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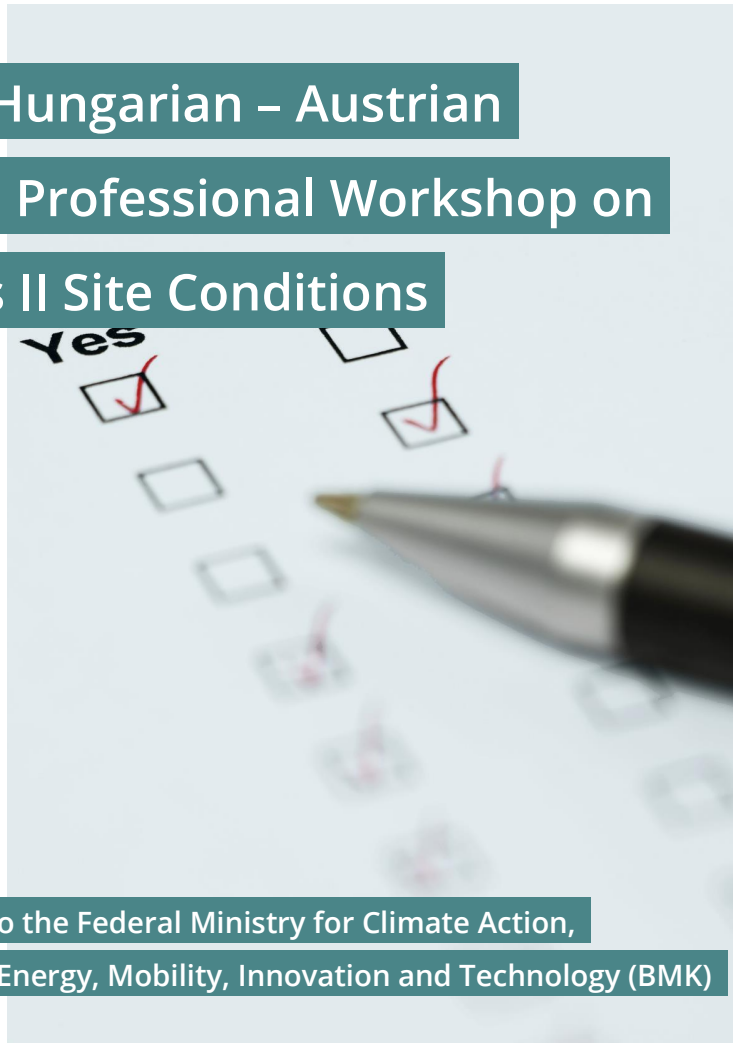
Second Hungarian – Austrian Bilateral Professional Workshop on the Paks II Site Conditions



Short Report to the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK)

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SECOND HUNGARIAN – AUSTRIAN BILATERAL PROFESSIONAL WORKSHOP ON THE PAKS II SITE CONDITIONS

Short Report to the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK)

Kurt Decker (Universität Wien, Austria)
Christoph Grützner (Universität Jena, Germany)
Esther Hintersberger (Universität Wien, Austria)
Manfred Strecker (Universität Potsdam, Germany)

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Project Manager Franz Meister

EAA Experts Kurt Decker, Universität Wien, Austria
Christoph Grützner, Universität Jena, Germany
Esther Hintersberger, Universität Wien, Austria
Manfred Strecker, Universität Potsdam, Germany

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SUMMARY

Based on the information obtained at the second bilateral workshop on the Paks II location on February 25, 2023, in Budapest, the EAA experts reiterate their earlier assessment that the geological and geophysical data of the Geological Site Report and the Site Safety Report on Paks II NPP are not sufficient to reliably exclude the potential of a permanent surface displacement (fault capability) at the site. Contrary to international guidance and safety requirements (IAEA, WENRA) as well as internationally practiced recommended routines in paleoseismological investigations, the presently available data do not show the breadth and depth necessary to back up the provided assessments of fault capability and seismic hazard.

New data confirming faulting at the Paks II building site was presented by representatives of Paks II Zrt at the meeting. Their presentation demonstrated new geological data acquired at the site after the Geological Site Investigation Program (Agenda Item 3). Data included a detailed geological profile constructed from new borehole data that proved the existence of a steeply dipping fault cutting the Pannonian strata in the subsurface of the Paks II building site. The profile did not show offset of the overlying Quaternary sediments, and the timing constraints did not allow to further investigate this topic. The apparent non-existence of a fault cutting Quaternary strata is crucial with respect to the assessment of fault capability. The interpretation of the lack of a Quaternary fault may, however, be rooted in an artefact of the investigation setup, because the spacing of drill holes and, therefore, the recording of stratal continuity or stratal disruption by faulting may not have been sufficiently dense to image faults in Quaternary sediments; this would particularly apply if the fault plane affecting the Pannonian units dips steeply (i.e., a normal fault) or if the fault is an integral part of a steeply dipping strike-slip system of the Dunaszentgyörgy-Harta fault zone (DHFZ). The relevance of a correct interpretation of this setting is evident if the S-wave reflection profiles Pa-21-S and Pa-22-S[1] are taken into account, which undeniably show faults that do not terminate at the Pannonian-Quaternary boundary, but continue upward into the Quaternary sediments, and thus constitute potential capable faults.

Given the kinematic history of the DHFZ and the offsets of Quaternary sediments recorded along other faults in the region it is likely that similar small offsets at decimeter scale cannot be detected in geological profiles constructed solely with borehole information (Figure 1). Likewise, offsets in Quaternary sediments would be virtually impossible to verify by drilling if the Quaternary kinematic style has been characterized by strike-slip faulting. In combination with the currently available database this uncertainty could only be resolved by paleoseismological trenching.

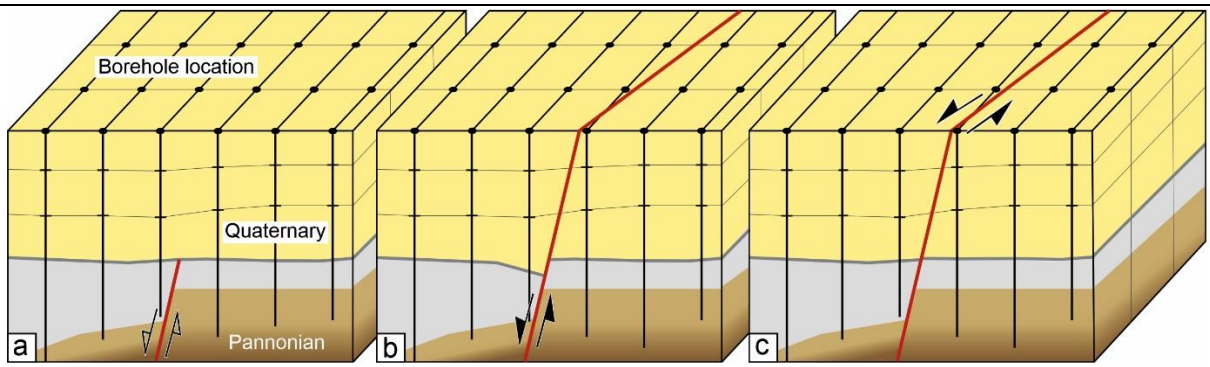
The EAA experts consequently reiterate their suggestion to consider comprehensive paleoseismological investigations of the excavation pit with the aim to

[1] Ács et al., 2016, Figs. 420, 422.

prove the non-existence of capable faults below the future base mats of the reactor buildings and other safety-related engineered structures. Such decision would be a way forward toward a better overall understanding of the site, and it would be in line with IAEA, WENRA, national requirements in other countries, and the current state of science and technology.

In light of these assessments the EAA Experts strongly recommend that BMK continue dialogue on the Paks II site conditions and a renewal of geological and paleoseismological observations.

Figure 1: *Geological profiles constructed from spaced boreholes cannot distinguish between (a) an* inactive *fault terminating at the base of the Quaternary strata, (b) a reactivated* capable fault *with vertical normal offset affecting Quaternary strata, and (c) a reactivated* capable strike-slip fault *with horizontal, but no vertical offset in Quaternary strata.*



Source: Own graph, © Manfred Strecker

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1 INTRODUCTION

On January 24, 2023, the second bilateral workshop on the Paks II site between Hungarian and Austrian delegates took place on the premises of the HAEA in Budapest. The meeting was attended by representatives of HAEA[2], MVM Paks II. Zrt. and SARA[3] from the Hungarian side, and the Austrian Ministry of Foreign Affairs, the Austrian BMK[4], EAA[5], and the EAA experts from the Austrian side. A list of participants was not provided.

The formal invitation to the workshop was received by the Austrian BMK on January 13, 2023. The workshop agenda was provided by the HAEA in the morning of January 24, prior to the beginning of the meeting (Appendix 1). Despite the lack of an agenda at the time of invitation the EAA experts prepared and showed a presentation focused on two principal points that have remained topics of open questions with regards to the safety assessment of the Paks II site and the geological reports that were prepared by Hungarian experts and MVM Paks II. Zrt.[6]:

1. *The inferred existence of capable faults at the future site of Paks II and in its vicinity.*
2. *Geological mapping and data collection of inferred capable fault zones according to international guidelines (i.e., IAEA SSR-1, SSG-9, Rev. 1) with the goal to exclude the existence of capable faults at the site.*

During the opening of the meeting HAEA highlighted two major points to be discussed at this venue:

1. *Consultations concerning the wording of the latest EAA report on the Paks II site visit and the recommendation to consider additional paleoseismological investigations at the site.*
2. *Results of the geotechnical site investigations during the last approx. six years, the generation of a comprehensive geological and geophysical database, preparatory measures of soil improvement, and the construction of a cutoff wall around the future building site.*

During the following sessions, presentations were given by (1) the EAA experts on the Paks II site characteristics with particular emphasis on fault capability and procedural issues of geological and paleoseismological aspects of the site investigations; (2) MVM Paks II. Zrt. on results of the geological site investigation program; (3) MVM Paks II. Zrt. on site preparation; (4) HAEA on the subject of practical elimination.

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[2] HAEA: Hungarian Atomic Energy Authority

[3] SARA: Supervisory Authority of Regulatory Affairs

[4] BMK: Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology

[5] EAA: Environmental Agency Austria

[6] Geological Site Report, Site Safety Report and Site License

2 AGENDA

2.1 Agenda Item 1: Opening, introduction of the participants and the agenda (HAEA)

The representatives of the Hungarian Atomic Energy Agency opened the meeting at 10:00.

2.2 Agenda Item 2: Paks II Site Characteristics (presentation by the EAA Experts)

The EAA experts presented a summary of their assessment of the publicly accessible geological database[7] for the Paks II site with respect to the potential capability of individual faults in the Dunaszentgyörgy-Harta fault zone and the possible existence of capable faults on the Paks site[8]. It was stressed that the expert opinion formulated in EAA Report REP-0759 (2021) was still valid: *The geological and geophysical data documented in the Geological Site Report and the Site Safety Report of the Paks II NPP are not sufficient to reliably exclude the potential of a permanent surface displacement (fault capability) at the site.*

The presentation focused on queries to HAEA, which were regarded to not have been fully clarified during the discussions at the first Hungarian-Austrian workshop on the Paks II site characteristics (Budapest, February 15, 2022) and answers presented in writing by HAEA:

- The question regarding the assessment and mitigation of fault capability and the consideration of near-fault effects on vibratory ground motion (Question 2, EAA Report REP-0759, 2021);
- The question how the hazard of permanent surface displacement can be excluded in light of the results presented for PA-II-21 (Question 6 in the cited report);
- The question if there is evidence that led to the exclusion of surface displacement at the site and within at least 10 km of the site in the last 100.000 years (Question 7).

Most importantly, the EAA experts reiterated their earlier appraisal that a comprehensive paleoseismological documentation of the excavation pits for the Paks II NPP should be achieved according to the current state of science and technology and in accordance with international safety standards.

[7] Geological Site Report and Site Safety Report

[8] The presentation of the EAA experts is included in Appendix 3

The Hungarian experts stated that they were not in the position to discuss the topics addressed by the EAA experts, but instead prepared presentations on the acquisition of new geological and geophysical data at the Paks II site.

2.3 Agenda Item 3. Surveys and Mapping on the Paks II Site Since the Geological Site Investigation Program (presentation by MVM Paks II. Zrt.)

During this presentation geotechnical data was provided mainly showing results of an extensive drilling and soil-property analysis campaign as well as geophysical data acquisition. The data acquisition was mainly carried out under the auspices of the Russian contractor. Although the spatial mesh of boreholes appeared to be rather coarse (the exact spacing was not provided), the borehole campaign confirmed at least one steeply dipping fault zone that is responsible for offsets of sedimentary rocks below the building site (Pannonian units). According to the interpretation of the borehole data no offsets exist in the Quaternary fill units.

Another relevant point that was learned from this presentation, and which repeatedly was addressed in the following discussion, was the fact that Paks II Zrt. did not analyze the new borehole and geophysical data in the context of its usefulness to document or exclude the existence of capable faults. In fact, the representatives of Paks II Zrt. mentioned that there is no need of further investigating the site and using available data to follow up on this issue, because capable faults were already excluded *a priori* in the two siting permits.

EAA Expert Assessment

Importantly, the detailed stratigraphic descriptions of boreholes and the construction of geological profiles documented the existence of a steeply dipping fault cutting the sedimentary strata below the Quaternary fill units under the building site. Apparently, there is no offset of the overlying strata. Unfortunately, detailed views of the horizontal continuity of Quaternary strata were not provided. This point is crucial, however, with respect to the assessment of fault capability and the inherent hazards of the site. The interpretation of lacking capable faults may be rooted in an artefact related to the investigation setup in the field, because the spacing of drill holes and, therefore, the recording of stratal continuity or fault-related offsets may not have been sufficiently dense to image a fault; this especially applies if the fault plane is very steeply dipping and related to dip-slip motion with small offsets or if the fault is part of a steeply dipping strike-slip system. Given the kinematic history of the DHFZ and recorded Quaternary offsets on other faults in the region, it is likely that offsets related to earthquakes with moderate magnitudes cannot be discovered with this technique. Only those faults that experienced multiple vertical offsets might be detectable with such a drilling campaign. Conversely, if the principal kinematic style of deformation is strike-slip, corresponding offsets would be virtually impossible to verify by drilling alone. These issues could be resolved, however, if

drilling and geophysical prospecting were used as an integral part of a multi-methodological approach of fault mapping, which involves paleoseismological trenching – a typical approach used in site characterizations. Indeed, the early trenching studies published in stringently reviewed scientific outlets were performed to resolve exactly these kinds of questions in areas with lateral and vertical offsets by applying 3D trenching techniques (e.g., Pantosti & Yeats, 1993; Weldon et al., 1996; Sieh, 2003). The EAA experts also stress that the characterization of a major fault such as the DHFZ can not be based on a single trench alone; instead, a paleoseismological campaign should involve multiple trenches along strike of the fault and should cover the entire width of the fault zone.

The relevance of, and need for, such an approach is evident, if the S-wave reflection profiles (e.g., Pa-21-S, Pa-22-S) are considered. The profiles unambiguously show that fault zones in the vicinity of the site do not necessarily terminate at the Pannonian-Quaternary boundary, but continue upward into the Quaternary sediments and thus constitute potentially capable faults. Furthermore, a geological, geophysical, and *paleoseismological* workflow would be in line with:

1. IAEA recommendations (IAEA SSG-1, 5.3, p. 18[9]; IAEA SSG-9 Rev. 1, 7.7, p. 51[10]). Although the term *paleoseismology* is not explicitly mentioned in SSG-1, *"detailed geological mapping of excavations for safety related engineered structures"* is recommended and this corresponds to paleoseismological workflows, for example, the mapping of outcrop walls (e.g., Mc Calpin, 2009) as explained in IAEA Tecdoc 1767[11], which addresses the paleoseismological characterization of capable faults.
2. WENRA requirements for site-specific external hazard screening and assessment: *"Particular attention shall be given to extending the data available to include events beyond recorded and historical data.*" (WENRA, 2014, Issue T, Safety Reference Level T3.3, p. 51, and WENRA, 2021, Issue TU, Safety Reference Level TU3.3, p. 56). Guidance for this WENRA requirement clarifies that, with respect to seismotectonic hazards, this reference level particularly addresses paleoseismological data (WENRA, 2015, guidance for T3.3, p. 8, and WENRA, 2020a, guidance for TU3.3, p. 9: *"Geological records including observations of landscape and geomorphic changes, e.g. paleoseismology…"*; WENRA 2016, guidance for T3.3, p. 10, and WENRA 2020b, guidance for TU3.3, p. 11-12: *"Particular effort should be made to extend the*

[9] IAEA 2019, SSR-1, 5.3, p. 18:*"5.3 The potential effect of fault displacement on safety related structures, systems and components shall be evaluated.* ***The evaluation of fault displacement hazards shall include detailed geological mapping of excavations for safety related engineered structures*** *to enable the evaluation of fault capability for the site." (p.18).*

[10] IAEA 2022, SSG-9 Rev. 1, 7.7, p. 51: *"7.7. When surface faulting is known or suspected to be present,* ***investigations should be conducted at the site vicinity scale and should include*** *very detailed geological and geomorphological mapping, topographical analyses, geophysical surveys (including geodetic measurements, if necessary),* ***trenching,*** *boreholes, age dating of sediments or faulted rock, local seismological investigations, and any other appropriate and state of the art techniques (e.g. remote sensing methods) to ascertain the amount and age of previous displacements or deformations."*

[11] IAEA 2015, Tecdoc 1767, chapter 2.1: Paleoseismologic characterization of capable faults: assessing seismic source potential from paleoseismology, p. 7-38.)

earthquake database by historical research and paleoseismologic surveys ...[etc]*."*; WENRA 2016, guidance for T4.3, p. 15 and WENRA 2020b, guidance for TU4.3, p. 15).

3. Other national regulations (U.S.NRC, 2021, Revision 3, 6. Construction Mapping, p. 22[12]), international and national guidance (JANSI, 2013, On-site fault activity estimation method, Fig. 5-1.[13], p.11; Decker et al., 2017, Chapter 3.1.4., Data for assessing permanent ground displacement, p. 42; Chapter 4.2.1 Fault sources (active faults), p. 70-75[14]).

2.4 Agenda Item 4. Update site preparation activities (Paks II Zrt.)

In order to reduce the hazard of soil liquefaction during a seismic event affecting the site, soil-improvement measures are being carried out at Paks II. This technique involves deep soil mixing (DSM), during which a soil-cement slurry is generated and applied to a depth of several meters below the base mats of future buildings. This technique obliterates the original stratal characteristics of soil and unconsolidated sedimentary materials. In addition, slurry trench walls are being installed to prevent lateral groundwater inflow and to increase water tightness of the pit. These measures were used as arguments that trenching at the site would not yield valuable results for the assessment of capable faults.

EAA Expert Assessment The experts agreed on this assessment. But if geological mapping and trenching were performed prior to these engineering measures, valuable information about the fault zone imaged in the drilling campaign and with respect to the overall structural characteristics of the site could indeed be obtained and used for further considerations of the site's inherent seismotectonic hazards.

[12] *"**Detailed geologic mapping should be performed for all construction excavations for safety-related structures** and other excavations important for verification of subsurface conditions ... . Particular attention should be given to geologic features and characteristics that might be important in assessment of the behavior of foundation materials, **including tectonic** and nontectonic features and lithologic variations**, which might be undetected and different from what was assumed based on the results of site investigations prior to excavations.** .... **The importance of the geologic mapping is reinforced by the geologic mapping license condition normally imposed in a combined or construction license."***

[13] Diagram shown in Appendix 1

[14] See workflow diagram in Appendix 2

2.5 Agenda Item 5. The Subject of Practical Elimination (HAEA)

The presentation by HAEA provided an overview of the regulator's approach to practically eliminate large or early releases as required by the WENRA safety objectives for new reactors. It was stressed that the principle refers to practical elimination of accident scenarios leading to early or large releases, not to the elimination of hazards; and that practical elimination is usually achieved via design solutions rather than by removal of the initiating event. Scenarios resulting from the tilting of the reactor are considered in the process by design provisions (e.g., prevention of stuck control rods and containment design resistant against tilting). Unfortunately, accident scenarios based on the combination of fault capability and earthquake hazards in the context of uncertainty and limited knowledge of the site characteristics were not discussed explicitly.

An important topic during the discussion following this presentation was the confirmation by Paks II Zrt. representatives that no design measures were planned to be implemented with the aim to mitigate the consequences of potential surface ruptures affecting the site. However, it was confirmed that provisions will be made to counteract potential *en-bloc* tilting of safety-related buildings in the context of differential ground settling.

EAA Expert Assessment

Measures to counteract tilting of safety related buildings are based on the assumption that no ground ruptures will develop under the site during a future earthquake. In light of the new data obtained by the drilling campaign and the uncertainty of fault strands reaching higher into the Quaternary fill units, it appears difficult to follow this reasoning, particularly, when the results of the S-wave reflection profiles in the site vicinity are taken into account, which record Quaternary faults that are rooted in deep-seated structures (Geological Site Report, Acs et al., 2016, Figs 420, 422) and that impact unconsolidated near-surface deposits. Coseismic fault rupture at or near the surface is typically associated with strain concentration in a narrow fault zone and high strain rates, which is different from ground settlement leading to tilting. In the latter case deformation is expected to be slow and distributed over a larger area.

The notion of practical elimination (WENRA, 2019) makes reference to the WENRA safety objectives for new NPP designs (WENRA, 2010), which include the expectation that new NPPs are sited with the objective to reduce the impact of external hazards (Safety Objective O2). This expectation is rendered more precisely in Position 6 on external hazards in WENRA (2013, p. 35): *"Minimising the risk from external hazards by initial siting of the facility".* It appears questionable if this objective has been reached for the Paks II site by locating the plant above a documented active fault zone.

2.6 Final comments

At the end of the consultations the content and duct of the report concerning the site visit and the outcomes of the Hungarian-Austrian bilateral meeting between November 30 and December 01, 2022, was discussed. The HAEA expressed wishes to change the section on recommendations by the EAA experts. It was unanimously agreed that a revised version would be sent to HAEA in due course.

Finally, HAEA announced that the writing of a document in response to the EAA expert's report and queries regarding the 1st Workshop on the Paks II site conditions is in progress and will be available, soon. All parties agreed not to prepare a press release concerning the contents of this meeting.

The meeting was closed at 17:00.

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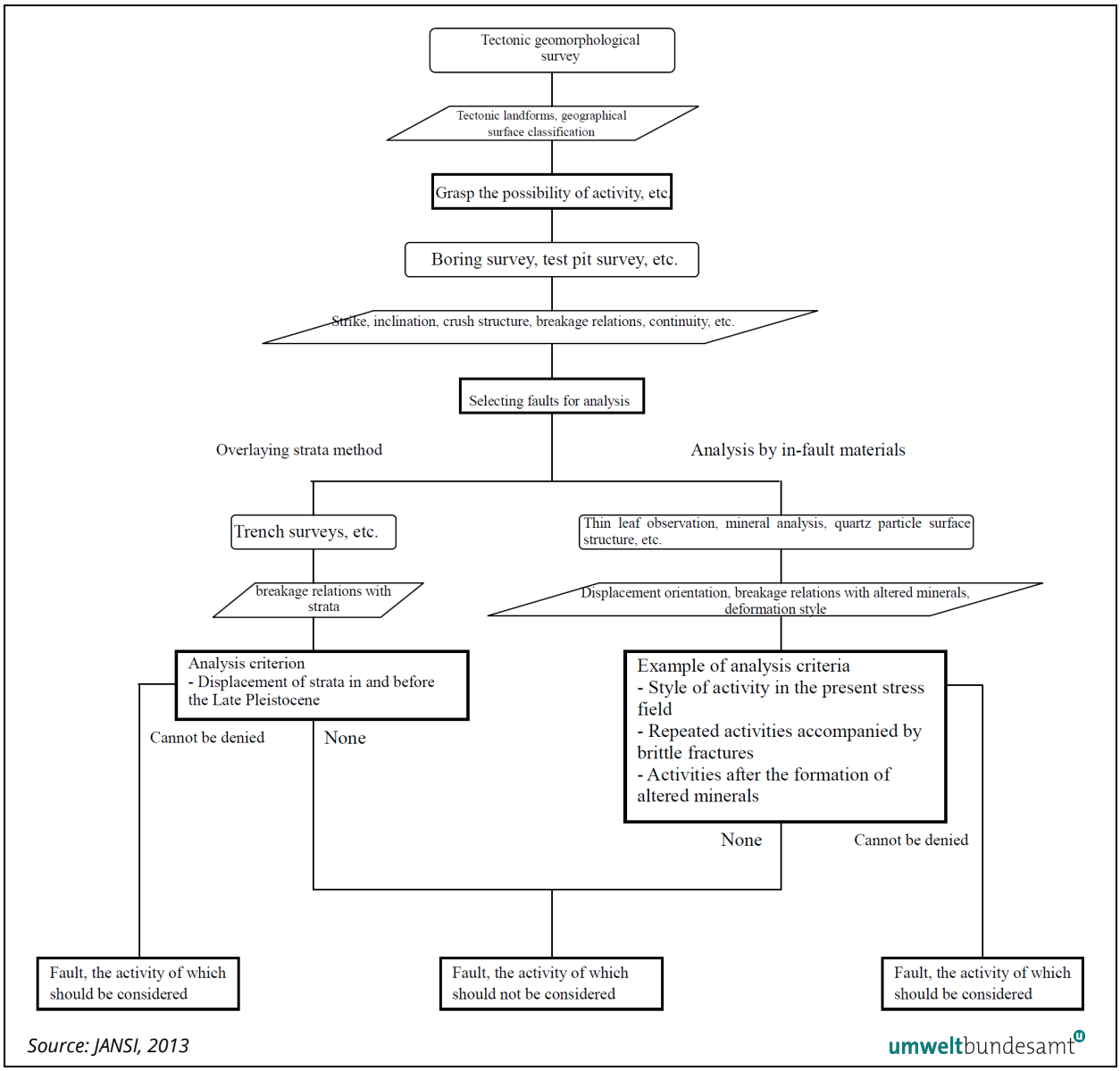
APPENDIX 1

JANSI, 2013: On-site Fault Activity Estimation Method (Fig. 5.1, p .11)



Source: JANSI, 2013

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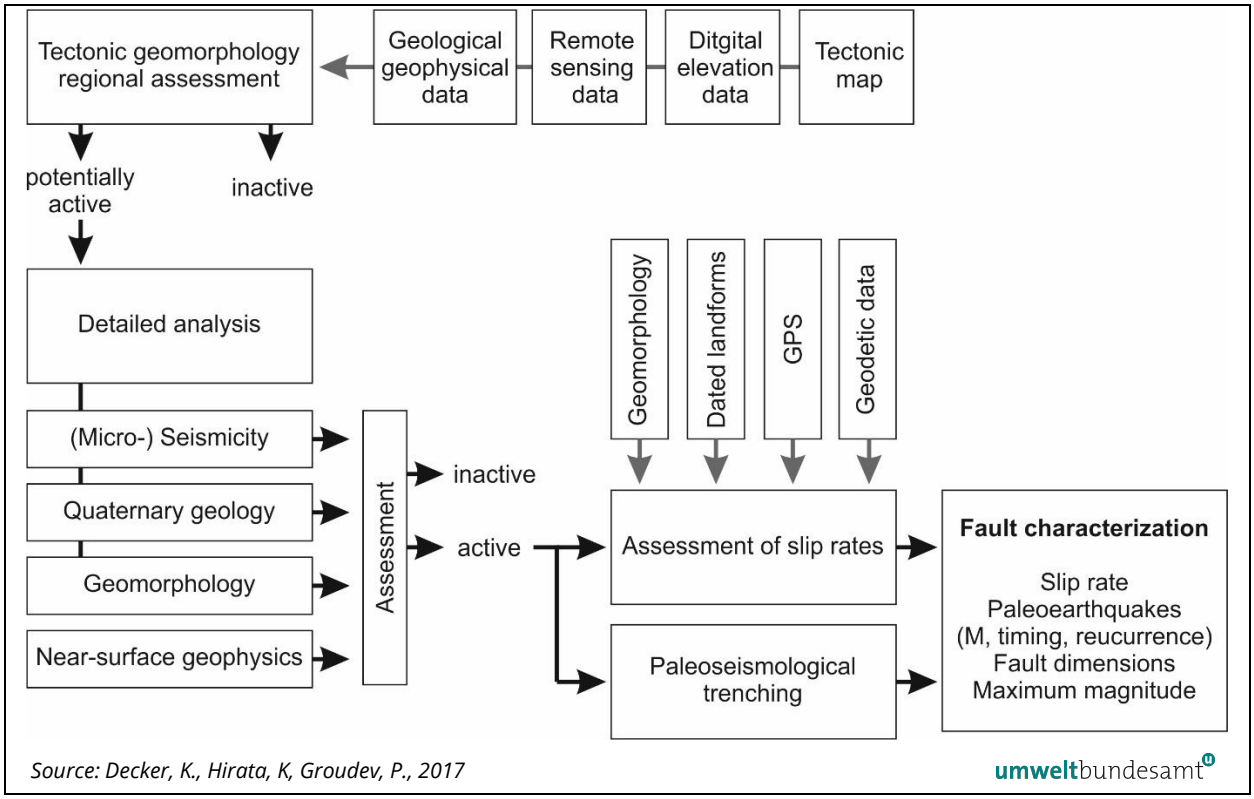
APPENDIX 2

Decker, K., Hirata, K, Groudev, P., 2017: Flow chart of the graded approach for the identification and assessment of active / capable faults in the near-region and region of a site (Fig. 14, p. 71).



APPENDIX 3

EAA Experts (K. Decker, C. Grützner, E. Hintersberger, M. Strecker) 2023: Workshop on the Paks II site characteristics. Presentation to HAEA, Budapest, Jan 24, 2023.

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Umweltbundesamt GmbH
Spittelauer Laende 5
1090 Vienna/Austria

Tel.: +43-1-313 04

office@umweltbundesamt.at
www.umweltbundesamt.at

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