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WORKSHOP ON THE PAKS II SITE CHARACTERISTICS

Key comments on the presentations and discussions during the Hungarian-Austrian professional workshop on the Paks II site characteristics in Budapest, Feb 15, 2022

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INTRODUCTION

The current document reports on the *"Hungarian - Austrian Bilateral Professional Workshop on the Open Questions Raised by the Environment Agency Austria, 15th of February 2022, Budapest"*. The workshop was held within the framework of the bilateral nuclear expert talks under the Agreement between the Government of Hungary and the Government of Austria on Issues of Common Interest in the Field of Nuclear Safety. The workshop was kindly hosted by the Hungarian Atomic Energy Authority (OAH) to address open questions that were raised by the Austrian side on the issue of the suitability of the Paks II site as a future nuclear power plant.

During the workshop the Austrian delegates and the EAA experts focused on the clarification of the capable fault issue at the Paks II site as described in the report by Decker & Hintersberger (2021). The matter is of particular importance due to the strictness of the Hungarian Governmental Decree No. 118 of 2011, requirement 7.3.1.1100: *"If the potential of occurrence of a permanent surface displacement on the site cannot be reliably excluded by scientific evidences, and the displacement may affect the nuclear facility, the site shall be qualified as unsuitable."* [Remark: permanent surface displacement on the site is referred to as fault capability in the IAEA terminology].

During the meeting the Hungarian side broached the issue of a possible misunderstanding of the wording of the requirement, which could be based on inaccurate translation. The EAA experts consequently double-checked that the source of the translation used in Decker & Hintersberger (2021) is the official English translation of the Hungarian wording[1].

[1] http://www.oah.hu/web/v3/haeaportal.nsf/8EE55B54901CDD60C1257CDD004367CB/$FILE/118%202011%20Korm.%20Rendelet%20_7.%20k%C3%B6tet_EN_2018_04_10.pdf

OBJECTIVES

This brief report provides summaries of the key arguments presented by the Hungarian experts to support their view on the characteristics of the Paks II site. These summaries are followed by corresponding key comments of the EAA experts. It is emphasized that an exchange of the technical presentations at the workshop was still pending at the time of the completion of this report. Both, summaries and comments must therefore be considered as preliminary.

During the workshop the Hungarian delegates also presented replies to the 8 questions to the Hungarian Regulatory Authority that were formulated in the report by Decker & Hintersberger (2021, p. 74-78). Due to the tight time constraints of the meeting schedule these replies could not be assessed and discussed in depth. The Hungarian replies were not available in written form at the time of the completion of this report and will be addressed in greater detail at a later stage when this information will be made available.

1 SUMMARIES OF KEY ARGUMENTS PROVIDED BY THE HU SIDE AND EAA KEY COMMENTS

1.1 Fault Capability

1.1.1 Key argument Paks II Zrt: exclusion of fault capability

In his presentation Dr. László Tóth informed about the seismological database covering the greater region of the Paks II site and its implications for the site characteristics. From the seismological data he concluded that surface-breaking faults are not plausible in this environment. It was understood by the EAA team that this conclusion was drawn from the argument that seismicity in the area occurs at an extremely low level; thus, based on all available information a M=6 earthquake is thought to be unlikely to rupture the surface in a time frame of 100.000 years.

1.1.2 Key comments EAA experts: evidence of fault capability

The above statements consequently suggested to the EAA experts that the exclusion of fault capability at the site is mostly (or solely?) based on instrumental earthquake records. Other existing data and toolkits for the identification and analysis of capable faults were not fully exploited. This approach appears surprising and it is contrary to the workflow generally adopted by governmental agencies and private firms when seismotectonic hazards of nuclear power installations are to be assessed over a wide range of low occurrence probabilities (typically 10-4 to 10-7 per year). Ignoring such an approach does not correspond to the guidelines of the IAEA (see presentation by S. Baize) in which the analysis of fault behavior on long timescales is recommended for the evaluation of capable faults, especially in low-strain intraplate areas (i.e., Pliocene-Quaternary). Even in seismically very active plate-boundary regions with frequent earthquakes, regulators require paleoseismological and geological data to be included in hazard calculations in addition to instrumentally recorded seismicity data. Indeed, nowhere in the world is seismology considered as the sole methodology to assess seismic hazard.

The approach presented to justify the statement *“a M=6 earthquake cannot rupture the surface in a time frame of 100.000 years”* is also not in line with the WENRA requirements of Safety Reference Level TU3.3 (WENRA, 2021: *“The hazard assessment shall be based on all relevant site and regional data. Particular attention shall be given to extending the data available to include events beyond recorded and historical data.”* WENRA (2020) renders this requirement more precisely stating that data shall include paleoseismological results.

During the discussion, Dr. László Tóth conceded that methodologies solely based on the analysis of historical and instrumentally recorded earthquakes are unsuitable to reliably exclude fault capability.

In the dataset provided in the Hungarian Geological Site Report, state-of-the-art shear wave reflection seismic data were acquired that unambiguously document the rupture of Late Pleistocene to Holocene sediments (profiles Pa-21-S, Pa-22-S; Geological Site Report, Ács et al., 2016, Fig. 420, Fig. 422). Fault sticks shown in the seismic profile PA-22-S reach up to depths as shallow as 50 ms shear wave TWT (Two-Way Travel Time). This TWT value corresponds to a depth level of only a few meters below the surface. Importantly, some of the faults depicted by the seismic profile PA-21-S were exposed in the paleoseismological trench Pa-21-II (see below).

In addition, road outcrops along Highway M6 about 9.7-10.5 km N of the Paks II site[2] exhibit faults that cut Late Pleistocene loessic sediments (Magyary, 2016). This author reported rupture ages between 5.5±1.1 and 7.7±1.1 and 13.2±1.9 and 14.3±2.7 ky, respectively, for two events identified by paleoseismological methods.

Furthermore, in the man-made trench Pa-21-II, deformation of near-surface sediments was recorded. The identified structures offset 20-ky-old floodplain sediments (Halász et al., 2016, Attachment 2, trench log). Based on paleoseismological criteria (e.g., McCalpin, 2009, Fig. 6.34, 6.35) these structures are related to fault offsets. The arrangement of the offset strata is related to a brittle deformation process and cannot be mistaken for a sedimentological feature that might have been caused by paleoclimatic conditions under a periglacial regime (e.g., ice-wedge fill). Neither can these features be explained as liquefaction phenomena associated with the upward escape of water-saturated sediment, such as those described by Obermeier (1996) or Tuttle (1999, 2001). A tectonic interpretation of the described features by Halász et al. (2016) has also been adopted by Wórum et al. (2020; figure caption of Fig. 3 showing a structure from the trench Pa-21-II: *"3. Faulting-induced paleosurface rupture trenched in Upper Pleistocene eolian sand"*.)

Consequently, the IAEA criterion for the identification of a capable fault is clearly met.

(IAEA, 2010, SSG 9, p. 51: *"3.6. A fault shall be considered capable if … one or more of the following conditions applies: … (a) It [The fault] shows evidence of past movement or movements (significant deformations and/or dislocations) of a recurring nature within such a period that it is reasonable to infer that further movements at or near the surface could occur…."*).

[2] The stated distance from the Paks II site is in line with the outcrop documentation by Magyary (2016, particularly Fig. 1 and 3). The distance of some 20 km from the site claimed during the meeting is apparently based on a misunderstanding of the original report.

1.2 Maximum Earthquake

1.2.1 Key argument Paks II Zrt: Assumption of M=6 as a maximum earthquake magnitude at the Paks site

During the presentation by Dr. László Toth it was stated that the greater region of the site could be subjected to a maximum magnitude M=6 earthquake (Mmax). In addition, it was claimed that such an event could affect the area on timescales of 100.000 years. Apparently, this assessment was exclusively based on instrumentally and historically recorded seismicity.

1.2.2 Key comments EAA experts on maximum earthquake magnitude and timing

As mentioned by the presenter himself, the site region is situated in a low-strain intracontinental area, yet GPS data indicate that deformation is occurring (Grenerczy et al., 2005; Nocquet, 2012). For this reason, it is realistic to assume that the central Hungarian region is subject to continuing, widely distributed deformation (Mid Hungarian Shear Zone; Fodor et al., 2005). Consequently, in an anastomosing network of WSW-ENE- to SW-NE-striking faults, earthquakes can be triggered under the present-day tectonic stress field. Geological observations suggest that this has occurred in the recent geological past (Fodor et al., 2005). Based on the present-day geodynamic setting it has to be assumed that this process will continue in the future. In light of the low level of seismicity recorded during the last 30 years in the Paks region, these regional neotectonic characteristics require that the seismicity record for the site's fault evaluation has to be extended to longer timescales, i.e., the Pliocene and Quaternary periods (IAEA, 2010). This has to be taken into account because the return periods of potential ground-rupturing earthquakes exceed historical and instrumental data by several orders of magnitude. The EAA experts further note that the presented approach is not consistent with WENRA guidance on the assessment of maximum earthquake magnitudes (WENRA, 2020, guidance on Safety Reference Levels TU3.3 and TU6.2).

Clearly, under these circumstances the assumption of a Mmax=6 earthquake and an arbitrary choice of a 100.000-year timeframe are not warranted. Interestingly, the SHARE database lists values of the maximum earthquake magnitude between 6.5 and 7.5 in Central Hungary (Woessner et al., 2015). These values exceed the claimed value for Mmax=6 by far.

1.3 Regional Faults

1.3.1 Key argument Paks II Zrt and former Geological Survey: Assessment of the role of regional faults linked with the DHFZ

During the discussion it was stated that regional faults with similar strike to the DHFZ exist, they are not considered active and not kinematically linked to the DHFZ. The case was made for the Németker Fault, which is located more than 10 km to the North of the site and the faults previously exposed in outcrops at the highway M6 (Mágyary, 2016). In addition, classified seismic reflection data were mentioned that were said not to indicate rupture of young geological units. These data, however, were neither used in the Geological Site Report nor in the Site Safety Report.

1.3.2 Key comments EAA experts on linked faults

The area under consideration is characterized by neotectonic structures that are related to the compressional reactivation of Miocene extensional and strike-slip fault systems (e.g., Fodor et al., 2005). Such zones are typically characterized by transfer structures that kinematically link different faults branches. In the present-day tectonic stress field these zones with such an inherited structural framework constitute a broad zone of deformation with complex anastomosing strike-slip and normal faults (Wórum et al., 2020). It is therefore conceivable that individual faults within this fault network are being loaded and will ultimately trigger failure of neighboring faults after an earthquake has occurred. Examples of such static or dynamic triggering of linked fault strands include the re-activated structures underlying the intraplate St. Lawrence lowland or the North China Craton (Liu et al., 2011) or the active regions of the Walker Lane (Western USA) with the 2019 Ridgecrest, 1992 Landers and 1999 Hector Mine earthquakes or along interplate faults like the 2016 Kaikoura earthquake (New Zealand) or the 2010 El Mayor Cucapah earthquake of Mexico[3]. Earthquakes in all of these regions have demonstrated that the build-up of tectonic stresses and their release on one fault may trigger ground-breaking earthquakes on adjacent or more distant pre-existing faults.

Although it cannot be proven with presently available data that such processes have occurred in central Hungary, under the current tectonic stress-field conditions the triggering or loading of adjacent faults during a potential earthquake is also conceivable for the principal SE-NW-striking structures such as Dunaszentgyörgy-Harta fault zone and linked subordinate structures such as those described by Mágyary (2016). This is important in context of the identification of ground-breaking paleo-earthquakes and the capable fault definition stated by IAEA (2010, SSG 9, p. 51: *"3.6. A fault shall be considered capable if, … one or more*

[3] Most of these examples and references to original scientific papers are included in the workshop presentations by S. Baize, C. Grützner and E. Hintersberger.

of the following conditions applies: …(b) A structural relationship with a known capable fault has been demonstrated such that movement of one could cause movement of the other at or near the surface.“)

For these reasons, a closer investigation of the spatial and temporal characteristics of the faults within the near-region of the Paks site is warranted, especially in the context of the paleoseismological results obtained from the highway M6 outcrops (Mágyary, 2016), which are located at distances between about 9.7-10.5 km N of the Paks II site.

Unfortunately, the seismic reflection data used in the argumentation of the Hungarian experts against fault activity at the Paks II site was presented for the first time at this meeting. The validity of the exclusion of fault rupture below the outcrops at the highway M6 could not be assessed by the EAA experts.

2 CONCLUSIONS AND KEY RECOMMENDATIONS

The information gained during the first workshop on the site conditions of the Paks II site lead the EAA experts to the following conclusions:

- The EAA experts regard the presented data on seismicity insufficient to allow a reliable assessment of capable faults (*"7.3.1.0800. The potential occurrence of a permanent surface displacement on the site shall be analyzed and evaluated. The examination must be sufficiently detailed to enable a substantive decision to be taken on the question of the possibility of discarding the site by the occurrence of permanent surface displacement."*)[4]
- To reliably assess fault capability, it will be important to expand the observation periods of possible seismic surface faulting beyond the coverage of historical and instrumental earthquake data. In line with international scientific practice and WENRA requirements the expansion of the timescale towards centennial and millennial timescales requires that a paleoseismological approach is adopted, especially in an intraplate setting like Hungary.
- The available paleoseismological (trenching) data are not sufficient to exclude fault capability. For a comprehensive assessment, other fault strands with inferred near-surface faults need to be trenched.
- The EAA experts state their concerns about the validity of the maximum earthquake magnitude inferred for the area under consideration. The stated value of M=6 is challenged by the assessment provided in the European SHARE project and the paleoseismological results obtained from the near-region of the Paks II site.
- In their study, Decker & Hintersberger (2021) concluded that *« the paleoseismological data derived from the trench Pa-21-II next to the site confirm the existence of capable faults in the site vicinity of Paks II. These capable faults are part of the Dunaszentgyörgy-Harta fault zone, their strike continues into the site, and they reveal evidence of repeated, significant surface displacements during the last ca. 20,000 years. »* The information provided during the bilateral workshop does not suffice to revise these conclusions.
- The latter conclusion is particularly important with regards to the Hungarian Governmental Decree No. 118 of 2011, requirement 7.3.1.1100:. *"If the potential of occurrence of a permanent surface displacement on the site cannot be reliably excluded by scientific evidences, and the displacement may affect the nuclear facility, the site shall be qualified as unsuitable."*[5].

Although the workshop provided a valuable opportunity to exchange opinions on the Paks II site conditions, it was not possible to reach a technically satisfac-

[4] http://www.oah.hu/web/v3/haeaportal.nsf/8EE55B54901CDD60C1257CDD004367CB/$FILE/118%202011%20Korm.%20Rendelet%20_7.%20k%C3%B6tet_EN_2018_04_10.pdf

[5] http://www.oah.hu/web/v3/haeaportal.nsf/8EE55B54901CDD60C1257CDD004367CB/$FILE/118%202011%20Korm.%20Rendelet%20_7.%20k%C3%B6tet_EN_2018_04_10.pdf

tory clarification of the mutual positions. Due to this, and due to the high relevance of the issue for nuclear safety, the EAA experts suggest continuing the dialogue on the expert level with the continuous involvement of additional international experts.

To continue dialogue, the Austrian delegates suggested to the Hungarian side to grant permission to the EAA experts to visit open construction pits on the Paks II site. This should enable gathering first-hand observation of the geological site conditions. The Hungarian delegates responded positively to the Austrian suggestion. This courtesy is highly appreciated and underscores the open spirit of the meeting.

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APPENDIX 2: WORKSHOP PRESENTATIONS

Stéphane Baize, Observer, IRSN – French Technical Support Organization of Nuclear Safety Authority: Capable Fault, ground shaking & displacement hazards. An illustration of the phenomena behind the regulatory guidelines

Kurt Decker & Esther Hintersberger, EAA Experts (University of Vienna): NPP Paks II – Paleoseismological assessment of the Siting Report and the Site License with respect to fault capability

Esther Hintersberger & Christoph Grützner, EAA Experts (University of Vienna, Jena University): Examples for surface breaking earthquakes and their paleoseismological record umweltbundesamt

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