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ON RADON ACTIVITY OF TECTONIC FAULTS IN THE AREA OF SITING THE SINOP NPP IN THE REPUBLIC OF TŰRKIYE

SEDIN V.L.[1], *Dr. Sc. (Tech.), Prof.,*
ULYANOV V.Yu.[2], *Ass.,*
ZAHILSKYI V.A.[3], *Ph. D., Assoc. Prof.,*
KOVBA V.V.[4*], *Ph. D., Assoc. Prof.,*
HORLACH S.M.[5], *Ph. D., Assoc. Prof.,*
BILYK V.V.[6], *Postgrad. Stud., Research Fellow*

[1.] Department of Engineering Geology and Geotechnics, Prydniprovska State Academy of Civil Engineering and Architecture, 24-a, Architect Oleh Petrov St., Dnipro, 49005, Ukraine, e-mail: sedin.volodymyr@pdaba.edu.ua, ORCID ID: 0000-0003-2293-7243
[2.] Department of Engineering Geology and Geotechnics, Prydniprovska State Academy of Civil Engineering and Architecture, 24-a, Architect Oleh Petrov St., Dnipro, 49005, Ukraine, e-mail: uluanovvu@gmail.com, ORCID ID: 0000-0002-9028-3408
[3.] Department of Engineering Geology and Geotechnics, Prydniprovska State Academy of Civil Engineering and Architecture, 24-a, Architect Oleh Petrov St., Dnipro, 49005, Ukraine, e-mail: zahilskyi.vitalii@pdaba.edu.ua, ORCID ID: 0000-0002-5140-8140
[4*.] Department of Engineering Geology and Geotechnics, Prydniprovska State Academy of Civil Engineering and Architecture, 24-a, Architect Oleh Petrov St., Dnipro, 49005, Ukraine, tel. +38 (096) 588-46-71, e-mail: kovba.vladyslav@pdaba.edu.ua, ORCID ID: 0000-0001-7888-4393
[5.] Department of Engineering Geology and Geotechnics, Prydniprovska State Academy of Civil Engineering and Architecture, 24-a, Architect Oleh Petrov St., Dnipro, 49005, Ukraine, e-mail: horlach.serhii@pdaba.edu.ua, ORCID ID: 0000-0001-6511-7574
[6]Laboratory of Research of Nuclear and Thermal Power Plants, Prydniprovska State Academy of Civil Engineering and Architecture, 24-a, Architect Oleh Petrov St., Dnipro, 49005, Ukraine, tel. +380 (63) 247-27-42, e-mail: kolemasakar@gmail.com, ORCID ID: 0000-0002-4435-2388

Abstract. *Problem statement.* The paper provides an additional expanded justification for applying an innovative methodology in the area of the future Sinop NPP, planned to be deployed in the Republic of Tűrkiye, to identify the activity rate of tectonic faults in soil foundation based on comprehensive radon measurements using the PSACEA universal estimation scale. ***The purpose of the article.*** Current radon activity assessment of existing tectonic faults in Earth's crust based on archival measurements of soil radon carried out earlier in Sinop Province. ***Conclusions and results.*** Current analysis of radon measurement results obtained previously by the track method made it possible to further assess the radon activity rate of tectonic faults existing in the area of the future nuclear power plant. The proposed methodology to assess radon activity of tectonic faults in Earth's crust involves increasing safety during the construction and operation of the future nuclear power plant. The regulation on using this methodology as part of the subsurface monitoring at the Sinop NPP can be enshrined in job descriptions. This methodology can also be used as part of the seismic monitoring of other sites at the nuclear power plant, especially those located in high seismic risk zones.

Keywords: *NPP; Sinop NPP; seismic risk zone; radon; tectonic fault*

ДО ПИТАННЯ РАДОНОВОЇ АКТИВНОСТІ ТЕКТОНІЧНИХ РОЗЛОМІВ РАЙОНУ РОЗМІЩЕННЯ АЕС «СИНОП» У ТУРЕЦЬКІЙ РЕСПУБЛІЦІ

СЄДІН В. Л.[1], *докт. техн. наук, проф.,*
УЛЬЯНОВ В. Ю. [2], *ас.,*
ЗАГІЛЬСЬКИЙ В. А.[3], *канд. техн. наук, доц.,*
КОВБА В. В.[4*], *канд. техн. наук, доц.,*
ГОРЛАЧ С. М.[5], *канд. техн. наук, доц.,*
БІЛИК В. В.[6], *асп., н. с.*

[1.]Кафедра інженерної геології і геотехніки, Придніпровська державна академія будівництва та архітектури, вул. Архітектора Олега Петрова, 24-а, 49005, Дніпро, Україна, e-mail: sedin.volodymyr@pdaba.edu.ua, ORCID ID: 0000-0003-2293-7243
[2] Кафедра інженерної геології і геотехніки, Придніпровська державна академія будівництва та архітектури, вул. Архітектора Олега Петрова, 24-а, 49005, Дніпро, Україна, e-mail: uluanovvu@gmail.com, ORCID ID: 0000-0002-9028-3408
[3.]Кафедра інженерної геології і геотехніки, Придніпровська державна академія будівництва та архітектури, вул. Архітектора Олега Петрова, 24-а, 49005, Дніпро, Україна, e-mail: zahilskyi.vitalii@pdaba.edu.ua, ORCID ID: 0000-0002-7853-565X

[4*] Кафедра інженерної геології і геотехніки, Придніпровська державна академія будівництва та архітектури, вул. Архітектора Олега Петрова, 24-а, 49005, Дніпро, Україна, тел. +38(096)588-46-71, e-mail: kovba.vladyslav@pdaba.edu.ua, ORCID ID: 0000-0002-5140-8140
[5] Кафедра інженерної геології і геотехніки, Придніпровська державна академія будівництва та архітектури, вул. Архітектора Олега Петрова, 24-а, 49005, Дніпро, Україна, e-mail: horlach.serhii@pdaba.edu.ua, ORCID ID: 0000-0001-6511-7574
[6] Лабораторія досліджень атомних та теплових електростанцій, Придніпровська державна академія будівництва та архітектури, вул. Архітектора Олега Петрова, 24-а, 49005, Дніпро, Україна, e-mail: kolemasakar@gmail.com, ORCID ID: 0000-0002-4435-2388

Анотація. ***Постановка проблеми.*** Наведено додаткове розширене обґрунтування застосування в районі майбутньої АЕС «Синоп», розташованої в Турецькій Республіці, інноваційної для даних умов методики виявлення ступеня активності тектонічних розломів ґрунтового утворення на основі комплексних вимірювань радону за допомогою універсальної оціночної шкали ПДАБА. ***Мета статті*** – сучасне оцінення радонової активності існуючих тектонічних розломів земної кори на основі архівних вимірювань ґрунтового радону, раніше виконаних у турецькій провінції Синоп. ***Висновки.*** Сучасний аналіз раніше отриманих результатів вимірювань радону трековим методом дозволив додатково оцінити ступінь активності радону існуючих тектонічних розломів району майбутньої АЕС. Пропонована методика оцінювання радонової активності тектонічних розломів земної кори передбачає підвищення безпеки під час будівництва та експлуатації майбутньої АЕС. Положення про застосування цієї методики в рамках моніторингу глибин земної кори на АЕС «Синоп» може бути закріплене в посадових інструкціях. Методика може бути використана і в рамках сейсмічного моніторингу інших майданчиків АЕС, особливо розташованих у зонах із підвищеною сейсмічністю.

Ключові слова: *АЕС; АЕС «Синоп»; зона з підвищеною сейсмічністю; радон; тектонічні розломи*

Formulation of the problem. Along with other natural gases that are freely discharged into the atmosphere in zones of tectonic faults in Earth's crust, the best-known one is the radioactive gas Radon (^{222}Rn). The properties of this gas, namely inertness, short half-life period (up to 3.8 days) and availability of progeny distinguish it from other gases, such as methane, hydrogen, helium, etc. These properties of radon served as the basis for its use as one of the available indicators in establishing the activity rate of tectonic fault zones. Monitoring the stressed state of subsurface resources in such zones is absolutely necessary, since near them various deformations of the Earth's surface are observed. Such processes lead to violations in the planned high-altitude position and integrity of residential and public buildings, transport infrastructure facilities, as well as construction works of particularly important power assets, such as nuclear power plants [1].

As part of numerous field studies in the 70−80s of the last century, a direct connection was established between the intensity of radon anomalies and geodynamic processes in tectonic fault zones. This phenomenon constituted a ground to start up a fundamentally new direction of applied research in the field of engineering geology: – structural geodynamic mapping [2; 3].

The behavioral features of radon (^{222}Rn) in geological space, e.g. abnormally high or abnormally low gas concentrations in periods preceding earthquakes, created the conditions for the continuous monitoring of radon as one of the indicators of possible seismic events. The importance of radon monitoring with the aim of seismic forecasting has been repeatedly confirmed in practice, including the notorious events in L`Aquila (Abruzzo), Italy, which occurred in April 2009, having been predicted by the local seismologist Giampaolo Giuliani several months before based on observations of soil radon. Considering the tectonics and seismicity of the country, the relevance of such monitoring in Turkey is beyond doubt.

Despite the numerous facts of quite successful application of this method, radon, as a possible indicator of changes in the stressed state of subsurface on the sites of nuclear power plants being designed, under construction and in operation, has got undeservedly little attention so far. This was especially true for measurements of radon concentration in groundwater.

However, in recent years, measurements of soil radon for the purpose of studying the geodynamics of NPP sites using gas-emanation methods have already been enshrined, albeit with reservations – "indirect" or "auxiliary" in regulatory documents of a number of countries. But the method of radon measurement in groundwater for geodynamics and seismic forecasting purposes has yet to prove its value, although separate studies have already been carried out in this area [25; 26; 31; 32].

The purpose of the article. The purpose of this paper is to provide an up-to-date assessment of tectonic fault activity based on soil radon measurements, previously performed by external researchers in Sinop Province, Turkey, as well as the rationale for using a methodology to identify the activity rate of tectonic faults already in the area of the future Sinop NPP, in reliance of complex radon measurements and with the own PDABA universal scale subsequently finalized.

Materials and Methods. In furtherance of energy construction, the coastal region of Sinop Province had been repeatedly studied by various Turkish and foreign companies and organizations since the 80s of the last century. Numerous large-scale geotechnical and geo-environmental investigations were carried out in both mountainous and coastal areas [4−6]. In particular, the peninsula itself, on which the future nuclear power plant is supposed to be located, was explored at the request of a French-Japanese Consortium already in the 21st century. The exploratory survey included aerial photography, field reconnaissance, geophysical and paleo-seismological studies, etc. Their results among others formed the basis for an EIA of this project [27; 28]. However, the final EIA report itself, despite its approval, was met by the public with a mixed reception.

As previously mentioned, following numerous investigations, the geological structure, tectonics and seismicity of the province were studied relatively in their entirety and described in many papers available for wide acquaintance and analysis. Moreover, the specialized survey was carried out not only on land, but also offshore a water body, as required by documents regulating studies on the territory intended for the construction of nuclear power plants.

Geology. Geologically, the described area is located within the Sinop Depression of the Middle Pontids, filled with Lower Cretaceous and Tertiary (Neogene) deposits. The Sinop Suite of Middle and Upper Miocene is the most characteristic formation of the local geological section. It is essentially terrigenous-clastic and represented by limestone deposits, although sandstones and mudstones are noted at the bottom.

On the surface, the suite deposits are overlapped by the Quaternary deposits. Modern deposits are represented by river alluvium, palustrian deposits, colluvium, sands of seashore terraces and Aeolian relief forms. A more detailed description of the geological and stratigraphic features of the area where the future nuclear power plant has to be located is actually beyond the scope of this paper. Therefore, it can be found in Chapter VI.1.5.4. of the final EIA report.

Tectonics. There is an opinion that tectonically, the Sinop Trough, like other troughs of the suture trough system in the eastern region of the Black Sea, apparently has a dual nature. Having arisen initially as an orogenic or overrift trough on the base formed by the Upper Cretaceous volcanogenic and volcanogenic-sedimentary complexes of the Pontids, it was divided at subsequent stages into two parts: − the southern, "continental", with the basement depths of 4−5 km, and the northern "near-basin", where the foundation submerged to the depths of 7−10 km.

The first one, filled with Paleogene and Neogene deposits that had been deformed with the underlying rocks, may continue to develop as a foretrough of the Pontus orogenic system. The second one bounded from the south by a tectonic scrap already belongs to the system of the Black Sea Abyssal Basin and develops as its boundary suture element.

The main faults identified and subsequently studied, including by radonometry methods, in the 80s of the last cantury, were as follows (see the diagram in Fig. 1):

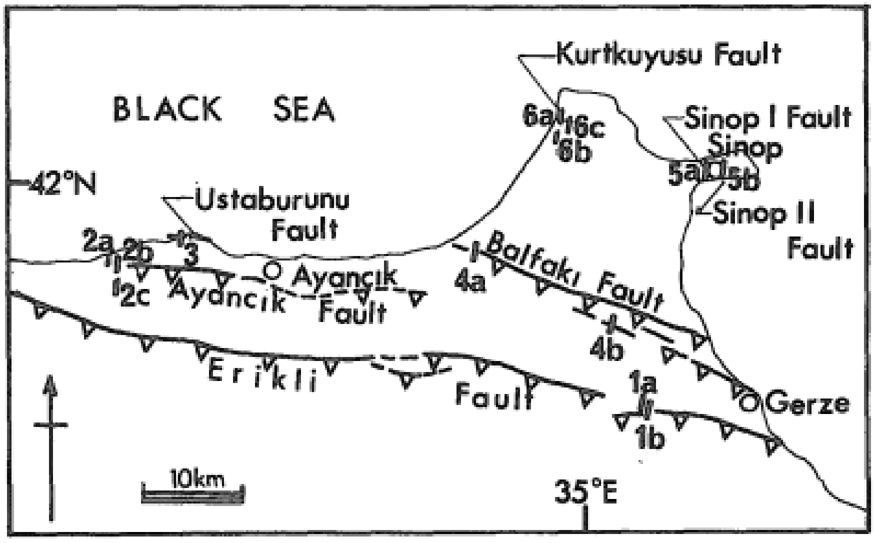

Fig. 1. Main faults on the territory being explored, with the indication of measurement areas (sections). Source: Paper of Hirokazu Kato, Kan Katoh, Aykut Barka and Ismail Kusgu. Alpha track measurements for faults in northern Turkey / Bulletin of the Geological Survey of Japan (1990)

Erikli (Eocene), Ayancik (late Eocene), Balifakl (late Eocene – early Miocene), Ustaburunu (late Eocene – early Miocene), Kurtkuyusu and Sinop I/II (late Miocene – early Pleistocene). It should be noted that all of the above-mentioned faults did not have strong geological and physiographic evidence of their activity at the time of investigations. And the supposed Kurtkuyusu Fault was generally identified only from aerial photographs and could well be a lineament. On the later maps and diagrams, Ayancik and Kurtkuyusu Faults were no longer indicated at all. But near the Kurtkuyusu location, a certain fault called Miocene Basin-Margin Fault was nevertheless plotted on the geological map of the peninsula [7]. The possible location of Sinop I/II Faults is also indicated on some maps [30].

Seismicity. The seismic conditions, tectonic faults identified and criteria for determining their activity at the site of the future nuclear power plant have been described in detail in a number of papers [8−10].

In 2005−2008, MTA (MADEN TETKİ VE ARAMA) carried out active studies that had been ordered by ICC EUAS to compile EIA of the Sinop NPP Project in the area with a radius of 150 km around the Sinop Peninsula, aimed at exploring the identified fault zones in segments of the Sinop underwater lineament and faults at the bottom of the Pontic Gulf, as well as Balifakl, Ustaburunu, North Anatolian (NAF) Faults, and Erfelek Segment of Erikli Fault on land [11]. The most attention was paid to NAF Fault, Erfelek Segment of Erikli Fault and Pontic Ridge undersea, as the most significant in the region. In particular, the seismic events of 1942, 1943 and 1944 were associated with NAF Fault in the area of Tosya-Erbaa located 120 km south of the future nuclear power plant site, with M>7. The GPS-investigation data indicate a slip rate of 24 mm/year along NAF Fault. For this reason, it is its seismic potential that was studied most thoroughly. This report containing a deterministic seismic hazard assessment shows that an earthquake with a magnitude of 8.0 is quite possible in the area of NAF. As concerns the area between the Black Sea and the north of NAF zone, velocities are minimal. The GPS-velocities were measured around the Sinop Peninsula, and there were obtained the values of 1,4 ± 1,7 mm/year [29]. According to the results of research in 2008, it was noted that more detailed seismicity assessments would be presented in the future final EIA report.

Also, the information about seismicity in the region was collected from the reports “Tectonic Framework and Seismic Potential of the Sinop Peninsula in Relation to Sinop Nuclear Research Center” and “Seismic Hazard Assessment for Sinop Nuclear Technology

Center" prepared by ODTÜ DMAM Research Center for Türkiye Atom Enerjisi Kurumu (TAEK). The assessment in the report "Tectonic Framework and Seismic Potential of the Sinop Peninsula in Relation to Sinop Nuclear Research Center" is mainly based on a re-evaluation of geological and paleo-seismological studies carried out by MTA, investigation of deep seismic profiling conducted by Türkiye Petrolleri Anonim Ortaklığı (TPAO), and microseismic studies conducted by Marmara Research Center (TÜBİTAK MAM) in 2008. The faults assessed in the study were as follows: North Anatolian Fault Zone, Erbaa-Tosya Segment (NAF), Ekinveren Fault, Erikli Fault, Balıfakı Fault, Bartın Fault and small marine faults observed in the western Sinop Peninsula. Based on the research results, it was also concluded that the only fault playing an active role in seismicity of the Sinop Peninsula was Erbaa-Tosya Segment (NAF) due to the earthquake in 1943. All other mentioned structures were either inactive or subactive, or just very slight. Similar conclusions were contained in Chapter VI.1.5.8. of the final EIA Report. Individual studies in this area were continued by various specialized organizations virtually until 2020, including with the involvement of FUGRO specialists and equipment for works offshore a water body.

As regards Balıfakı Fault, that is the closest to the future construction site and accurately mapped, as well as other fault zones located nearby, the absence of any activity in them in the Quaternary is still questioned by a number of researchers. Sedimentological and geomorphological observations, collection of regional structural data and OSL-dating of deposits, including seashore terraces, indicate the continued participation of the Sinop Peninsula in the general process of Pontic orogeny. When studying rise rates of individual sections on the peninsula, it turned out, in particular, that Incheburun and Bozburun Capes situated on its northernmost tip experienced slow uplifts at a rate of 0.02…0.08 mm/year and 0.26 mm/year respectively, within the period from 570,000 to 190,000 years ago. This was presumably related to some kind of fault slow-moving to the north of both sites. Some capes in the south of the peninsula experienced a rise rate of 0.22 mm/year during the same time. This, in turn, pointed to tectonic activity, but already along Balıfakı Thrust precisely in the Quaternary. This was also indicated by Steepnes normalized map of river networks crossing the fault zone, which showed a coherent deviation from their graduated profiles.

It was also noted that in Sinop area there were no historical records or instrumental evidence of large earthquakes in the distant historical past. Although sometimes, small and moderate earthquakes occurred in the so-called Pontidian Escarpment. The only major seismic event that occurred during the instrumental period at the southern edge of the Black Sea was an earthquake with a magnitude of 6.8, which took place in Bartın in September 1968. The mechanism of this seismic event is still a subject of debates.

However, numerous researchers seem to have completely failed to take into acount that with the beginning of construction of the nuclear power plant, when planning the territory, its stressed state will inevitably change due to extraction and movement of a large volume of mined bulk from the rock mass, even though seismic events were recorded there with a maximum magnitude of $M<6.8$. This becomes more probable with a subsequent additional technogenic flooding of possible fault zones and other technogenic impacts (blasting operations, vibration, etc.). In addition, the specific behavior of faults on aseismic territories revealed in recent years, to which the drafters of the document, apparently, have rightfully attributed the site of this nuclear power plant, is completely ignored. But disregard for any modern geodynamics of the site's soil foundation can have a very negative impact in construction of the nuclear power plant. This is especially true for installing powerful concrete beddings and deep foundations of essential structures (the so-termed "nuclear islands") that are ranked as the purported "active" geodynamic zones, as well as will manifest itself subsequently, already during the operation of completely constructed facilities of the nuclear power plant and, first of all, its extended buried structures (cable and technological channels, galleries, circulating water pipelines, etc.). The possible "contribution" to the above processes of the so-called "swarm" of weak seismic events occurring from time to time both on land and in the sea, near the coast of the province, must never be underestimated.

Research results. One of the questions raised during the public discussion of EIA had relation directly to geology, namely determining the presence of tectonic faults with unknown activity on the site. In light of this situation, it became necessary to return to the issue of active tectonics in the future NPP construction area once again. And here radon studies, as on the site of the Akkuyu NPP under construction, could play a significant role in clarifying the situation [12]. For this reason, it makes sense not only to pay attention to modern materials, but also to return to archival data, presumably, to primary radon observations in tectonic fault zones, identified at the time of works completed by Turkish and Japanese researchers in the 80s of the last century [13–15]. It should be especially noted that, unlike other provinces of the country, which are replete with fault zones and often subject to seismic events, radon measurements in Sinop Province have been relatively rare until now and carried out for environmental purposes, mainly concerning safety of residential units, industrial premises and building materials. Information about the repeated large-scale studies of the 80s of the last century was not found by the authors. Why are the research data of the 80s especially valuable in light of the aims and objectives of this paper?

As mentioned above, the measurements in Sinop Province were carried out in the 80s of the last century by the method of registering "alpha-particles", later called "track method", or more precisely "measurement of the volumetric activity of radon using emanation-tracking or thermo-luminescent detectors". This method has become relatively widespread due to its simplicity and low requirements for available electricity, especially when measuring radon indoors. Two modifications of the method were tested at once, and were referred to in the reporting materials as the "tube-method" and the "cup-method" that later became classic. The "cup-method" has been most widely applied and used across all fault zones studied in the province. The determined parameter was referred to by the authors of the reporting materials as T.D. and calculated using the formula:

$$\text{T.D.} = N/(S \times T),$$

where T.D. is the flux density of alpha-particles, N is the number of tracks, S is the area of film (см²), T is the exposure time (a day).

Under certain conditions, this parameter is quite comparable with the concept of soil radon volumetric activity (RVA). And it can also be used in calculating the activity of tectonic faults using the universal scale proposed by PSACEA, although it has other criteria. However, taking into acount the fact that the applied parameter is a certain averaged value associated with the RVA, the ratios $\text{T.D.}_{max} / \text{T.D.}_{min}$ and Q_{max} / Q_{min} in the PSACEA scale are essentially identical, just so as the so-called contrast coefficients KT.D. and KQ derived on their basis in the PSACEA scale.

As previously mentioned, the measurements by the track method were carried out in 1983 in the areas of faults shown above in Figure 1, namely: Erikli (Profiles 1*a* and 1*b*); Ayancik (Profiles 2*a*, 2*b* and 2*c*); Balifakl (Profiles 4*a* and 4*b*); Ustaburunu (Profile 3); Kurtkuyusu (Profiles 6*a*, 6*b* and 6*c*); Sinop I (Profile 5*a*); and Sinop II (Profile 5*b*). The measurement results are shown in Figure 2.

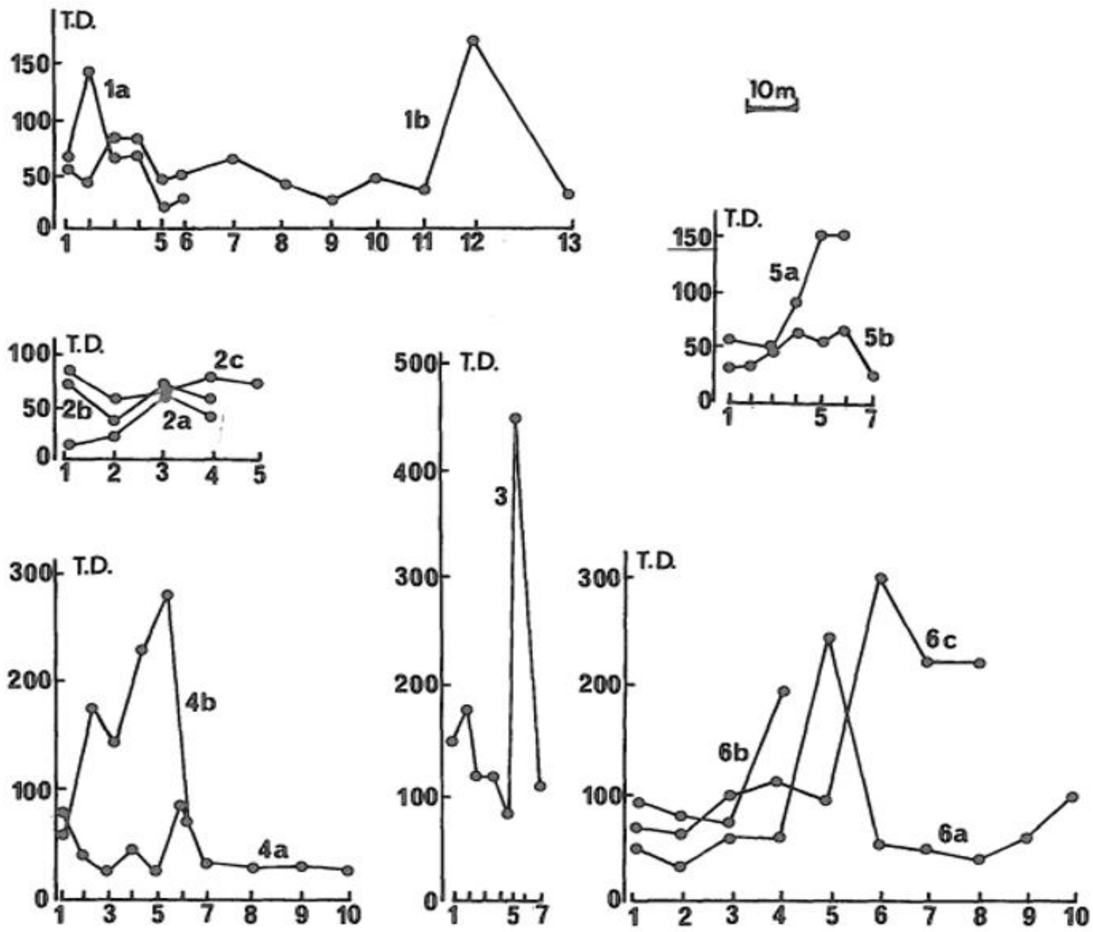

Fig. 2. Results of measurements on Profiles No. 1−6 in 1983. Source: Paper of Hirokazu Kato, Kan Katoh, Aykut Barka and Ismail Kusgu. Alpha track measurements for faults in northern Turkey / Bulletin of the Geological Survey of Japan (1990)

Table 1

Degree of radon activity based on the contrast ratio of emanational anomalies

Fault	Profile No.	Max. T.D. value	Min. T.D. value	Contrast Coefficient, Kt.d = max/min	Fault Activity Indicator (similar to Kq of the PSACEA scale)
Erikli	1a	145	65	2.2	low
	1b	175	40	4.4	average
Ayancik	2a	60	25	2.4	low
	2b	80	40	2.0	not active
	2c	90	70	1.3	not active
Ustaburunu	3	460	80	5.8	active
Balfaki	4a	90	35	2.6	low
	4b	290	85	3.4	average
Sinop I	5a	160	55	2.9	low
Sinop II	5b	70	25	2.8	low
Kurtkuyusu	6a	250	60	4.2	average
	6b	200	80	2.5	low
	6c	310	100	3.1	average

As follows from Table 1, the results of studies for radon emissions from subsurface in 1983 on the territory of the peninsula may well be used at the present time. And the conclusions following the results of studies by different methods are also quite comparable. It should be especially noted that the given sample values are too small, and for this reason, they cannot reflect the whole picture, but the unexpectedly significant scatter in the values of radon volumetric activity (VA) on Profile No. 3, as well as on Profiles 1b, 4b, 6a, and 6c already leads to assess the stressed state of soil body in a different manner. There is no doubt that special attention during the upcoming studies of the future site, including by radonometry methods, should be given to the area of the supposed Kurtkuyusu fault zone, as that located in close proximity to the site of the future nuclear power plant. The activity of Kurtkuyusu fault zone must be explained despite the existing clarifications in the final EIA report (see Chapter VI.1.5.4.). If necessary, radon measurements should also be carried out in the coastal zone of water space, although the latter is associated with a number of methodological and technological difficulties. That is, we can already talk about the presence of clearly defined radon anomalies, presumably associated with modern geodynamics. The degree of the possible activity of identified faults at the site of the Akkuyo NPP under construction was assessed in a similar way. It is difficult to assess the seismic-tectonic situation using other indicators of the PSACEA scale due to insufficient data on radon measurements in this province being available to the public. The existing scattered data on the concentration of radon in the premises of cities and rural settlements of the province can only be of a poorly applicable indirect nature for the purposes of seismotectonics [16; 17]. However, the EIA report still provides some information about measuring RVA in residential premises (see Map of Sampling Sites VI.1.1-3 and Table of Results VI.1.1-59), and in water sources (see Map of Water Points VI.1.1-6 and Table of Sample Data VI.1.1-79 and VI.1.1-80). Despite the low RVA values obtained during the research, their significant difference within a small area already shows us to raise a question of continuing and expanding the scale of such observations.

In addition to the geological and structural-tectonic component, the study of radon emissions from subsurface also has a clearly expressed technical aspect. A relatively little-studied area is the possible impact of the identified geodynamic structures on the welds of pipelines for various purposes in buildings and facilities of the future nuclear power plant. According to a number of researchers (Seliukov N.I., Riaboshtan Yu.S., etc.), the negative impact of such structures can be reduced to three main factors, namely:

− mechanical-dynamic, associated with local fluctuations of the daytime surface of soil mass;

− gas-chemical, associated with the increased release of corrosive gases from the fault zones of active geodynamic structures;

− radiation.

The latter is the least studied due to the peculiarities of the impact of alpha-particles, formed as a result of the decay of radon in places of its intensive release from subsurface, on the corrosive environment, and, above all, groundwater, as well as the so-called technogenic aquifers inevitably formed during the operation of nuclear power plants (radiolysis effect). Hydrogen peroxide, ozone, and OH and H_2O_2 radicals formed during the water radiolysis are energetic cathodic depolarizers. For the same reason, the radiolysis effect enhances the cathodic process, and consequently, corrosion itself, including metal of pipeline welds, when they cross such structures within the site.

As follows from the above, it is quite likely that not all issues regarding the fault tectonics on the territory of Sinop Province, and especially the site of the nuclear power plant itself, were fully and correctly covered in the final EIA report of the French-Japanese Project. For this reason, if the need to compile a new EIA nevertheless arises, additional special comprehensive studies at the nuclear power plant site and surrounding area are highly desirable for it. As per a high-quality analysis of the current geodynamic situation, the list of planned geophysical studies should additionally include the following types of work, namely: measurement of radon VA in groundwater of exploration grid wells, and measurement of soil radon VA in drill holes near exploration grid wells. Marine works must also be carried out. Moreover, sampling is necessary both from the bottom seawater and from the layer of bottom sediments at a depth of at least 1 m. As on land, profiles in offshore should be located across fault zones identified by seismic exploration.

When outfitting a permanent network of hydrogeological monitoring by the start time of exploring wells, they should also be included immediately in the number of water points tested for radon. There is experience in high-quality radonometry for the purposes of seismic forecasting, seismotectonics and radioecology in Turkey [18–23]. It is not worth postponing such studies, given the traditionally quite tight schedule in construction of the future facility in its entirety, as well as more frequent cases of resonance seismic phenomena in the Republic, in particular, those that occurred in the southeastern provinces on the border with Syria on 6.02.2023 and after. It is also worth considering that the catastrophic seismic events that occurred there may well contribute to the activation of tectonic structures in the described area. In particular, this is confirmed by the seismic event in the Black Sea with M = 3.6, which took place on 17.02.2023 nearby, 99 km from Samsun at a depth of 2 km that clearly points to its neotectonic nature.

Further, similar studies may become an integral part of subsurface monitoring both at the Sinop NPP site itself and on the adjacent territory of the province [24], including the monitoring of modern tectonic movements in Earth's crust. Refusal to conduct such studies is rife in the near future with the manifestation of negative geotechnical processes and phenomena that could complicate both the construction itself and the trouble-free operation of systems of the already commissioned nuclear power plant. If, during the proposed additional studies, active segments of geodynamic structures associated with radon anomalies are detected in certain areas of the nuclear power plant site (and, with sufficient justification, near it), it will be worthwhile to consider the question concerning feasibility of timely changes in some design decisions.

Conclusion. Processing the available data received in 1983 by means of the PSACEA universal scale allowed us to give our own assessment of the results obtained and radon activity of the tested fault zones.

The results after investigations of radon emissions from subsurface, conducted in 1983 on the territory of the peninsula, may well be used at the present time. And the conclusions based on the results of comparative studies with the use of different methods are also quite comparable.

According to opponents of the project, not all issues regarding the fault tectonics of the area and nuclear power plant site itself were quite correctly covered in the final EIA report of the French-Japanese Project. Therefore, when carrying out works both within the existing project and a new one, if one does take place, additional comprehensive geotechnical studies, which have to include radonometry, are highly desirable. Moreover, this applies to both soil radon and radon in groundwater. Despite the low VAR values obtained during the research, their significant difference within a small area already allows us to raise the question of continuing and expanding the scale of such observations. At the time of writing this paper, the issue to restart building a nuclear power plant is again on the agenda, and therefore, additional studies being proposed might be quite appropriate.

There is no doubt that special attention during the upcoming studies of the future site, including by radonometry methods, should be given to the area of the supposed Kurtkuyusu fault zone as that located in close proximity to the site of the future nuclear power plant. The activity of Kurtkuyusu fault zone must be explained. If necessary and when technical capabilities are available, radon measurements should be carried out in the coastal zone offshore as well, especially on the western side of the peninsula.

If, during the proposed additional studies, active segments of geodynamic structures associated with radon anomalies are discovered at the NPP site and adjacent territory, it will be necessary to consider the question concerning feasibility of timely changes in design decisions.

The exploratory survey can be combined with planned works to clarify engineering and geological conditions for specific buildings and structures of the nuclear power plant. Such survey may further become an integral part of subsurface monitoring at the nuclear power plant site.

The expected additional studies will be able to provide more complete seismic protection of units at the future nuclear power plant and, as a result, trouble-free operation of its completed buildings and structures for a long term.

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