Satellite Exploration of Earth Resources Using Nuclear Magnetic Resonance Phenomenon: Application for Estonia

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Now, humanity stands in front of serious challenges due to political, economic, energy and climate problems. To solve the described challenges, innovative, more effective, economically feasible, faster, and environmentally friendly technologies are needed to explore underground to produce metals, rare elements, critical raw materials, water and geothermal energy. Among new exploration targets are geological resources for underground storage of energy (hydrogen storage or compressed air energy storage (CAES), CO_2 storage, or radioactive waste storage.

The innovative technology of Satellite Exploration of Earth Resources Using the Nuclear Magnetic Resonance (NMR) Phenomenon – "SKYGEOEXPLORENOVA-NMR" (SGEN-NMR) – is proposed to be applied in Estonia. The main idea of the innovative method lies in the point-by-point sounding of an area with frequency spectra that excite resonance in the target substance. Sounding radio-frequency radiation should be highly directional to concentrate the transmitter's power in the right direction. Point-by-point resonance location sounding allows to search for deposits, obtain their underground contours, and geological sections and select optimal drilling points. Based on these data geological resources of the deposit could be estimated. The magnetic field of the Earth is used as the source of a constant magnetic field to create NMR conditions in the molecules of a target substance at depths of up to 5 km (Ivashchenko et al. 2016, Patent 2011, 2013).

For the first time an updated routine for the exploration process is presented here (Fig. 1). The preparatory work phase-1 consists of four sub-phases: a collection of space images, mineralogical samples, laboratory production of test gel plates and recording or transfer of the electromagnetic spectrum of the required substances to test plates. The following sub-phases of the preparatory phase-1 are explained in the more detailed workflow:

1.1. Satellite images of the studied area are ordered from NASA and collected in the high-resolution analogue form made in the infrared spectrum (200–400 THz, Fig.1).

1.2. All minerals and elements in the periodic table have their own distinct passive heating radiation. The differences in wavelengths and radiation intensities are used to study the properties of a remote object. To improve the accuracy of measurements the rock sample could be collected from the explored reservoir.

1.3. The spectrum of resonance absorption signal of each of the target minerals could be recorded on special test plates. In this phase, special test plates are produced in the laboratory implementing a patented technology (Patent 2011, 2013).

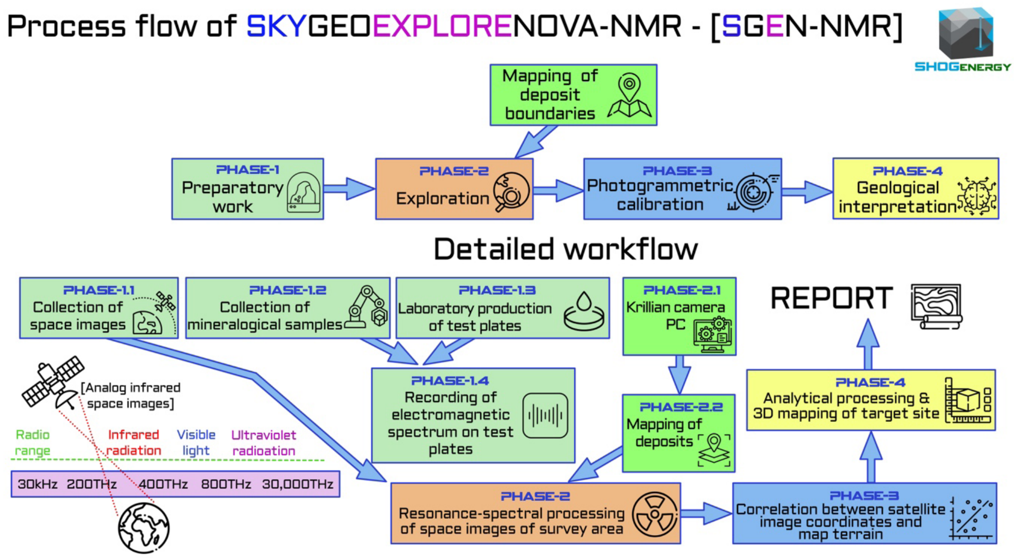

Figure 1. Four main phases and detailed workflow of SGEN-NMR technology and frequency range used for analogue space images.

1.4. The Earth's magnetic field is used as the source of a constant magnetic field to create NMR conditions in the molecules of target fluids and minerals at depths of up to 5 km. The spectrum of resonance absorption signal of each of the target materials (water, metals, rare elements, critical raw materials) with the chemical composition of the collected reference sample or maximum temperature detection is pre-recorded on the test plates using vacuum sputtering of helium and reference minerals.

It is applied as a resonator in the radiation-chemical processing of analogue satellite images of the target area in the infrared band and used as a base layer for comparison of the data received from NASA analogue images and target materials filter.

2. Exploration. The exploration phase consists of two sub-phases integrated into the main resonance-spectral processing of space images of the survey area (NMR) process: (2.1) Kirlian camera and (2.2) Mapping of the deposit.

2.1. To reprint the space image data to the plates a special software (Kirlian camera) for visualization of deposit boundaries in a high-voltage pulse field and sub-phase resonance-spectral processing of space images of the survey area (NMR) - "sandwich container processing" is applied. During this phase, a unique special X-ray film will be made in coordinates of the space image to transfer deposits to the map (transformation-visualisation).

2.2. In this step we receive a clear image of the deposits in the limits of the ordered coordinates using resonance-spectral processing of space images of the survey area (NMR) in the presence of the test plates. A deposit survey is carried out with the help of the method of point-wise measurements along the deposit's contour as well as along its sections. The routine is irradiation of the "Sandwich" by α, β & γ rays in the laboratory. The "Sandwich" consists of a plate with data from an analogue image, a test plate with all searched elements and an X-ray plate. Chemical composition is decoded into a spectrum. X-ray film is done in coordinates of the image to transfer deposits to the map for transformation-visualisation (Phase 2.1–2.2). At the point of coincidences of the signal spectrum from the test plate and space image, we see deposits on the X-ray plate. During irradiation of the "sandwich container", the NMR phenomenon is conducted. After that, the result is transferred to the map.

3. Photogrammetric calibration. This phase is a correlation between the coordinates of the satellite image and the terrain. In this step, the previous sandwich container data is going to be represented over the topographic map. The procedure for measuring deposit depth using analogue satellite images, obtained at different location angles from satellites.

4. Geological interpretation. In the final stage, the analytical data processing, 3D mapping, analysis, conclusion and recommendations are prepared. The obtained results help to explore the deposit remotely, without drilling exploration wells: the surface contours of the deposit or geothermal reservoir, depths and horizons of the reservoir including the volume of water, pressure, geological sections, points for optimal drilling, rock porosity, geothermal map and gradient of the studied area.

The main benefits of the presented method compared to traditional geophysical methods are (1) accuracy (up to 95%), (2) time of exploration (2–3 months), (3) avoiding of permits from public authorities and public acceptance issues, (4) lower price and (5) environmentally friendly technology.

SGEN-NMR is recommended for exploration of the Estonian underground for (1) updating of regional geothermal maps; (2) exploration of metals, rare elements and critical raw materials and updating of existing data; (3) mapping of storage sites for CO_2, hydrogen, and compressed air energy storage (CAES); (4) mapping and risk management of possible nuclear waste storage sites, (5) construction of geological atlases of Estonia: Geothermal, Mineral, Geological Storage, and (6) monitoring of storage sites.

References

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