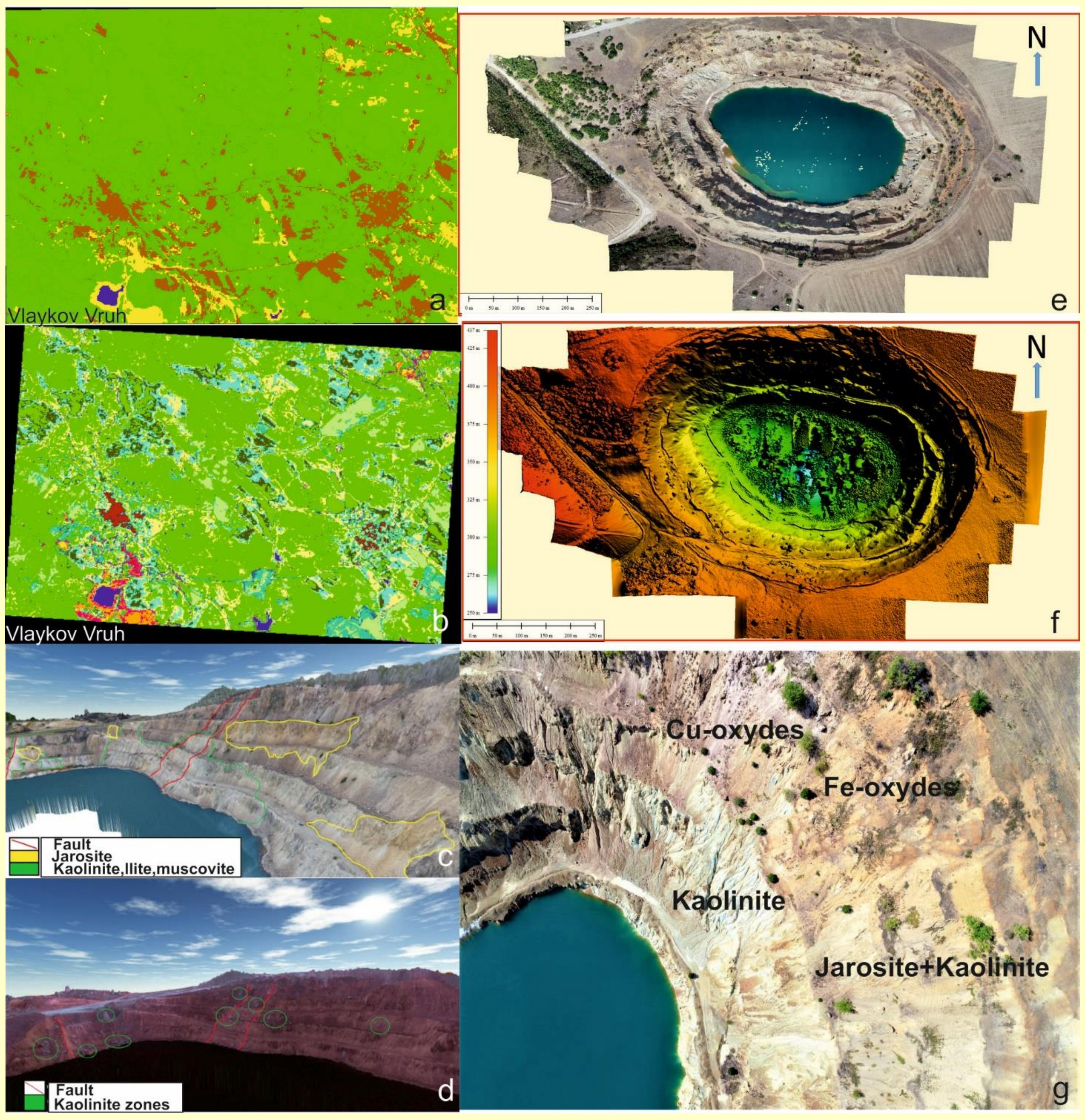

Figure 2: a) Sentinel-2 image with classification of ore mineralisations; b) Aster image with classification of ore mineralisations; c) Drone visual imaging overlayed on 3D generatedmodel with detected mineral zones.; d) Drone IR imaging overlayed on 3D denertated model with ground sample locations; e) VIS spectral image of Tsar Assen porphyry-copper deposit; f) IR spectral image of Tsar Assen porphyry-copper deposit; g) Generated digital surface model with zones of mineralisation.

Results and discussion

Satellite images for Panagyurishte ore district (Fig. 2 a,b) that have been obtained from open sources were processed according to criteria for maximum reliability of classification to distinguish known deposits from surrounding environment. The use of UAS as a tool for generating ortho-photo mosaic and a precise surface model of the imaged area is based on an algorithm developed by a research group from the Polytechnic University of Turin (Lingua et al., 2009). The survey of the territory is carried out by a pre-prepared flight plan with partially (up to 80%) overlapping individual images (Fig. 2), which ensures their reliable integration into the orthophoto-mosaic and the generation of a digital surface model (Fig. 2, c-g). The acquisition of individual images is performed by the UAS in automatic flight mode, as for the capture of relatively small areas (up to 1 km^2, as in this case) are using "rotating wing" aircraft, while for capturing larger areas using "fixed wing" aircraft.

The results of a preliminary geological reconnaissance study by means of an unmanned aerial vehicle "rotating wing" type with the ability to acquire images in two spectral regions: visible (400-700 *nm*) and near infrared (700-900 *nm*) zone. The scanning took place in three separate missions at an altitude of 200 *m* (AGL). This allowed the acquisition of images with a spatial resolution of 0.056 *m* for images from the visible spectral range and 0.087 *m* for images from the near infrared range.

The captured images processing was performed with Agisoft Photoscan software and as a result were generated 6 orthophoto-mosaics (three for each spectral region) and 3 digital surface models (Fig.2,c,d,g).

Another challenging task in our research was to develop such classification criteria to reliably discriminate Cu and Au ore deposits targets from surround environment. In case of images with good spectral resolution (high number of spectral channels 200-300), task is well defined and algorithms for classification give good results.When we use limited number of channels (Sentinel-2: 3 SWIR bands, Aster: 6 SWIR bands) task is very challenging. In case of Sentinel-2 results are visible (Fig. 2a), but there are many false areas. In case of Aster with 6 SWIR bands, results are significantly better (Fig. 2b). Classified areas (Fig. 2b) match very close the shape of Cu porphyry deposits (Bakardjiev, Popov,2015) that is a good initial point for mineral prospecting purposes.

Conclusions

As a result of the initial remote sensing survey potentially target areas for future mineral detection and exploration were identified on satellite multi-spectral images. The challenge is to perform detailed high resolution mapping in RGB and NIR channels to obtain more clear picture of exploration targets location and evaluation. Next level of development is to find the way to map from drone in SWIR even with minimal number of channels. This will significantly enhance picture and give us more trustworthy results.

As a conclusion we could note that even limited number of remote-sensing data could be very useful for the exploration geologists for documenting and discovery of mineral deposits.

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GOLDENEYE

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