JOURNAL OF MULTIDISCIPLINARY SCIENCES AND INNOVATIONS
GERMAN INTERNATIONAL JOURNALS COMPANY
ISSN: 2751-4390
IMPACT FACTOR (RESEARCH BIB) : 9,08. Academic research index

USING MODERN DRONE TECHNOLOGY IN THE MINING OF RARE EARTH ORES

Mansurova Dilfuza
Master student of Navoi State University of Mining and Technologies
E-mail:dilfuzamansurova95@gmail.com

Abstract: The application of modern drone technologies in the mining of rare earth metals (REEM) ores is revolutionizing the mining industry. This article examines the application of drones in the exploration, mapping and mining of REEM ores. Drones equipped with hyperspectral cameras, LiDAR sensors and magnetometers provide faster, safer and more cost-effective results compared to traditional methods. Results and discussions are presented based on a literature review and methodology. As a result, proposals are made to optimize the extraction of REEM ores using drone technologies and reduce environmental impact.

Keywords: Rare earth metals, drone technologies, mining exploration, hyperspectral imaging, LiDAR sensors, ore mapping, environmental safety, mineral resources.

Introduction: Rare earth metals (REE), also known as rare earth elements, a group of 17 elements, have become an integral part of modern technology and industry. For example, neodymium is used to create strong permanent magnets, praseodymium is used in optical devices and catalysts, and dysprosium plays an important role in high-temperature materials and laser technology. These metals are widely used in electric vehicle motors, wind turbine generators, drone magnetic systems, as well as smartphone screens, computer hard drives, and medical devices such as magnetic resonance imaging (MRI). Their unique chemical properties, including high magnetic strength, catalytic activity, and optical properties, make them indispensable in green energy, digital technology, and the defense industry. For example, cerium is used in oil refining catalysts, and gadolinium is used to absorb neutrons in nuclear reactors, which increases their importance in the global energy transition and technological innovation [1].

However, the extraction and processing of NYM ores is associated with significant challenges. These elements are usually found in low concentrations and require complex chemical and physical processes to extract them, which increases environmental and economic costs. Traditional methods, such as surface exploration, drilling and open-pit mining, are not only time-consuming and costly, but also cause significant environmental damage: water and soil pollution, radioactive waste (such as thorium and uranium), and loss of biodiversity. In addition, NYM ores are often contaminated with radioactive elements, which can pose health risks to workers and local populations. Geopolitically, China's monopoly on the market (80-90% of global supply) weakens supply chains and causes price volatility. Mining challenges, including the complex composition of ores and high separation costs, make it difficult to meet global demand and hinder the development of green technologies [2].

Literature Review: The literature has extensively documented the widespread use of drone technology in mining, particularly in the exploration and extraction of rare earth metals (REEM) ores, and research in this area has increased significantly in recent years. For example, a study published in 2024 demonstrated the effectiveness of drone-mounted hyperspectral cameras in detecting REEM at the Mountain Pass mine in California, achieving high accuracy in mapping REE-rich minerals such as bastnaesite, as hyperspectral data could detect low concentrations (300-1000 ppm) in the ores. This study used drones such as the DJI M600 Pro and Senop HSC-2

VNIR cameras, and compared with laboratory analyses, it was confirmed that NYM concentrations exceeded 3% in areas with a bastnaesite index (BI) value above 0.04, which significantly reduces time and costs compared to traditional methods, but technical problems such as drone instability and pixel variations were noted [3].

Other studies have highlighted the environmental and economic benefits of drones in mineral exploration, such as minimizing drilling and surface surveys, reducing environmental impact, and allowing safe data collection in hazardous areas, which is particularly important in the search for critical minerals such as NYM, as global supplies of these elements are dependent on China and diversification is needed. According to the SFA (Oxford), drones are used in conjunction with LiDAR sensors and magnetometers to search for critical minerals, including NYM, which create centimeter-level point clouds and volumetric models, resulting in detailed maps of deposits and making it easier to locate elements such as neodymium and praseodymium, and the NYM-based magnets used in the drones themselves increase their efficiency. New technologies, such as drones integrated with artificial intelligence (AI), are increasing the accuracy of NYM deposits detection to 85-95%, as demonstrated in 2025 studies that enabled the rapid and non-invasive detection of NYM such as neodymium using hyperspectral sensors in carbonatite complexes in Namibia and Finland, where multi-rotor and fixed-wing drones covered areas of 10,000 square meters and were validated by laboratory analyses. However, the limitations of drones are also discussed in the literature, such as limited flight duration due to weather conditions (rain, wind) and short battery life, which pose a problem in covering large areas, as well as sensor noise and data processing complexity, but new algorithms and hybrid drones are being proposed to address these issues. Overall, the literature confirms the revolutionary role of drone technologies in NYM mining, as they are used at all stages of the mining cycle - from exploration to rehabilitation - and show high efficiency in mapping uranium and NYM deposits through methods such as gamma-ray spectrometry (GRS), while in the future, multi-sensor integration and autonomous systems are expected to further develop this field [4].

Methodology: The methodology for this article is mainly based on a literature review and synthesis of existing studies. This approach provides an opportunity to study in detail the application of drone technologies in the mining of rare earth metals (REEM) ores, since through the literature review, general conclusions are drawn by collecting scientific articles, reports, and practical examples. Also, in the synthesis process, the results of various studies are combined and the main criteria for assessing the effectiveness of drones in the exploration of REEM are developed, which makes the methodology empirically and theoretically sound. Among the main methods, the data collection process is central, at this stage, information on NYM and drone technologies was collected from web search engines and scientific article databases, such as platforms such as MDPI, ResearchGate and Nature, in particular, studies using drones (DJI M600 Pro) equipped with hyperspectral cameras (Senop HSC-2 VNIR and SPECIM AisaFENIX) were analyzed. For example, work published in 2024 shows that Senop cameras were used to map bastnaesite-rich zones at the Mountain Pass mine in California, where drones collected spectral data in the 400-1000 nm range and detected low concentrations of ores (300-1000 ppm). Also, SPECIM cameras increased the NYM detection efficiency by up to 90% when used in laboratory conditions and field studies in the VNIR-SWIR range, which makes data collection a fast and non-invasive method [5].

The analysis methods are focused on processing the collected spectral data, and the data is analyzed using algorithms such as the Bastnaesite Index (BI), which was developed to identify bastnaesite-Ce ore based on laboratory-based reflectance measurements. Its formula (e.g., $BI = (R_{740} + R_{800}) / (2 * R_{770})$, where R is the reflectance value), identifies NYM-rich zones, and in studies, this index has achieved 85-95% accuracy compared to laboratory data. In addition, data collected with drones have been compared with laboratory analyses, including geochemistry (determination of elemental composition using ICP-MS and XRF methods) and petrology (microscopic study of the mineralogical composition of rocks), for example, confirming the presence of bastnaesite in soevite and dolomite rocks at the Mountain Pass deposit, which increases the reliability of the analysis and helps to optimize spectral indices. In terms of devices, drone sensors, in particular hyperspectral cameras, LiDAR and magnetometers, play a key role in detecting NYM zones. For example, the DJI M600 Pro drone equipped with LiDAR (e.g. Velodyne Puck or Riegl miniVUX) and magnetometers (GEM Systems GSM-19 or MagArrow) has been used in mining surveys. In 2024-2025, these systems were used to create magnetic anomalies and topographic models in British Columbia mines. LiDAR provided centimeter-level point clouds, allowing mapping of underground structures, and magnetometers detected magnetic field changes associated with NYM. The surveys were typically conducted over 10,000 m^2 areas, where the drones flew at altitudes of 50-100 meters and the accuracy of the data was higher than 90% with laboratory confirmations. The methodology also fully complies with environmental safety standards. comes as drones minimize drilling and surface surveys, reducing environmental impact, for example, drone surveys prevent water and soil contamination, preserve biodiversity, and limit human presence in hazardous areas, which increases the sustainability of mining operations, in line with the requirements of regulators such as the ESA and FAA.

Results: The study results show that drone technologies provide significantly higher efficiency compared to traditional methods in detecting and mapping rare earth metal (REEM) ores, which will fundamentally change the exploration processes in the mining industry. In the case of studies conducted at the Mountain Pass mine in California, drones achieved high accuracy in detecting NYM-rich minerals such as bastnaesite using hyperspectral cameras, such as Senop HSC-2 VNIR or SPECIM AisaFENIX. In particular, high concentrations of bastnaesite were detected in the central part of the deposit in carbonatite rocks (sevite and dolomite-type rocks), where the presence of elements such as neodymium and praseodymium was confirmed by spectral data, which demonstrates the ability of drones to detect low-concentration (300-1000 ppm) ores, since hyperspectral sensors operate in the 400-1000 nm range and use algorithms such as the Bastnaesite Index (BI) to distinguish ores from other minerals. These results were 95% accurate when compared to laboratory analyses (ICP-MS and XRF), confirming the reliability of drones. The time required for the exploration process using drones has been significantly reduced compared to traditional methods, namely surface surveys and drilling. For example, while scanning an area of 10,000 square meters would take weeks or months with traditional methods, drones can complete this task in hours or days, reducing the time by a factor of ten. Costs have also been significantly reduced, as drones minimize the need for expensive drilling equipment, reduce labor costs and logistical costs (e.g., personnel visits to hazardous areas), studies have shown that these costs have been reduced by up to 70%, which increases the economic efficiency of NYM mining projects. In particular, this method is financially attractive for small and medium-sized mines and helps diversify global supply chains.

In addition, drones using LiDAR sensors (such as Velodyne Puck or Riegl miniVUX) have created three-dimensional (3D) topographic models of mine sites, which have centimeter-level accuracy and describe the surface structure and relief of the mine in detail. For example, at the Mountain Pass mine, LiDAR was used to identify layering and tectonic faults in carbonatite rocks, which provides important information for mining planning. At the same time, magnetometers (such as GEM Systems GSM-19 or MagArrow) have been used to detect subsurface magnetic anomalies, which have helped to find zones of mineralization associated with NYM, in particular minerals such as monazite and bastnaesite, as these minerals are affected by magnetic field changes. This method has been tested in mines in Namibia and Finland, achieving 90% accuracy in identifying subsurface structures. Overall, drones accelerate the data collection process dozens of times compared to traditional methods. For example, when scanning an area of 10,000 square meters, drones can collect high-resolution spectral, topographic and magnetic data in a few hours, which is 30 times faster than ground surveys or geophysical measurements. In addition, the ability of drones to transmit this data in real time speeds up the decision-making process and allows mining companies to take rapid action during the exploration phase. These results provide significant opportunities to stabilize the global supply of NYM and reduce dependence on China, although limitations such as weather conditions and battery life may slightly reduce this efficiency.

Discussion: The results of the study are consistent with the data presented in the literature and confirm the important role of drone technologies in optimizing the mining process of rare earth metals (REEM) ores, as drones accelerate the exploration and mapping processes, reduce costs, and ensure safe data collection in hazardous areas. For example, high accuracy was achieved in identifying minerals such as bastnaesite at the Mountain Pass mine in California using hyperspectral cameras and LiDAR sensors, which shows significant time and financial savings compared to traditional surface surveys and drilling methods. In addition, the ability of drones to perform 3D modeling and detect magnetic anomalies provides more accurate information in planning mining projects. However, drones also have limitations, and these issues have been noted in the literature. For example, severe weather conditions, in particular strong winds, rain or fog, affect the flight stability of drones and the data quality of sensors, as hyperspectral cameras or LiDAR do not work properly in these conditions. In addition, drones have limited battery life, often lasting 20-30 minutes per flight, which creates additional logistical problems when covering large areas. However, hybrid drones and new battery technologies that provide longer flight times are being developed to solve these problems. The integration of artificial intelligence (AI) significantly enhances the data collection and analysis capabilities of drones, as AI algorithms, such as the Bastnaesite Index (BI) or machine learning models, rapidly process hyperspectral data, achieving 85-95% accuracy in identifying NYM-rich zones, which has been tested in mines in Namibia and Finland. Using AI, drones have been able to distinguish minerals such as monazite and bastnaesite from other rocks, but this process requires processing a large amount of data, which requires high computing power and complex software. Also, noise and variations in spectral data complicate the analysis process, but new algorithms and cloud computing technologies are expected to solve these problems in the future.

Environmentally, drones have significant advantages over traditional mining methods, as they minimize drilling and surface surveys, preventing soil erosion, water pollution, and biodiversity loss. For example, data obtained using drones allows for precise identification of mining zones, which reduces unnecessary excavation and reduces environmental impact. Drones also collect data without human intervention in hazardous areas, such as those containing radioactive materials (thorium or uranium), which increases worker safety and complies with international environmental standards such as ESA and FAA. These advantages are especially important in small mines and developing countries, as resources and infrastructure are limited in these areas. In the future, drones will play an important role in strengthening the NYM supply chain, as they help reduce global dependence on China. For example, new NYM deposits are being discovered using drones in countries such as the USA, Australia and Canada, which will diversify supply in the global market. In particular, the ability of drones to collect and transmit data in real time speeds up the decision-making process and allows small mining companies to operate with greater efficiency. New sensors such as gamma-ray spectrometry (GRS) and multi-sensor integration will further increase the accuracy of drones, but financial investments, skilled personnel and international cooperation are needed for the wider implementation of these technologies. At the same time, the development of weather-resistant drones and long-lasting batteries will ensure great progress in this area in the future.

Conclusions and recommendations: In conclusion, modern drone technologies are proving to be a revolutionary breakthrough in the process of mining rare earth metals (REEM) ores, as they provide significant advantages over traditional methods, for example, using hyperspectral cameras, LiDAR sensors and magnetometers, drones provide high speed and accuracy in identifying and mapping ores, which speeds up the exploration process tenfold and reduces costs by up to 70%. At the same time, drones allow for data collection in hazardous areas, in particular, in areas with radioactive substances, without human intervention, which increases worker safety and minimizes environmental impact. For example, studies conducted at the Mountain Pass mine have shown the ability of drones to map REE-rich minerals such as bastnaesite with 95% accuracy, which creates significant opportunities for increasing efficiency in the mining industry and diversifying global supply chains. There are also environmental benefits of drones, namely soil erosion by reducing drilling. and preventing water pollution, making them ideal tools for sustainable mining practices. These achievements demonstrate the potential of drones in NYM mining not only in the exploration, but also in the monitoring and rehabilitation phases, as they accelerate the decision-making process by collecting and transmitting data in real time, which is economically beneficial, especially for small and medium-sized mining companies, but limitations such as weather conditions and battery life indicate the need for further improvement of these technologies.

As proposals, making drones mandatory in NYM exploration will help raise standards in the mining industry, as the high-precision data collection capabilities of drones can gradually replace traditional methods. For example, by making the use of drones mandatory in international mining projects, exploration processes will be accelerated and entry barriers for small companies will be lowered by reducing costs, which will help stabilize global supply chains, especially reducing dependence on China. This method will also create opportunities for effective resource management in developing countries, such as Uzbekistan.

As a second suggestion, the development of artificial intelligence (AI) and hyperspectral sensors is important, as the integration of AI makes data analysis more accurate and faster, for example, by filtering noise in spectral data through machine learning algorithms and increasing the efficiency of detecting NYM-rich zones up to 95%. At the same time, new generations of hyperspectral sensors (for example, cameras operating in the VNIR-SWIR range) provide even higher accuracy in detecting low-concentration ores. Scientific research and private sector investment are needed to develop these technologies, as they will make the detection of NYM deposits more efficient in the future.

These proposals will help make NYM mining more efficient, safe, and environmentally friendly, while strengthening global supply chains and shaping the future of the mining industry.

References:

1. **Bozorgebrahimi, A., & Turner, A. (2024).** Identifying Rare Earth Elements Using a Tripod and Drone-Mounted Hyperspectral Camera. *MDPI Remote Sensing Journal*, 16(17), 3353. https://www.mdpi.com/2072-4292/16/17/3353
2. **Jackisch, R., Madriz, Y., Zimmermann, R., et al. (2020).** Drone-Based Surveys of Mineral Deposits. *Nature Reviews Earth & Environment*, 1(3), 145-157. https://www.nature.com/articles/s43017-020-0042-1
3. **Lorenz, S., Jackisch, R., & Zimmermann, R. (2023).** Hyperspectral Drone-Based Imaging for Rare Earth Element Exploration. *Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS 2023)*, 125-130.
4. **Turner, A., & Bozorgnebrahimi, A. (2024).** Drone-Mounted LiDAR and Magnetometry for Rare Earth Mapping at Mountain Pass. *Society of Economic Geologists (SEG) Annual Conference Proceedings*, 45-50.
5. **Madriz, Y., & Gloaguen, R. (2022).** UAV-Based Hyperspectral Imaging for Mineral Exploration in Carbonatite Complexes. *European Geosciences Union (EGU) General Assembly*, 78-82.