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# Verification of the radiometric map of the Czech Republic

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ABSTRACT

The radiometric map of the Czech Republic is based on uniform regional airborne radiometric total count measurements (1957–1959) which covered 100% of the country. The airborne radiometric instrument was calibrated to a $^{226}$Ra point source. The calibration facility for field gamma-ray spectrometers, established in the Czech Republic in 1975, significantly contributed to the subsequent radiometric data standardization. In the 1990's, the original analogue airborne radiometric data were digitized and using the method of back-calibration (IAEA, 2003) converted to dose rate. The map of terrestrial gamma radiation expressed in dose rate (nGy/h) was published on the scale 1:500,000 in 1995. Terrestrial radiation in the Czech Republic, formed by magmatic, sedimentary and metamorphic rocks of Proterozoic to Quaternary age, ranges mostly from 6 to 245 nGy/h, with a mean of 65.6 ± 19.0 nGy/h. The elevated terrestrial radiation in the Czech Republic, in comparison to the global dose rate average of 54 nGy/h, reflects an enhanced content of natural radioactive elements in the rocks.

The 1995 published radiometric map of the Czech Republic was successively studied and verified by additional ground gamma-ray spectrometric measurements and by comparison to radiometric maps of Germany, Poland and Slovakia in border zones. A ground dose rate intercomparison measurement under participation of foreign and domestic professional institutions revealed mutual dose rate deviations about 20 nGy/h and more due to differing technical parameters of applied radiometric instruments. Studies and verification of the radiometric map of the Czech Republic illustrate the magnitude of current deviations in dose rate data. This gained experience can assist in harmonization of dose rate data on the European scale.

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## 1. Introduction

Geophysical radiometric maps describe the level of radiation and the distribution of natural and man-made radionuclides in the environment. Terrestrial radiation, a significant component of environmental radiation sources, is generated by natural radionuclides in rocks and superficial deposits and reflects the Earth's surface geological setting. Primordial radionuclides potassium, uranium, and thorium are fundamental sources of radioactivity in rocks. Their decay is accompanied by alpha, beta and gamma radiation. Radioactivity of the environment is predominantly determined by the detection of gamma-rays and expressed in gamma dose rate (nGy/h) or by the contents of individual radionuclides. Geophysical radiometric maps are applicable to basic geological studies, exploration for radioactive raw materials and other minerals, delimitation of radon risk regions, mapping of nuclear fallout and assessment of the radiation level of the environment. Geogenic radiation is a subject of interest for the exploitation of Earth's thermal sources.

The Czech Republic (78,863 km$^2$, delimitated by geographical coordinates 12°06′ - 18° 52′ E, and 48°33′- 51°03′ N) consists of two regional geological units. The Bohemian Massif, which belongs to the European Variscan belt, forms the major part of the Czech Republic. It is formed by Proterozoic and pre-Variscan Palaeozoic crystalline basement and younger platform cover. The Bohemian Massif contains magmatic, sedimentary and metamorphic rocks. The second regional geological unit is the Western Carpathians, located in the eastern part of the Czech Republic. They are formed by Mesozoic to Tertiary flysh and basin sediments. A schematic geological map shows the regional lithological units in the Czech Republic (Fig. 1). Publications Cháb et al. (2007) and Cháb et al. (2010) introduce a detailed description of the geology of the Czech Republic.

The aim of the work is to summarize the radiometric measurements in the Czech Republic, describe the compilation of the

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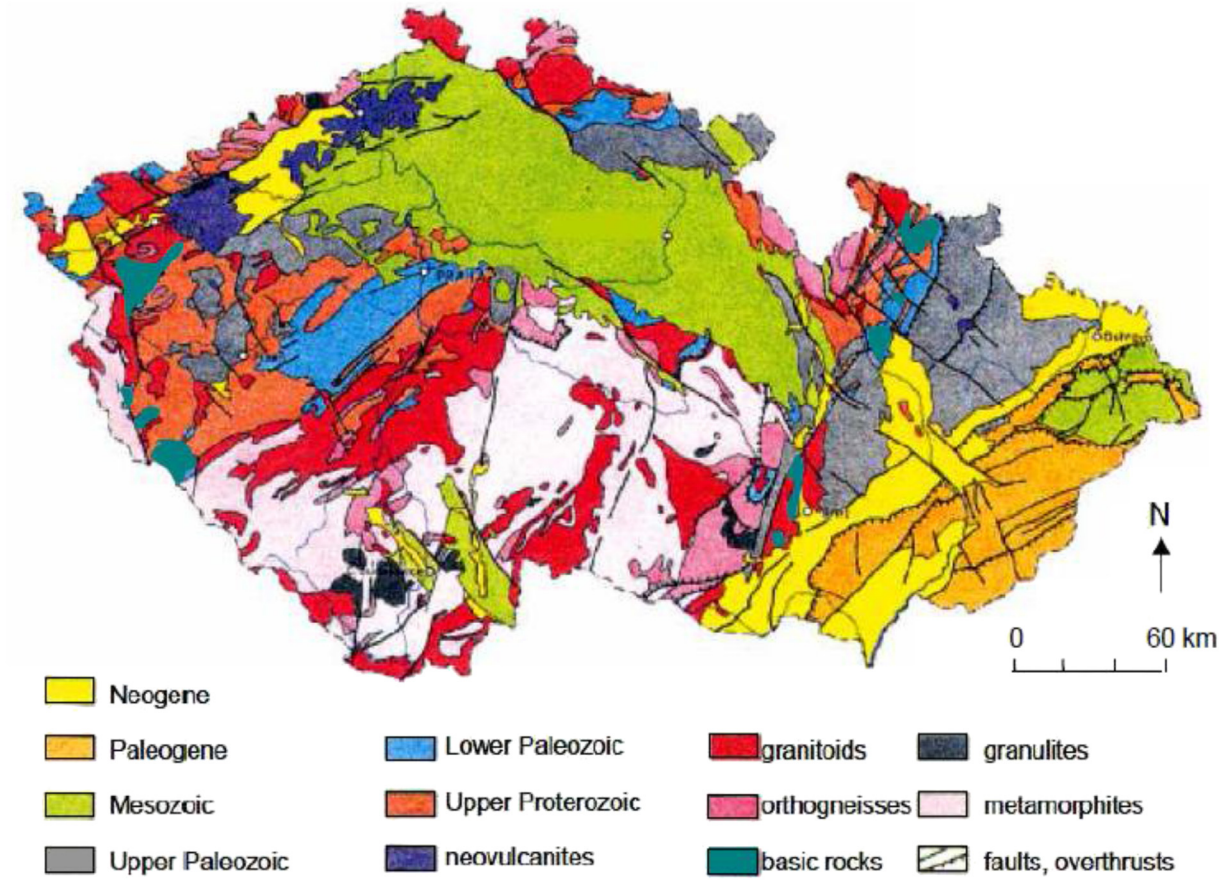


**Fig. 1.** Schematic geological map of the Czech Republic. (After Czech Geological Survey, Praha, www.geology.cz, adapted).

radiometric map of the Czech Republic 1:500,000, demonstrate the level and range of terrestrial radiation in the Czech Republic, and define deviations in dose rate data revealed in the multilateral verification of the radiometric map.

## 2. Geophysical radiometric measurements and calibration of instruments

Radioactivity of the rocks in the Czech Republic has been intensively studied since 1945. Modern techniques of geophysical radiometric surveying and of data processing have the sensitivity for determining contents of single radioactive elements and to distinguish the dose rates of lithological units.

### *2.1. Regional and detailed airborne and ground radiometric measurements of the Czech Republic*

In 1957–1959, a systematic regional airborne radiometric total count measurement was done with a Russian airborne instrument ASGM-25 equipped with 72 Geiger-Mueller tubes VS-9, installed in an AN-2 two-wing airplane. Flight profiles were separated by 2000 m, flight altitude was 100 m and flight speed was 150 km/h. Potential errors in location of radiometric data were on an average up to ± 100 m. The airborne radiometric equipment was calibrated to a $^{226}$Ra point source. Exposure rate of rocks at the level of Earth's surface was expressed in μR/h. The mapping was scaled to 1:200,000. Simultaneous geophysical radiometric and magnetic airborne measurements covered 100% of the Czech Republic. Regional airborne radiometric measurement (1957–1959) was used for evaluation and systematic description of radioactivity of rocks in the Czech Republic (Matolín, 1970, 1976), and later for a new compilation of the radiometric map of the Czech Republic 1:500,000 (Manová and Matolín, 1995).

Then in 1960–1971, a more detailed airborne mapping was carried out covering most of the Czech Republic with an ASGM-25 airborne station installed in a fixed-wing aircraft AN-2 or with an ARS-2 airborne scintillation rate meter placed on a helicopter. The scale was 1:25,000 based on a flight profile separation of 250 m and flight altitude at 80 m. The instruments were calibrated to a $^{226}$Ra point source and the processed airborne data were expressed in exposure rate (μR/h) at ground level. Further detailed mapping at the same scale and flight altitude was performed from 1976 by the state enterprise Geofyzika using a Canadian airborne gamma-ray spectrometer DiGRS 3001 with a scintillation detector NaI(Tl) of 14,800 cm$^3$ volume. In 1988, the airborne gamma-ray spectrometer was changed for a GR-800D with scintillation detector NaI(Tl) of 33,600 cm$^3$ volume. Both instruments have automatic gamma-ray energy spectrum stabilization. Results of airborne gamma-ray spectrometry measurements were reported in contour maps of % K, ppm eU and ppm eTh concentrations, and maps of gamma total count (TC). By 2015, approximately 60% of the Czech Republic was covered by airborne gamma-ray spectrometry. The airborne gamma-ray spectrometer was calibrated using calibration pads and three natural calibration strips established over granulites, a two-mica granite and a syenite, which differ by their K, U and Th concentrations.

A car-borne gamma survey was carried out by the Czechoslovak Uranium Industry (CSUP) in the Bohemian Massif regions in the fifties and sixties using a Russian analogue rate meter RA-69 equipped with 72 Geiger-Mueller tubes VS-9. The instrument was

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