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Complex UAS-Geophysical Surveys at the First Stages of Geological Prospecting: Case in the Western Sayan (Russia)

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Summary

One of the most real factors of geological exploration optimization is low-altitude Earth remote sensing that includes geophysical prospecting methods. This article describes a case of the efficient application of complex low-altitude UAV-based aerogeophysical surveying during greenfield prospecting for gold in greenfield localized in the Western Sayan mountains (Russia). 90 sq. km site characterized by extremely complicated landscape and terrain conditions as well as controversial views on its geological conditions. Surveys from a multirotor UAV (unmanned aircraft vehicle) were made with terrain flowing and included a simultaneous magnetic and gamma-ray radiometric surveying as well as gamma-ray spectrometry by the 'static hovering' method and multispectral photogrammetry. The articles sets forth main principles of the method applied as well as demonstrates the advantages of unmanned aircraft technologies vs. traditional geophysical prospecting methods, i.e. high performance and low costs even in those conditions when ground and aerial surveys are economically impractical or entirely impossible. Application of low-altitude UAV-surveys allowed for a large-scale geological and geophysical mapping involving low costs, for clearing up a controversial point of the site geological conditions and for planning further prospecting, while avoiding erroneous solutions prompted by wrong priori assumptions about a geological structure of the site.

Introduction

At present, geological exploration works are mainly carried out on sites with complicated natural and landscape conditions: forestry, swampiness, a highly broken terrain – these factors hinder and increase costs of works by traditional ground and aerial methods. It is the first stage of studying greenfields that is known to be the most risky from the business perspective, when expediency of substantial investments into geological works is not yet substantiated by the actual resource potential of a deposit site, due to which methods that ensure obtaining informative geological data in a prompt and cost-effective way already at this stage become especially sought-after. One of the best solutions in this case are robot aerographic systems based on unmanned aircraft vehicles (UAVs), which allow to increase the amount of details in the geophysical survey if compared to a traditional aerial geophysics, as well as to avoid problems with setting up a ground survey, on the other hand. In deposit prospecting tasks are mainly used surveys with an exact terrain flowing, which are usually conducted on multirotor aircrafts. According to the authors' opinion, such option of airborne geophysics serves, in the first place, as a substitute for ground geophysical works, and, in practice, it often surpasses both ground and traditional aerial surveys in terms of the information content (Parshin et al, 2016, 2018). Despite a rampant development of this area in the recent years, known unmanned aerial systems (UAS) based on multirotor UAVs carry only one type of surveying instruments: it is usually a magnetometer (Cunningham et al, 2018; Malehmir et al. 2017), less often it is a gamma-ray spectrometer (Saleka et al, 2018; Parshin et al, 2018). In the authors' opinion, further development of the area, embracing low-altitude geophysical and other means of a remote sensing of the Earth, centers around complexing several types of surveying instruments on the one UAV, as far as performance and economic efficiency of works in this case can be increased practically many-fold if compared to sequentially made mono-method surveys. Obviously, an efficient complex for a large-scale geophysical mapping should incorporate minimum two most objective and flexible methods – magnetic and gamma-ray surveying, whereas aerial photographic surveying, LIDAR scanning and electromagnetic methods can be their logical additions.

This study considers one of the typical cases for a junior gold mining business, which demonstrates an experience of applying integrated UAS-geophysical surveys for geological prospecting works in highly complicated geological and landscape morphological conditions. Taking that into account, the authors hope that it can appeal to a broad audience of specialists.

Description of the site

Unmanned surveys in the site of about 90 sq. km were carried out in a surveying season 2018 at the first stage of gold prospecting works in mountain regions of the Western Siberia (Russia). A license for the site was obtained in the entrepreneurial risk conditions. Site N (the name and coordinates of the site are not disclosed for commercial sensitivity reasons) is characterized by complicated landscape morphological conditions: shoots of the mountain ridges within the area of works represent heavy rugged river water divides with narrow, often rocky ridges and mountain faces; a relative elevation of water divides over the rivers can exceed a thousand of meters, with river valleys being swamped and impassable for wheeled vehicles (fig. 1). The climate is unfavorable: short and rainy summer, strong winds. At the same time, the site is located close to a federal highway, with this fact ensuring profitable operation or sale of the site, subject to positive results of its geological prospecting. The geological situation is also quite complicated. Difficult working conditions and almost total lack of bed rocks exposure prevented geologists, who have explored the region for the last 60 years, from coming to a consensus as to its geological structure and ore deposition; it becomes evident even based on purely mapping points (Fig. 1, for confidentiality reasons, only a part of the site with an area of about 60 sq. m is demonstrated here and further on). According to the recent studies (Kornev, 2008), formation of the studied area is connected to greenstone belts, and a gold potential of the site is based on its association with the Koyard ore cluster, within which there are three 'gold ore areas' singled out, being perspective for deposits of the gold sulfide ore formation (Fig. 1г). Two of them should be traced also on site N, manifesting themselves in geophysical fields by anomalies of increased magnetic field values and a reduced radioactivity level.

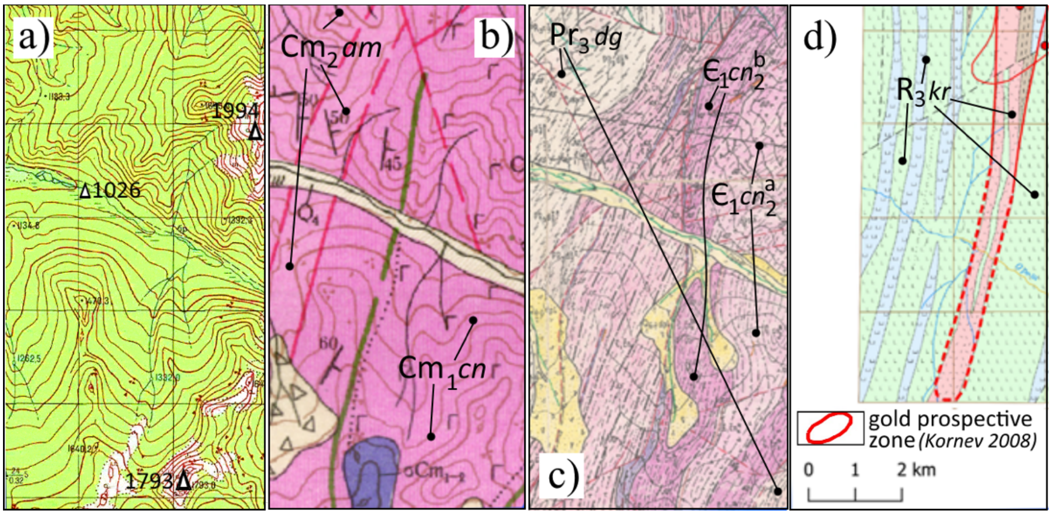

Figure 1 *Fragment of topographical map of the site N with some elevations (a); and illustration of different views on site geology: Krasilnikov 1964 (b), Sarbaa et al, 1972(c) and Kornev, 2008 (c).*

The main task planned to be solved with the help of unmanned low-altitude surveys was mapping these areas at a scale of 1:10000 (profiles for every 100 meters), being sufficiently detailed for using them as the basis of further mining works.

Method and technique of low-altitude geophysical surveys

For surveying to be carried out, there was an unmanned airborne geophysical system SibGIS UAS used (Parshin, 2016-2018), developed by the authors and made as a set of specialized UAVs of multirotor and VTOL-schemes with various sensors and a software for flight mission creation and data processing. An option of the system used on site N contained a carrier of the multicopter type (fig. 2a), which is characterized by high piloting precision and wind resistance, a considerable weight of operation load to be carried, but, at the same time, by a relatively small flight range requiring the filed team to move around the site.

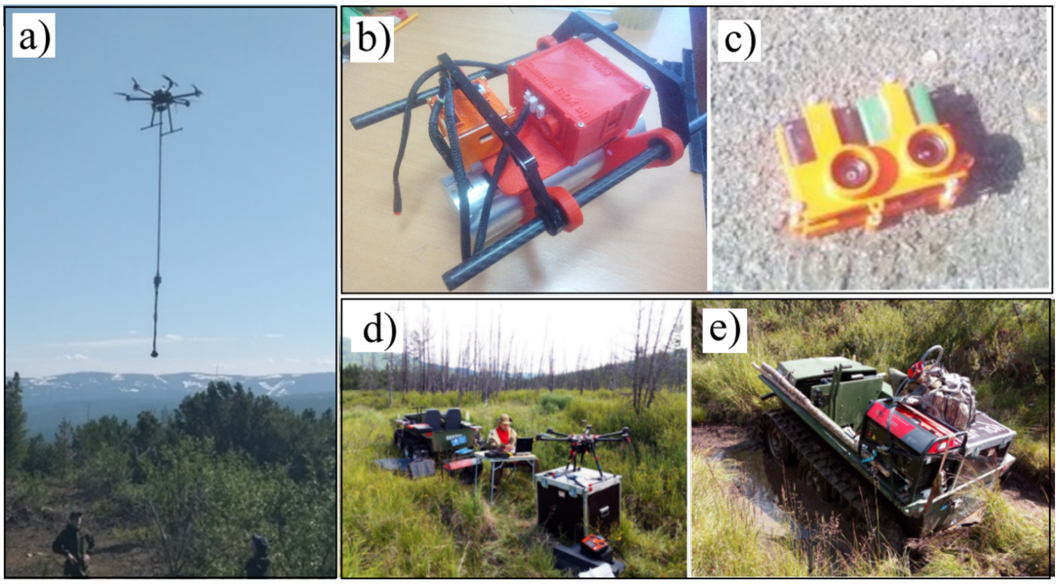

Figure 2 *Unmanned Aerial System SibGIS UAS (Parshin, 2016) in summer 2018: base variant for complex magnetic and gamma-ray surveying (a); gamma-ray spectrometer with CsI crystal 63x63 (b); cameras for multispectral photogrammetry (c); operation in the swampland (d), (e).*

The design of UAVs and geophysical sensors is optimized in such a way that there are no hardware electromagnetic interference for the detectors, whereas an absolute nature of measurements and small to negligible orientation inaccuracies enable to avoid additional surveying stages and software corrections, which was demonstrated in the studies (Parshin et al., 2016-2018). A magnetometric channel of the system – the proton Overhauser magnetometer with the optimum measuring frequency of 2 – 3 Hz is described in previous publications of the authors (Parshin et al., 2016-2018; Sapunov et al., 2017). The radiometer is also specially designed for UAV-surveys, its design is equipped with silicon photomultipliers of low sensitivity to temperature fluctuations and electromagnetic interferences as well as with two scintillator crystals with the dimensions 8x8x100mm made of cesium iodide that is more efficient and stable in different temperature conditions than traditional NaI. The measuring frequency of the radiometer is 0.5 Hz. During gamma-ray spectrometric surveying by the 'static hovering' method a specially designed spectrometer was used, which had an ordinary vacuum photomultiplier tube and CsI(Tl) crystal of 63x63mm with 2000 channels and a relative energy resolution for Cs^{137} within 7% (fig. 2b). At first, simultaneous magnetic survey and gamma-ray radiometry were performed; later, to determine the nature of discovered gamma-ray background anomalies, their spectrometry was carried out by the 'static hovering' method. Multispectral surveying (fig. 2c) was applied to interpret the data of gamma-ray radiometry. The main principles of the integrated magnetic and radiometric surveying methodology are similar to those of the separately performed magnetic survey and detailed in the studies (Parshin et al., 2016-2018). In addition, upon obtaining the gamma field scheme of the site, a spectrometer was installed on the UAV instead of the magnetometer and the radiometer, and the points of specific anomalies were step-wise flied over and hovered over for a period of time being necessary to accumulate a representative spectrum.

Operators with the unmanned system moved around swamped river valleys by a small-size all-terrain truck (Fig. 2d, 2e), which can be towed in an ordinary trailer behind a car. Flights were made from river valleys up to water divides, in such a way a complete diagram of the site area was generated. 80 meter height was considered as the survey height because of high cedars, pines and firs abundant in the area. Surveying of 90 square kilometers was carried out for 14 working days or 26 calendar days, as far as during two of every three days it rained on the site.

Results and discussion

This case is especially interesting, because results of the geophysical works have clearly brought out the invalidity of initial views on the geological structure of the site, namely: a concept of greenstone belts development on its area. It is apparent that diagrams of the fields (Fig. 3A, 3B) do not reflect interbedding of one and the same material complexes trending EW, whereas 'gold ore zones' searched for are reflected neither in magnetic, nor in gamma fields (as far as they are apparently nonexistent). On the other hand, there are works of 1970's (Sarbaa, 1972) that perfectly match the objective geophysical data obtained. Interpretation of the obtained geophysical data from the standpoint of these works enables to single out other potentially gold-bearing sites of the area. So, it becomes evident that a magnetic field of the site is mainly formed by a difference in magnetic properties of rocks from two ophiolitic complexes and one igneous complex of the Riphaean age, whereas a gamma-filed formed by synchronous changes in potassium and uranium channels (fig. 3d), in the first place, maps dislocations with a break in continuity and adjacent areas with metasomatic alterations. The ophiolitic complex with a higher gold-bearing potential is characterized by an increased gamma-ray background (and a reduced magnetic one) and localized in the northwest (in Fig.3) and southeast parts of the site; besides, tectonic contacts and soil softening areas, which are adjacent to intrusions, also belong to perspective sites; all these objects are mapped by the integrated UAV-survey in detail. As far as gamma field variability is not high, the impact of the vegetation cover upon the radiometric data was additionally evaluated. Based on the data of the multispectral survey, there was a biomass vegetation index (NDVI) calculated (Fig. 3c). It turned out that, although the vegetation impact upon the gamma-ray background is significant in some parts of the site (for instance, the western mountainous slope, which is less covered with trees and located in the center of the site, is characterized by a higher gamma-ray background, and the area trending EW, swamped and covered by trees and located along the central stream is seen pretty well), rock factors anyway prevail over it, and the obtained gamma-field diagram adequately reflects specific features in the geological structure of the area.

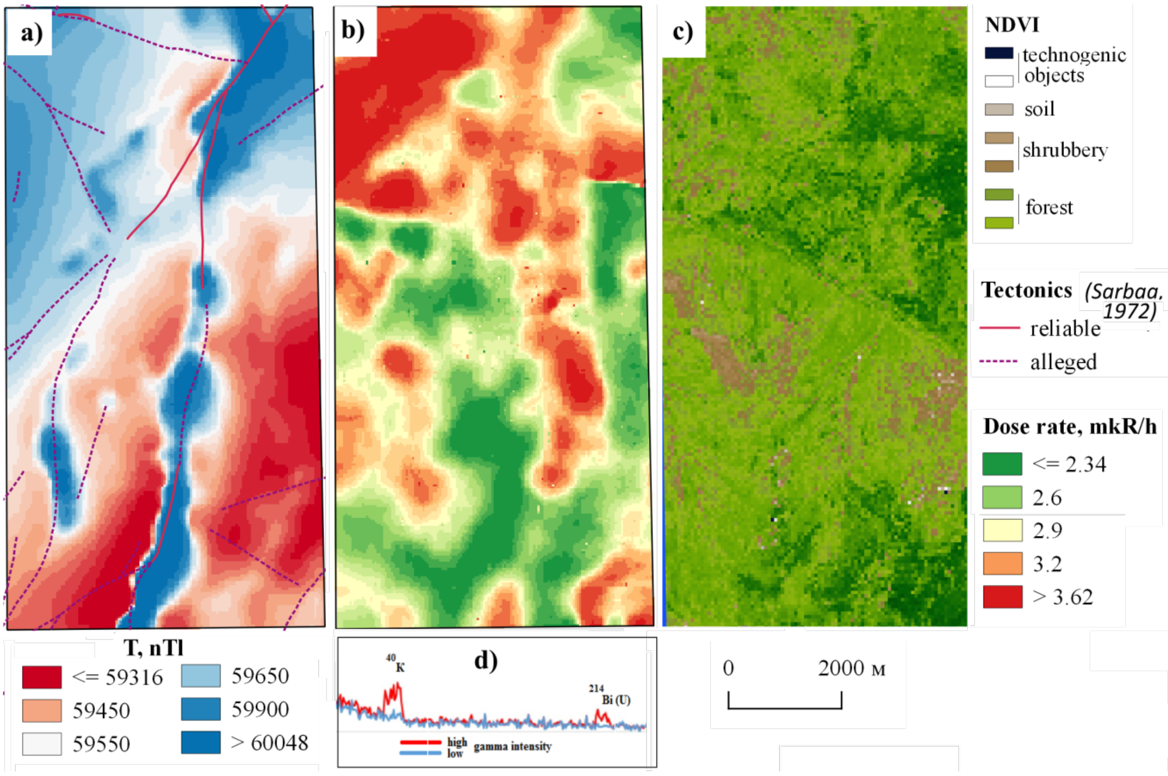

Figure 3 *Fragments of the survey results: magnetic survey (a); gamma-radiometry (b); multispectral photo (NDVI index) (c); nature of gamma-anomalies by hovering spectrometry (d).*

Thus, owing to the application of UAV-surveys at the leading stage of geological prospecting, it became possible to avoid taking wrong decisions as to the course of further, much more expensive works on the site. Costs of 1 square kilometer survey by the above methods amount to $60, excluding mobilization costs, that is incomparable to a potential economic loss on verifying nonexistent 'gold-bearing zones' through exploration works. Thanks to development of unmanned technologies, such sites with rugged topography and unclear resource prospects become quite appealing objects to a junior business, as far as there is now a tool for their prompt and cost-effective study.

Acknowledgements

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