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RADON EMANATION AS A SOURCE OF RADIATION HAZARD TO THE ENVIRONMENT: THE CASE OF THE UKRAINIAN SHIELD

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Abstract: The article examines uranium ore manifestations, mining and associated radon emanation potential from the point of view of radiation hazard to the environment in the region of the Ukrainian Shield and its slopes, namely within the Central Ukrainian Uranium Province. The maximum amount of radon is established in the geodynamically active zones in overlapping rocks associated with new tectonic anomalies in parent rocks. Most hazardous are areas where new tectonic activation zones and uranium ore manifestations occur relatively close to the surface. The approach towards 'radon-prone areas' in accordance with the European Basic Safety Standards is emphasized.

Keywords: uranium ore deposits, uranium ore manifestations, radon emanation, Ukrainian Shield, Central Ukrainian Uranium Province.

Introduction

European Basic Safety Standards (EU, 2013), Article 103 § 3 states: "Member States shall identify areas where the radon concentration (as annual average) in a significant number of buildings is expected to exceed the relevant national reference level" (cf. "radon-prone areas," "high radon area," "radon affected area"). In many European countries, included into the project of "European Atlas of Natural Radiation Sources," indoor radiation measurements are made according to the general network and utilizing a unified technique. Ukraine is not member of the European Union yet, but pursuing such membership, the study follows the European standards.

Natural ionizing radiation sources are considered as the largest contributors to the collective effective dose received by the world population. In this respect the concept of geogenic radon potential (GRP) was developed by the Joint Research Center (JRC)

experts.[1] The set of potential sources was considered: U/Ra content in soil and bedrock; radon concentration in soil; soil permeability; (standardized) indoor radon concentration; terrestrial dose rate; geology; rock fracturing, presence of fault lines, tectonic features; aquifers characterization; special natural features such as karstification, caves; special anthropogenic features such as mines, degree of urbanization, landscaping.

Ukraine is known as a uranium-mining country with Europe's largest resources. Unfortunately, in the nearest future the country is supposed to stay heavily dependent on nuclear energy. In this respect, the capacity of uranium production might be considered through improving the existing production potential. “In Ukraine, ambitious plans are in place to start supplying electricity to the European Union by 2019 via its planned ‘energy bridge’, was mentioned in the World Nuclear Performance Report 2017 produced by the World Nuclear Association.[2]

Taking into account a long experience in uranium geology and accumulated archival materials on the Ukrainian Shield metallogeny, the authors of this publication put as the presented research goal to generalize and process available data on radon emanations associated with uranium geology, as a source of potential threat to the environment within the Central Ukrainian Uranium Province (CUUP) located in the central part of the Shield.

Background (Geology, Faults, Rock Fracturing, Tectonic Features)

The CUUP is situated within the Central axial uplift of the Korsun’-Novoukrainskii anticlinorium. The region is elongated in the latitudinal direction with a general meridional orientation of granite-gneissic plicated structures and uranium ore fields. It is bounded on the north by the Subbotsko-Koshorinskii latitudinal fault and on the east and west by the Kirovogradskaya and Zvenigorodsko-Annovskaya tectono-metasomatic zones; at the south it has no distinct structural boundary. As found by complex seismic studies, this uranium-ore region is disposed in a latitudinal-strike earth crust block with a distinct northern boundary along the Subbotinsko-Moshorinskii fault, characterized by a relatively greater thickness of the earth crust (45 km) and the greatest depth (20 km) of occurrence of palingenetic granitoids. So, rock fracturing, presence of fault lines, tectonic features are available to make radon emanations highly potential.

The uranium commercial deposits are represented with endogenous deposits in albitites of the Kirovogradskyi geoblock of the Ukrainian Shield (Figure 1).

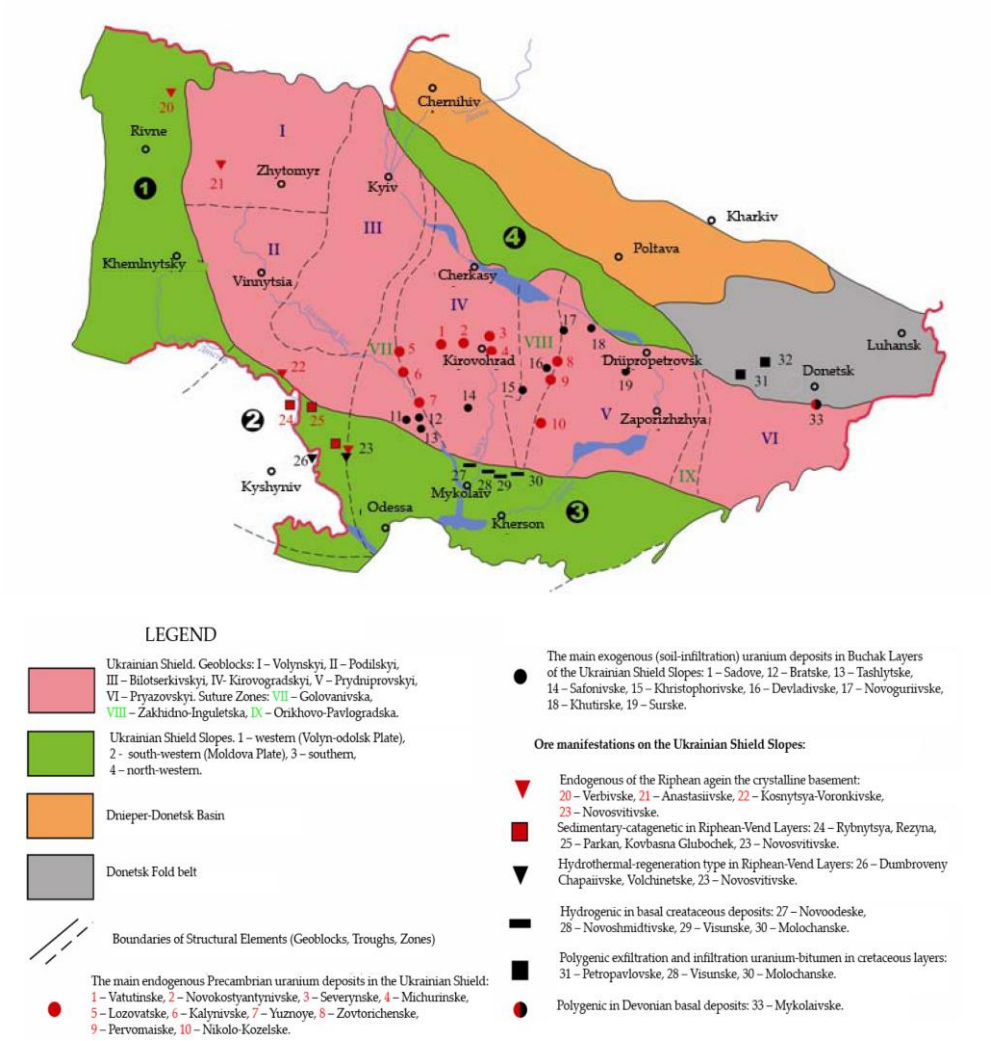

Figure 1: Localization of the major uranium deposits and manifestations on the territory of the Ukrainian Shield and its slopes (according to E.G. Sushchuk [3]).

Ukrainian uranium resources were estimated at 221 000 tU according to the IAEA 'Red Book' 2016, 59 000 tU of these recoverable at under $80/kgU. Reasonably assured resources are 139 400 tU, nearly all in metasomatite deposits in the Kirovogradskyi block of the Ukrainian Shield.[2] According to total resources and proven reserves Ukraine is among the top ten countries in the world and is considered a key producer in Europe.

The origin of uranium mineralization is associated with sodium metasomatism superimposed on granite-gneiss basement within an area of tectono-magmatic protoactivization occurred at the end of the Ukrainian Shield orogenesis. It is supposed that post ultra-metamorphic solutions penetrated along long-lived fault zones and led to sodium metasomatism and ore formation in albitites. Uranium was transferred in hydrothermal solutions in the form of uranyl-sodium-carbonate or uranylpotassium-carbonate ions (complexes). Diaphthorites (syenite-like desilicated rocks) were formed as a product of incomplete sodium metasomatism and are mainly contaminated with uranium and do not contain commercial ore mineralization. Structural control of mineralization is obvious for each deposit and connected with correspondent faults in the tectonic and metasomatic zones.

There are a quite number of prospected endogenous deposits with total reserves capable to provide needs of operating nuclear power plants for the period of about a hundred years according to different estimations.

Radon emanation sources within the CUUP (Mining, Urbanization, Landscaping)

During the last decades many Ukrainian experts from different academician institutions were involved into the radon sources studies in different regions of diverse geogenic radon potential (GRP) level. Researches were made on radon concentration in soil and in bedrock, indoor and outdoor radon measurements; special anthropogenic features such as mining and landscaping were also considered. But data generalization and radon mapping at national level have not been made. It is still yet to be done.

Uranium deposits located within the CUUP are characterized by a low content of uranium. Nevertheless developed infrastructure of their mining and uranium concentrate production along with big sizes of uranium deposits, high thickness of uranium-containing rocks, relatively low water content in mining tunnels, relatively simple measure of radiation protection (because of low content of uranium in ores) – all these facts provide competitive capacity for the uranium concentrate on the market.[4]

If to consider the GRP for the territory of the CUUP – then this potential is of high threat here. The environmental impacts of uranium mining and milling activities are severe. These impacts range from the creation of massive stockpiles of radioactive and toxic waste rocks and sand-like tailings to serious contamination of surface and underground waters with radioactive and toxic pollutants, and releases of conventional, toxic and radioactive air pollutants.[5]

Underground uranium mining highly contributes to exit to the surface of huge reserves of radon that was accumulated for millions of years at a depth. Additional cracks appeared in the rock massifs from explosions and from the movement of underground

transport, serve as easy pathways for radon emanations coming uplift to the surface. Released cavities are filled in with new gas, which is continuously formed in the decay of radioactive elements.

Under supervision of Dr. Verkhovtsev, the map of neotectonics for the territory of the Ukrainian Shield and its slopes was developed at the Institute of Environmental Geochemistry NAS of Ukraine.[6] The fragment of this map is presented at Figure 2 where numerous uranium deposits and manifestations are depicted with black dots and where their correlation with fractured zones and ring structures is obviously observed.

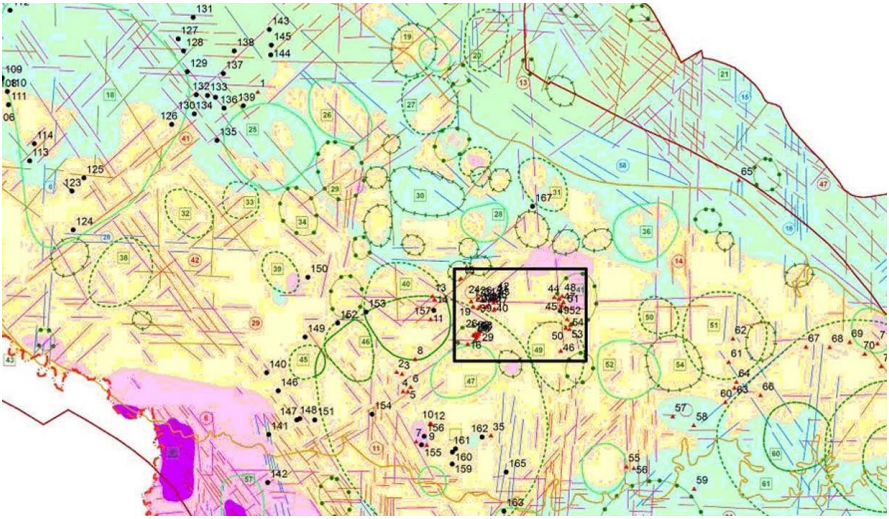

Figure 2: Fragment from the map of neotectonics of the Ukrainian Shield central part in comparison with uranium deposits and manifestations location (according to V.G. Verkhovtsev [6])

The most radon hazardous areas are zones where intensively fractured rocks located relatively close to the surface. The maximum amount of radon was established in the geodynamically active zones of the sedimentary cover associated with fractured sites in parent rocks.

A clear correlation between the detected local sites of high radon emanation level (manifested in the form of local radiohydrogeochemical halos formed by radon and the uranium-238 decay products) and newest tectonic activation zones (lineament domains, faults zones and nodes of their intersection) was recently confirmed by our research within the Kremenchukske uranium deposits and close located to it the Belanovske iron ore deposit.[7]

Conclusion

Research on the Ukrainian Shield neotectonic activation proved clear correlation between areas of high radon content and fractured zones and ring structures of different level. The maximum amount of radon was established in the geodynamically active zones of the sedimentary cover associated with fractured sites in parent rocks.

Research on radon emanation as a source of potential hazard to the environment and the population health has to be considered at national level. Generation a map with delineation of radon priority areas (according to the European Basic Safety Standards "radon-prone areas," "high radon area," "radon affected area") and series of larger scale maps for uranium mining and tailing areas, for the cities areas etc. has to be planned and considered for further research and coordinated at national level.

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