umweltbundesamt

ETE Road Map

According to Chapter IV and V of the “Conclusions of the Melk Process and Follow-Up”

Item 6
Site Seismicity

Preliminary Monitoring Report

Report to the Federal Ministry of Agriculture, Forestry, Environment and Water Management of Austria

Vienna, August 2004

vce

Institut für Risikoforschung
der Universität Wien

Project Coordination

Katja Lamprecht
(Umweltbundesamt – Federal Environment Agency Ltd. – Austria)

Layout

Manuela Kaitna/Claudia Kubelka
(Umweltbundesamt – Federal Environment Agency Ltd. – Austria)

Technical Project Management

Helmut Wenzel
(VCE Holding GmbH – Vienna, Austria)

Wolfgang Kromp
(Institute of Risk Research – University of Vienna, Austria)

Contributions by

Kurt Decker
(Institute of Geology – University of Vienna, Austria)

Ralph Hinsch
(Institute of Geology – University of Vienna, Austria)

Helmut Hirsch
(Working Group CERVUS – Germany)

Gerhard Jentzsch
(Working Group CERVUS, Institute of Applied Geophysics – University of Jena, Germany)

Franz Kohlbeck
(Institute of Geodesy and Geophysics – Vienna University of Technology, Austria)

Roman Lahodynsky
(Institute of Risk Research – University of Vienna, Austria)

Mustapha Meghraoui
(Ecole et Observatoire des Sciences de la Terre (EOST) – Strasbourg, France)

Roger M.W. Musson
(British Geological Survey – Edinburgh, UK)

Barbara Theilen-Willige
(Büro für Angewandte Geowissenschaftliche Fernerkundung (BAGF) – Stockach, Germany)

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Masthead

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Note to the Reader

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Should you encounter technical problems, please do not hesitate to contact mailto: marlene.engel@umweltbundesamt.at.

EXECUTIVE SUMMARY

Framework

The Republic of Austria and the Czech Republic have, using the good offices of Commissioner Verheugen, reached an accord on the “Conclusions of the Melk Process and Follow-up” on 29 November 2001. In order to enable an effective use of the “Melk Process” achievements in the area of nuclear safety, the Annex I of this “Brussels Agreement” contains details on specific actions to be taken as a follow-up to the “trialogue“ of the “Melk Process” in the framework of the pertinent Czech-Austrian Bilateral Agreement.

Furthermore, the Commission on the Assessment of Environmental Impact of the Temelín NPP - set up based on a resolution of the Government of the Czech Republic - presented a report and recommended in its Position the implementation of twenty-one concrete measures (Annex II of the “Brussels Agreement”).

The signatories agreed that the implementation of these measures would also be regularly monitored jointly by Czech and Austrian experts within the Czech-Austrian Bilateral Agreement.

A “Roadmap” regarding the monitoring on the technical level in the framework of the pertinent Czech-Austrian Bilateral Agreement as foreseen in the “Brussels Agreement” has been elaborated and agreed by the Deputy Prime Minister and the Minister of Foreign Affairs of the Czech Republic and the Minister of Agriculture and Forestry, Environment and Water Management of the Republic of Austria on 10 December 2001.

The Federal Ministry of Agriculture, Forestry, Environment and Water Management entrusted the Umweltbundesamt (Federal Environment Agency Ltd.) with the general management of the implementation of the “Roadmap”. Each entry to the “Roadmap” corresponds to a specific technical project.

Item Nr.6 “Site Seismicity” of Annex I of the “Brussels Agreement” covers the site selection in relating to the possible seismicity. As shown in Annex I of the “Brussels Agreement”, the objective under this issue is: *“Siting of the installation shall take into account seismic as one of the possible external hazards.”*

Annex I of the “Brussels Agreement” further specified the “Present Status and Specific Action Planned” as follows: *“The NPP Temelín underwent a thorough siting procedure in relation to possible seismic hazards. The Czech standard for this procedure is based on IAEA recommendations. A set of written documentation was released prior and in course of the “Trialogue” giving evidence of this process. Due to the complexity of this issue and in order to foster mutual understanding, a topical workshop will be organised in the frame of the bilateral co-operation.”*

The “Roadmap” specified that a Specialists’ Workshop would be held in the first half of the year 2003 to discuss this issue. The Workshop was held in Prague in March 27-28, 2003.

VCE Holding GmbH and the Institute of Risk Research of the University of Vienna was committed by the Federal Environment Agency on behalf of the Austrian Government to give technical support for the monitoring on the technical level of the implementation of the conclusions regarding the item Site Seismicity. This technical support focuses on the evaluation of the extent of conformity of the seismic hazard assessment for NPP Temelín with state-of-the-art practice in European Union member states and IAEA guidelines.

This specific technical project is referred to as project PN6 comprising altogether seven predefined “project milestones” (PM).

To focus preparatory work of the Austrian Expert Team and to guide the Austrian Delegation through the Experts’ Workshop, but also to enable proper preparation of the Experts’ Workshop on the bilateral level, in a first step (Project Milestone 1), the safety objective was broken down to Verifiable Line Items (VLIs). In a second step the Experts' Team prepared a list of documents, the Specific Information Request (SIR), considered to contain the kind of information required to provide for profound answers to the VLIs. Summarizing the VLIs treat the procedures of the seismic assessment, legal issues, risk management and data collection, as well as seismotectonic methods and results, practical implementation and the consequences of an earthquake.

Based on the recognition that the pertinent Czech-Austrian Bilateral Agreement is the appropriate framework giving the opportunity for further discussion and sharing additional information on these issues, it would be appreciated if the major findings could be resolved in the further monitoring process.

The Approach by the Czech Side

The key element in the monitoring process was the Experts' Workshop on the item PN6 "Seismic Hazard Assessment of the Temelín NPP Site" of the roadmap held within the frame of an additional expert meeting following § 7 (4) of the bilateral agreement on the exchange of information about nuclear safety on March 27 and 28, 2003.

Information about the following main areas was presented by experts from SÚJB, the State Office for Nuclear Safety, CEZ ETE, S&A-CZ Stevenson and Associates, Energoprůzkum, Institute of Rock Structure and Mechanics of the Academy of Science, the Institute of Physics of the Earth of the Masaryk University Brno and Energoprojekt:

- Site Seismic Licensing Requirements
- Introductory Remarks of the NPP Temelín
- Summary of International Seismic Missions and Audits
    - History of the construction of the Temelín NPP
    - Summary of international seismic missions and audits
- Geological Investigations
    - Regional and near-regional geological data
    - Site vicinity investigations
    - Site area investigations
- Seismological Data – Earthquake Hazard Assessment
    - Historical earthquake data and catalogues
    - Regional seismogenic zones
    - Isoseismal maps and macroseismic observations
    - Intensity attenuation relations
    - Probabilistic hazard assessment
- Microearthquake Monitoring
    - Local seismic network
    - Recorded seismic events and interpretation of results
    - Seismological information display
- Seismotectonic Investigations
    - Regional seismotectonic model, description and criteria
    - Deterministic hazard assessment
- Temelín Seismic Monitoring System

- Supplementary Earthquake Hazard Assessment
- Earthquake Hazard Assessment
- Seismic Design Basis
    - SL1 and SL2 determination
    - Response spectra and accelerograms.

The analysis of the information made available there (SÚJB, ed., 2003: Seismic Hazard Assessment of Temelín NPP Site. Workshop. Abstract Volume and CD-Rom) is the basis for the present Preliminary Monitoring Report of the Austrian Expert Team.

The Approach by the Austrian Expert Team

VCE Holding GmbH and the Institute of Risk Research of the University of Vienna, committed by the Federal Environment Agency on behalf of the Austrian Government to give technical support for the monitoring on the technical level, set up a team of ten international experts. The specific technical project is referred to as project PN6.

To focus preparatory work of the Austrian Expert Team and to guide the Austrian Delegation through the Experts' Workshop, but also to enable proper preparation of the Experts' Workshop on the bilateral level, in **a first step** (Project Milestone 1), the safety objective was broken down to Verifiable Line Items (VLIs)

In a **second step** the Experts' Team prepared a list of documents, the Specific Information Request (SIR), considered to contain the kind of information required to provide for profound answers in the VLIs.

The **third step** in the preparatory work for the workshop also included the identification of the IAEA Safety Standards for the Evaluation of the Seismic Hazards for Nuclear Power Plants and a GIS based tectonic investigation of Satellite Data from the Southern part of the Bohemian Massive.

Following the Workshop in the current **fourth step**, the Experts' Team reviewed the data received at the Experts' Workshop in Prague and during internal meetings of the Austrian Expert Team. The experts provided contributions to the Preliminary Monitoring Report (PMR).

Preliminary Result of the Monitoring

The monitoring process so far helped to clarify a number of VLIs. Based on the information available, the Austrian Expert Team formulates its view on the status of the seismicity and seismic hazard of the Temelín NPP site as follows:

There has been recently a considerable change in the engineering approach towards the seismic evaluation of existing nuclear facilities, particular affecting those plants situated in previously as "quiet" assessed sites. This trend, which is supported actually worldwide, is towards the consideration of longer return periods and the probability of site effects.

There is a clear consensus amongst the Austrian Expert Team that the information and materials received from the Czech experts during the Specialists Workshop at SUJB Praha (March 27 and 28, 2003) was very informative. The Czech experts demonstrated that they made efforts to clarify questions put by IAEA review teams concerning seismic hazard assessment that remained open.

Nevertheless there are remaining topics, which the Austrian Expert Team recommends to the Austrian Government to be further investigated to enable a conclusive assessment. The main questions of the Austrian Expert Team concern the following topics:

Geology &Tectonics

Only three out of twelve faults in the near region of Temelín were studied in some detail. No high resolution geophysical methods except geoelectrics were applied to locate and map near surface faults and choose the right places for state of the art trenching. The existing data for the most prominent scarp, the Hluboka fault, comprise only one section based on three boreholes and are insufficient to date the youngest fault activity. This has been also criticized by IAEA-mission in 2003.

The apparent uplift of Quaternary terraces (upward convex topography at the crossing of Vltava River and Hluboka fault) and the increased number of terraces north of Budweis Basin seem to be related to Quaternary tectonics. These geomorphological features are not addressed in the report (Simunek, 1995). Appropriate age data for quaternary sediments are lacking (no biostratigraphic or radiometric data). Segmented fans adjacent to the suspected Hluboka fault scarp may be indicative for active uplift along the scarp. Published geodetic data (Vyskocil, 1975) indicate an ongoing subsidence of the Budweis Basin.

Seismicity & Seismic Hazard Assessment

The deterministic method presented by Czech experts is based on an expert system that is not internationally verified. The near site hazard calculation is based on insufficient data and uncertainties are not given. For some zones the maximum credible earthquake (MCE) and also the SL2 level earthquake is based on the relation $I_{mc} = I_0 + 0.5°$ (I_0= observed intensity of the largest known earthquake within a region and I_{mc} = maximum credible earthquake of the region). However, standard safety margin would be 1° instead of 0.5° - see IAEA mission Feb. 2003 – whereas some authors add 1.5°. For that reason the seismic hazard for Temelín site is underestimated by at least 0.5° with that method. From historical reports an observed intensity of I = 6.0° – 6.5° is derived for Southern Bohemia. Based solely on the derivation of the MCE from data of the strongest historical earthquake of the whole region (Neulengbach, 1590) we conclude a conservative value of 7° - 7.5°MSK for the SSE. Especially areas of assumed low seismicity should take into account longer return periods of strong earthquakes and investigate the geochronological record to extend the catalogue coverage. Despite recommendations by IAEA (Guidelines and Site safety review mission, 1990) to determine a MCE by dating youngest movements of faults (paleoseismological method) this method was not performed.

The probabilistic method presented by Czech experts uses an inappropriate attenuation relation derived from an U.S site. This relation does not take into account the strong directional variation for attenuations on regional earthquakes felt in Southern Bohemia. The study presented by SUJB (2003) demonstrates attenuation for waves from the Mur-Mürz-Leitha Fault that is nearly one degree higher than that relation found by a more profound investigation by Simunek et al. (1995). In addition the probabilistic calculation does not use the correct spread of the data. Instead it uses a predefined unrealistic uncertainty. For that reason this approach is not a stochastic one and does not follow IAEA recommendations. We expect that a recalculation will give an SL2-level earthquake of at least 7° MSK.

The correlation between intensity I = 7° MSK and a MHPGA (maximum horizontal peak ground acceleration) of 0.1g reflects only a global mean value. French, German and Russian standards correlate intensity levels with higher g values and therefore follow a more conservative approach. The value of 0.1g accepted in Temelín for the SSE is equal only to the minimum requirements of the IAEA and does not contain any safety margin! The Czech hazard assessment therefore cannot be addressed as conservative.

ZUSAMMENFASSUNG

Rahmenbedingungen

Die Republik Österreich und die Tschechische Republik haben mit Unterstützung des Mitglieds der Kommission Verheugen am 29. November 2001 eine Übereinstimmung über die „Schlussfolgerungen des Melker Prozesses und das Follow-up“ erzielt. Um eine wirksame Umsetzung der Ergebnisse des Melker Prozesses im Bereich der nuklearen Sicherheit zu ermöglichen, enthält der Anhang I dieses „Brüsseler Abkommens“ Details zu spezifischen Maßnahmen, die als Follow-up zum „Trialog“ des Melker Prozesses im Rahmen des betreffenden bilateralen tschechisch-österreichischen Abkommens durchzuführen sind.

Weiters legte die Kommission zur Prüfung der Umweltverträglichkeit des KKWs Temelin, die auf Grund einer Resolution der Regierung der Tschechischen Republik eingesetzt wurde, einen Bericht vor und schlug in ihrer Stellungnahme die Umsetzung einundzwanzig konkreter Maßnahmen vor (Anhang II des „Brüsseler Abkommens“).

Die Unterzeichner kommen überein, dass die Umsetzung der genannten Maßnahmen von tschechischen und österreichischen Experten regelmäßig und gemeinsam im Rahmen des bilateralen Abkommens über den Austausch von Informationen überwacht wird.

Zur Überwachung auf technischer Ebene im Rahmen des diesbezüglichen tschechisch-österreichischen bilateralen Abkommens wurde, wie im „Brüsseler Abkommen“ vorgesehen, eine „Roadmap“ („Fahrplan“) ausgearbeitet und am 10. Dezember 2001 vom stellvertretenden Premierminister und Außenminister der Tschechischen Republik sowie vom Bundesminister für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft der Republik Österreich vereinbart.

Das österreichische Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft beauftragte das Umweltbundesamt mit der Gesamtkoordination der Umsetzung der „Roadmap“. Jeder Eintrag in der „Roadmap“ entspricht einem spezifischen technischen Projekt.

Punkt Nr. 6 „Erdbebengefährdung des Standortes“ im Anhang I des „Brüsseler Abkommens“ behandelt die Standortauswahl unter Einbezug einer möglichen Erdbebengefährdung. Wie im Anhang I des „Brüsseler Abkommens“ angeführt, lautet das Ziel unter diesem Punkt: *„Für den Standort der Einrichtung ist die Erdbebengefährdung als eine der möglichen externen Gefahren zu berücksichtigen“.*

Der derzeitige Stand und geplante spezifische Massnahmen wurden im Anhang I des „Brüsseler Abkommens“ folgendermaßen beschrieben*: „Das KKW Temelin ist einem gewissenhaften Standortauswahlverfahren bezüglich einer möglichen Erdbebengefährdung unterzogen worden. Der tschechische Standard für dieses Verfahren beruht auf Empfehlungen der IAEO. Eine Reihe von schriftlichen Unterlagen, die dieses Verfahren belegen, wurde vor und im Laufe des „Trialogs“ veröffentlicht. Aufgrund der Komplexität dieser Frage und zur Förderung des gegenseitigen Verständnisses wird im Rahmen der bilateralen Zusammenarbeit ein diesbezüglicher Workshop veranstaltet.“*

Die „Roadmap“ sah für die erste Hälfte des Jahres 2003 einen Experten-Workshop zur Erörterung dieser Thematik vor. Dieser Workshop wurde vom 27. bis 28. März, 2003 in Prag abgehalten.

VCE Holding GmbH und das Institut für Risikoforschung der Universität Wien wurden im Namen der Österreichischen Bundesregierung vom Umweltbundesamt beauftragt, den Monitoringprozess auf technischer Ebene in Hinblick auf das Thema Standortseismizität zu unterstützen. Diese technische Unterstützung konzentrierte sich auf die Bewertung der Übereinstimmung der seismischen Gefährdungseinschätzung für das Kernkraftwerk Temelín mit der derzeit in den Mitgliedstaaten der Europäischen Union geübten Praxis und mit den Richtlinien der IAEA.

Dieses spezifische technische Projekt wird als Projekt PN6 bezeichnet und umfasst insgesamt sieben vorgegebene „Projektmeilensteine“ (PM).

Um die Vorbereitungsarbeit des österreichischen Expertenteams zu bündeln und die österreichische Delegation durch den Experten-Workshop zu leiten, wurde in einem ersten Arbeitsschritt (Projektmeilenstein 1) das Sicherheitsziel zu überprüfbaren Programmpunkten (VLI) aufgegliedert.

In einem zweiten Arbeitsschritt bereitete die österreichische Expertengruppe eine Dokumentenliste, den sogenannten „Specific Information Request – SIR“ vor, die - nach Meinung des Expertenteams – die notwendige Information enthält, um eine fundierte Beantwortung der VLIs zu ermöglichen. Die VLIs umfassen Punkte zum Verfahren der Abschätzung der Seismizität, zu rechtlichen Aspekten, zum Risiko-Management und zur Datensammlung, aber auch zu seismotektonischen Methoden und Ergebnissen sowie zum Thema der praktischen Ausführung und der Konsequenzen eines Erdbebens.

Im Bewusstsein, dass das einschlägige Tschechisch-Österreichische Bilaterale Nuklearinformationsabkommen einen geeigneten Rahmen für weitere Diskussion und einen zusätzlichen Informationsaustausch darstellt, wäre es wünschenswert, wenn die wesentlichen Ergebnisse dieses Berichtes im Verlauf eines weiteren Monitoringprozesses behandelt werden könnten.

Der Ansatz der Tschechischen Seite

Ein wesentliches Ergebnis im Monitoringprozess war das Experten-Workshop zu dem Punkt Nr. 6 „Erdbebengefährdung des Standortes“ der „Roadmap“, der am 27. und 28. März 2003 in Prag im Rahmen eines zusätzlichen Expertentreffens gemäß Artikel 7 (4) des bilateralen Abkommens über den Austausch von Informationen über die nukleare Sicherheit abgehalten wurde.

Die Beurteilung der dort zur Verfügung gestellten Informationen dient als Grundlage für den vorliegenden Bericht (Preliminary Monitoring Report, PMR) des österreichischen Expertenteams.

Informationen zu den folgenden Themen wurde von Experten von SÚJB, dem Staatsamt für Nukleare Sicherheit, CEZ ETE, S&A-CZ Stevenson and Associates, Energoprùzkum, Institut für Gesteinsstruktur und Felsmechanik der Akademie der Wissenschaften, dem Institut für Physik der Erde der Masaryk Universität Brno und Energoprojekt präsentiert:

- Lizenzvoraussetzungen bezogen auf die Standortseismizität
- Einleitende Bemerkungen des Betreibers des AKW Temelín
- Zusammenfassung internationaler seismischer Entsendungen und Anhörungen
    - Geschichte der Errichtung des AKW Temelín
    - Zusammenfassung internationaler seismischer Entsendungen und Anhörungen
- Geologische Untersuchungen
    - Regionale und engräumig-regionale geologische Daten
    - Untersuchungen in der Umgebung des Standortes
    - Untersuchungen auf dem Standortgelände
- Seismologische Daten – Beurteilung der Erdbebengefährdung
    - Historische Erdbebendaten und Kataloge
    - Regionale seismogene Zonen
    - Karten der Isoseisten und makroseismische Beobachtungen
    - Beziehungen der Intensitätsabminderung
    - Probabilistische Gefährdungsabschätzung

- Aufzeichnung der Mikroerdbeben
    - Lokales seismisches Stationsnetz
    - Aufgezeichnete seismische Ereignisse und Interpretation der Ergebnisse
    - Demonstration der seismologischen Information
- Seismotektonische Untersuchungen
    - Regionales seismotektonisches Modell, Beschreibung und Kriterien
    - Deterministische Gefährdungsabschätzung
- Erdbebenaufzeichnungssystem in Temelín
- Ergänzende Erdbebengefährdungsabschätzung
- Erdbebengefährdungsbeurteilung
- Basis des Erdbeben-Designs
    - Festlegung von SL1 und SL2
    - Antwortspektren und Beschleunigungswerte

Der Ansatz des Österreichischen Expertenteams

VCE Holding GmbH und das Institut für Risikoforschung der Universität Wien, vom Umweltbundesamt im Namen der Österreichischen Bundesregierung für den technischen Support des Monitoringprozess auf technischer Ebene beauftragt, stellten ein Team von zehn internationalen Experten zusammen. Dieses spezielle technische Projekt wird als PN6 bezeichnet.

Um die Vorbereitungsarbeit des österreichischen Expertenteams zu bündeln und die österreichische Delegation durch den Experten-Workshop zu leiten, wurde in einem ersten Arbeitsschritt (Projektmeilenstein 1) das Sicherheitsziel zu überprüfbaren Programmpunkten (VLI) aufgegliedert.

In einem zweiten Arbeitsschritt bereitete die österreichische Expertengruppe eine Dokumentenliste, den sogenannten „Specific Information Request – SIR“ vor, die - nach Meinung des Expertenteams – die notwendige Information enthält, um eine tiefgreifende Beantwortung der VLIs zu ermöglichen.

Der dritte Schritt zur Vorbereitung des Experten-Workshops beinhaltete die Identifizierung der IAEA-Sicherheitsstandards zur Abschätzung der seismischen Gefährdung von Kernkraftwerken und eine auf geographische Informationssysteme beruhende tektonische Untersuchung auf Basis von Satellitendaten über den südlichen Teil der Böhmischen Masse.

Im vierten Schritt, welcher dem Workshop nachfolgte, diskutierte das Expertenteam jene Materialien und Informationen, die es während des Experten-Workshops in Prag erhalten hat. Die Experten erarbeiteten Beiträge für den vorliegenden Bericht.

Bisheriges Ergebnis des Monitoringprozesses

Der bisherige Verlauf des „Monitoring Process“ ermöglichte es, bereits eine Reihe von VLIs abzuklären. Basierend auf der verfügbaren Information formulierte das Expertenteam seine Sichtweise über den Stand der Seismizität und seismischen Gefährdung des Kernkraftwerkes Temelín wie folgt:

Der Ansatz der seismischen Evaluierung existierender Kernkraftwerke in bisher als “ruhig” gewerteten Standorten, hat sich in jüngster Zeit gravierend verändert. Dieser Trend, welcher weltweit wahrgenommen wird, geht in Richtung der Berücksichtigung erheblich längerer Wiederkehrintervalle und der Berücksichtigung der Möglichkeit von standortspezifischen Effekten.

Im österreichischen Expertenteam herrscht klare Übereinstimmung darüber, dass die von den Tschechischen Experten während des Experten-Workshops (bei SUJB in Prag, 27. – 28.März 2003) übermittelten Informationen und Materialien sehr informativ waren. Die Tschechischen Experten zeigten, dass sie Anstrengungen unternahmen um offene Fragen zur seismischen Gefährdungsabschätzung seitens der IAEA Review Teams klarzustellen.

Trotzdem verbleiben einige Punkte, zu welchen das Expertenteam der österreichischen Bundesregierung weitere Untersuchungen empfiehlt, um eine schlüssige Bewertung zu ermöglichen. Die wesentlichen Fragen des österreichischen Expertenteams betreffen die folgenden Themen:

Geologie & Tektonik

In der näheren Umgebung von Temelín wurden nur 3 von 12 tektonischen Störungen im Detail untersucht. Um oberflächennahe Störungen zu lokalisieren und die richtigen Stellen für Grabungsschlitze auszuwählen, wurden außer der Geoelektrik keine hochauflösenden Methoden angewendet.

Die vorhandene Information über die markanteste Geländestufe, der Hluboka Störung, besteht lediglich aus einem Profil, basierend auf drei Bohrlöchern. Diese Daten sind für eine Datierung der jüngsten Störungsaktivität nicht ausreichen. Dieses Manko wurde auch von der IAEA-Mission 2003 kritisiert.

Es scheint, dass die nachgewiesenen Hebungsvorgänge quartärer Terrassen (siehe ihre konvexe Topographie am Schnittpunkt von Moldau und Hluboka Störung) und die große Anzahl von Terrassen nördlich des Budweiser Beckens an die quartäre Tektonik geknüpft sind. Diese geomorphologischen Charakteristika werden im Bericht von Simunek (1995) nicht angesprochen. Es existieren keine entsprechenden Daten (biostratigraphische oder radiometrische) über das Alter der quartären Sedimente. Die segmentierten Fächer in der Nähe der Hluboka Störung könnten auf eine aktive Hebung entlang dieser Geländestufe hinweisen. Auch die publizierten Vermessungsdaten (Vyskocil, 1975) deuten auf eine anhaltende Absenkung des Budweiser Beckens hin.

Seismizität & Seismische Gefährdungsabschätzung

Die deterministische Methode, welche von den Tschechischen Experten vorgestellt wurde, basiert auf einem Expertensystem, das international nicht verifiziert ist. Die Gefährdungsberechnung für die Umgebung des Standortes basiert auf ungenügenden Daten, Unsicherheiten werden nicht angegeben. Für einige der beschriebenen Zonen basiert das maximal mögliche Beben (MCE) und auch das Beben der SL2-Stufe auf der Beziehung $I_{mc} = I_0 + 0.5°$ (I_0 = beobachtete Intensität des größten bekannten Bebens innerhalb einer Region und I_{mc} = maximal mögliches Beben der Region). Der anerkannte Sicherheitsrahmen beträgt jedoch 1° statt der verwendeten 0.5° (siehe Mission der IAEA im Februar 2003), manche Autoren addieren sogar 1.5°. Aus diesem Grund wird mit der angewendeten Methode die seismische Gefährdung von Temelín mindestens um 0.5° unterschätzt. Aus historischen Quellen wird für Südböhmen eine beobachtete Intensität von I_0 = 6.0° - 6.5° abgeleitet. Basierend auf der Herleitung des MCE aus Daten des historisch stärksten Bebens der gesamten Region (Neulengbach, 1590) schließen wir auf einen konservativen Wert von 7° - 7.5° MSK für das SSE. Speziell Gebiete mit angenommener, geringer Seismizität sollten längere Wiederkehrperioden von Starkbeben berücksichtigen und die geochronologische Vorgeschichte untersuchen. Trotz den Empfehlungen der IAEA - in den Richtlinien und im Bericht der Standortsicherheitsüberprüfungsmission (1990) -, ein MCE durch die Altersdatierung der jüngsten Bewegungen an tektonischen Störungen zu bestimmen (paläoseismologische Methode), wurde diese Methode nicht durchgeführt.

Die probabilistische Methode verwendet ein von einem US Standort hergeleitetes, ungeeignetes Abminderungsverhältnis. Dieses berücksichtigt nicht den stark richtungsabhängigen Wechsel in der Abminderung regionaler, in Südböhmen fühlbarer Erdbeben. In der von SUJB vorgestellten Studie (2003) ist die Abminderung der von der Mur-Mürz-Leitha Störung stammenden Bebenwellen um fast einen Grad höher, als in der von der tiefgehenden Untersuchung durch Simunek et al. (1995) vorgefundenen Beziehung. Dazu kommt, dass die probabilistische Berechnung nicht die korrekte Datenstreuung errechnet. Stattdessen verwendet sie eine vorher festgelegte unrealistische Unsicherheit. Aus diesem Grund ist der Ansatz nicht stochastisch und folgt nicht den Empfehlungen der IAEA. Im Falle einer Nachrechnung wird ein Mindestwert von 7°MSK für ein Erdbeben des SL2-Niveaus erwartet.

Die Korrelation zwischen der Intensitätsstufe I = 7° MSK und 0,1g (Spitzenwert der maximalen horizontalen Bodenbeschleunigung, MHPGA- oder PGA-Wert) spiegelt lediglich einen weltweiten Mittelwert wieder. In den deutschen, französischen und russischen Standards korrelieren die Intensitätsstufen mit höheren Beschleunigungswerten und entsprechen daher einem konservativeren Ansatz. Der in Temelín für das SSE angenommene Wert von 0,1g entspricht lediglich den Mindestanforderungen der IAEA. Daher kann die tschechische Gefährdungsabschätzung nicht als konservativ bezeichnet werden.

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1 INTRODUCTION

1.1 Framework

The Republic of Austria and the Czech Republic have, using the good offices of Commissioner Verheugen, reached an accord on the "Conclusions of the Melk Process and Follow-up" on 29 November 2001. In order to enable an effective use of the "Melk Process" achievements in the area of nuclear safety, the Annex I of this "Brussels Agreement" contains details on specific actions to be taken as a follow-up to the "Trialogue" of the "Melk Process" in the framework of the pertinent Czech-Austrian Bilateral Agreement.

To enable an effective "Trialogue" follow-up in the framework of the pertinent Czech-Austrian Bilateral Agreement, a seven-item structure given in Annex I of the "Brussels Agreement" has been adopted. Individual items are linked to:

- Specific objectives set in licensing case for NPP Temelín units
- Description of present status and future actions foreseen by the licensee and SÚJB respectively.

Each item under discussion will be pursued according to the work plan agreed at the Annual Meeting organised under the pertinent Czech-Austrian Bilateral Agreement.

Furthermore, the Commission on the Assessment of Environmental Impact of the Temelín NPP - set up based on a resolution of the Government of the Czech Republic - presented a report and recommended in its Position the implementation of twenty-one concrete measures (Annex II of the "Brussels Agreement).

The signatories agreed that Czech and Austrian experts within the Czech-Austrian Bilateral Agreement would also regularly monitor the implementation of these measures jointly.

A "Roadmap" regarding the monitoring on the technical level in the framework of the pertinent Czech-Austrian Bilateral Agreement as foreseen in the "Brussels Agreement" has been elaborated and agreed by the Deputy Prime Minister and Minister of Foreign Affairs of the Czech Republic and the Minister of Agriculture and Forestry, Environment and Water Management of the Republic of Austria on 10 December 2001.

This „Roadmap" is based on the following principles:

- The implementation of activities enumerated in Annex I and II of the "Brussels Agreement" will be continued to ensure that comprehensive material is available for the monitoring activities set out below.
- Having in mind the peer review procedure foreseen by the EU to monitor the implementation of the recommendations of the AQG/WPNS Report on Nuclear Safety in the Context of Enlargement, the Czech and Austrian sides agree that this peer review should serve as another important tool to handle remaining nuclear safety issues.
- As a general rule the regular annual meetings according to Art. 7(1) of the bilateral Agreement between the Government of Austria and the Government of the Czech Republic on Issues of Common Interest in the Field of Nuclear Safety and Radiation Protection will serve to monitor the implementation of those measures referred to in Chapter V of the Conclusions and to address questions regarding nuclear safety in general, in particular those issues which – according to Chapter IV of the Conclusions - have been found, due to the nature of the respective topics, suitable to be followed-up in the framework of this Bilateral Agreement.
- In addition, specialists' workshops and topical meetings will take place, organised as additional meetings according to Art. 7(4) of the bilateral Agreement between the Government of Austria and the Government of the Czech Republic on Issues of Common Interest in the Field of Nuclear Safety and Radiation Protection, as set out in the "Roadmap".

The Federal Ministry of Agriculture, Forestry, Environment and Water Management entrusted the Umweltbundesamt with the general management of the implementation of the “Roadmap”. Each entry to the “Roadmap” corresponds to a specific technical project.

Item Nr.6 “Site Seismicity” of Annex I of the “Brussels Agreement” covers the site selection in relating to the possible seismicity. As shown in Annex I of the “Brussels Agreement”, the objective under this issue is: *“Siting of the installation shall take into account seismic as one of the possible external hazards.”*

Annex I of the “Brussels Agreement” further specified the “Present Status and Specific Action Planned” as follows: *“The NPP Temelín underwent a thorough siting procedure in relation to possible seismic hazards. The Czech standard for this procedure is based on IAEA recommendations. A set of written documentation was released prior and in course of the “Trialogue” giving evidence of this process. Due to the complexity of this issue and in order to foster mutual understanding, a topical workshop will be organised in the frame of the bilateral co-operation.”*

The “Roadmap” specified that a Specialists’ Workshop would be held in the first half of the year 2003 to discuss this issue. The Workshop was held in Prague in March 27-28, 2003.

VCE Holding GmbH and the Institute of Risk Research of the University of Vienna was committed by the Federal Environment Agency on behalf of the Austrian Government to give technical support for the monitoring on the technical level of the implementation of the conclusions regarding the item Site Seismicity. This technical support focuses on the evaluation of the extent of conformity of the seismic hazard assessment for NPP Temelín with state-of-the-art practice in European Union member states and IAEA guidelines.

This specific technical project is referred to as project PN6 comprising altogether seven predefined “project milestones” (PM).

To focus preparatory work of the Austrian Expert Team and to guide the Austrian Delegation through the Experts’ Workshop, but also to enable proper preparation of the Experts’ Workshop on the bilateral level, in a first step (Project Milestone 1), the safety objective was broken down to Verifiable Line Items (VLIs). In a second step the Experts’ Team prepared a list of documents, the Specific Information Request (SIR), considered to contain the kind of information required to provide for profound answers to the VLIs. Summarizing the VLIs treat the procedures of the seismic assessment, legal issues, risk management and data collection, as well as seismotectonic methods and results, practical implementation and the consequences of an earthquake.

Based on the recognition that the pertinent Czech-Austrian Bilateral Agreement is the appropriate framework giving the opportunity for further discussion and sharing additional information on these issues, it would be appreciated if the major findings could be resolved in the further monitoring process.

1.2 Site Evaluation

Seismic hazard estimates based on historical earthquake data and other traditional methods tend to underestimate true risk. New methods based on geological evidence have been developed and are being applied in many countries, some of which have started reassessment of the seismic hazard for their nuclear power plants. The IAEA has taken this development into account in its guidelines issued 1991 and recommends i.e. dating the youngest activity of seismic faults as well as inclusion of paleoseismological methods.

Considering the operational experience in nuclear power plants worldwide extreme external events, even though they are rare, have proven to be some of the most serious initiators of degradation of defense in depth. Among them, earthquakes represent one of the most serious events, besides low temperatures, high winds, flooding, lightning, biological fouling, electromagnetic interference and terrorist attacks. These either directly effects the plant or cause degradation of safety features through the unavailability of off-site power and/or evacuation and access routes. Considering the very low probability of occurrence of such external events some intrinsic difficulties arise in the definition of the appropriate design parameters for such scenarios and particular for their combination. Furthermore discrepancies in engineering practices have been identified for different scenarios. This applies particular for earthquakes where some orders of magnitudes in difference are experienced in practice. An analysis of feedback experience from the operation of nuclear power plants shows few cases of degradation of the plant safety initiated by external events. However, when these had occurred, the consequences had been serious, involving challenges to the defense in depth of the plant. Different siting and design of nuclear power plants resulted in different engineering practices in the member states of the IAEA. This report covers the problem involved in the definition of the design bases parameters for the scenario earthquake, for the nuclear power plant Temelín shall be seen on the background of differences among the different regulators on the methods for the protection of operational NPPs in relation to external events.

One of the main topics for discussion concerned the generally accepted, ”risk based” context, where the probability of event occurrence is analyzed together with the probability of an induced radiological consequence (IAEA-TECDOC-1341). The engineering community conceptually accepts this, but its real application still proves to be unreliable and difficult. In fact, the evaluation of the risk usually adds large uncertainties to the whole siting and design process. Therefore the final plant safety level associated to a specific external event like earthquake is sometimes difficult to be demonstrated within a rigorous risk based approach. It has been found, that every member state gives different priorities to the relevant safety issues. A technical committee organized by IAEA in 2000 shows many relevant differences among the practices in the member states: Different classification criteria, different monitoring procedures and different operation procedures for pre- and post events, leaving the impression that every member state gives different priority to the relevant safety issues. Considering this experience it becomes clear that the evaluation of site seismicity might produce considerable different results depending on the approach and priority given. The demand for a systematic reevaluation approach has been recognized in the new IAEA-TECDOC-1333 [2, issued January 2003], which is devoted to “earthquake experience and seismic qualification by indirect methods in nuclear installation“.

In the IAEA safety guides the new term “site evaluation“ is defined in the following: “*The analysis of the sources of external events for a site that could give rise to hazards with potential consequences for the safety of a nuclear power plant constructed on that site. This includes: site characterization; consideration of external events that could lead to a degradation of the safety features of the plant and cause a release of radioactive material from the plant and/or affect the dispersion of such material in the environment; and consideration of population issues and access significant to safety (such as the feasibility of evacuation, the population distribution and the location of resources). The process of site evaluation continues throughout the lifetime of the facility, from the siting phase to design, construction, operation and decommissioning.”*

1.3 Objective of this Report

The objective of this report is to present an evaluation of the previous seismic hazard assessment for the Temelín NPP based on the information available to the Austrian side. The main information sources for this report were found in the published literature, in documents provided by the Czech side, in the documents of the former Melk Process and the previous environmental impact assessments and in the Workshop report of SÚJB. In particular, the aim of the report is to clarify and establish the issues which were resolved and to point out issues which are still pending. The basis for further monitoring within bilateral Czech-Austrian activities will be created out of these issues.

In particular this report will provide a technical background for the reassessment of the site seismicity of the NPP Temelín. Four major tasks are identified to comply with these objectives:

- Identification of major unresolved safety issues and of areas of future improvements/clarification,
- Overview of adopted approaches in comparable member states for site evaluation (I.E. Germany and France),
- Presentation and discussion of a few case studies and examples from regulatory and engineering practice, supported by data generated through remote sensing technologies,
- Preparation of a synthesis on the most updated engineering practice for a common understanding for major safety issues connected with site seismicity.

1.4 Report Structure

This report provides under chapter 1 (Introduction) an introduction to the framework of this report and to site assessment.

Under chapter 2 (Topics of Relevance from the Site Seismicity Assessment), a comprehensive summary of the work carried out by the Austrian Expert Team in order to establish the basic facts and figures necessary for assessment is provided.

Under chapter 3 (The Information Received from Czech Side) the information provided during the specialist’s workshop is summarized representing the approach of the Czech side.

Under chapter 4 (Conclusions from the Monitoring Process) the site seismicity is evaluated along the Verifiable Line Items defined for this process.

Some further, specific investigations are recommended to enable a final and conclusive assessment. These investigations and activities are summarized in chapter 5 (Recommended Additional Investigations).

Supplementary information is provided in the remaining chapters and **ANNEXES A – G.**

2 TOPICS OF RELEVANCE FOR SITE SEISMICITY ASSESSMENTS

In the following chapter the Austrian Expert Team has addressed the following specific topics in order to discuss technical details.

2.1 Site Seismic Licensing Requirements

2.1.1 Review of Documents on which the Decision on Site Selection was based

These Czech documents were not made available to the Austrian Expert Team. The literature published after the site selection gives only an indirect access to this process and is discussed in previous Austrian comments in the course of the Environmental Impact Assessments (UVP) of Temelín NPP and in the course of the Trialogue (Austrian Expert Team: 2001).

2.1.2 Czechoslovakian Standards for Seismic Site Evaluation Valid at the Time of Site Selection and Current Czech Standards

At the time of the site selection of the NPP Temelín the standard *“ČSN 730036 (1973, rev.1.10.1975) "Seismic loads and response of technical structures” has* been valid for civil structures. This standard was revised in 1990 and gained validity also for the non-important buildings of the NPP. Later on the Czechoslovakian Government issued several law collections addressing special regulations for NPPs. Seismic loads are addressed in the regulation *“Regulation No 4 of Czechoslovak Atomic Energy Commission on general criteria for sitting NPPs with regard to nuclear safety. Czechoslovak law collection, Praha 1979”* has been issued. Nuclear reactors of the type VVER-1000 (i.e., the Temelín reactor type) originally have been designed under observation of the Russian Standards *PN A3 G-5-006-87,* which includes norms for the design of seismically resistant nuclear power plants (revision 01.07.88, issued 1989, Moskau) and *PNAE G-7-002-86.*

Obviously these standards have also been observed during the first stage of construction of the Temelín reactors. At least since 1990 efforts have been undertaken to fulfil IAEA demands, especially the regulation *“IAEA, 50-SG-S1 (1991): Earthquakes and associated topics in relation to nuclear power plant sitting. Vienna: IAEA”.*

During the presentation of Czech experts in Prague March 2003 the following four regulations have been declared as being presently valid for NPP Temelín: *“Czech Atomic law Act No. 18/1997”, “Regulation No. 214/1997”, “Regulation No. 215/1997”,* and *“Regulation 195/1999”.*

At the Workshop at SÚJB Praha (2003) it was stated that these national standards are conform to the IAEA Standards *“IAEA 50-SG-S1”, “IAEA NS-G-3.3”, “IAEA 50-SG-D15”* and the IAEA Tecdocs *“TECDOC-343”* and *“TECDOC-724”.*

As a result of this accordance a detailed review of the documents as well as a comparison of Czechoslovakian regulations for seismic site evaluation and the new Czech standards seemed not to be necessary. A detailed evaluation of seismic hazard assessment and comparison of the Czech approach to the internationally valid IAEA standards is given in chapters below and summarized in chapter 2.9.

2.1.3 Equivalences and Differences to International Standards and Recommendations

An investigation of equivalences and differences to international standards and recommendations (in particular IAEA, EU, Russian and US) as well as a specific comparison of standards has already been presented by the Austrian side in comments on the Environmental Impact Assessment (UVP-1) (Umweltbundesamt, 2000).

According to the information by the Czech experts at the Workshop in Prague (2003) the IAEA regulations and Tecdocs *IAEA 50-SG-S1, IAEA NS-G-3.3, IAEA 50-SG-D15*, IAEA: *TECDOC-343* and *TECDOD-724* are accepted as normative for the seismic hazard assessment of the Temelín NPP site. Czech probabilistic and deterministic seismic hazard assessments for the NPP site, the procedure for determining the levels of the SL1 and SL2 earthquakes, the way of defining the seismic loads for the design basis earthquakes and the seismic engineering data (maximum accelerations, duration of excitation, free field response spectra) are therefore mainly reviewed in terms of the listed IAEA regulations.

Valid Czech regulations for the siting of NPPs are in some points more restrictive than IAEA criteria. According to Czech regulations NPPs may not be sited within areas with a maximum calculated earthquake (MCE) of 8°MSK or higher. In regions with MCE intensities greater than 7° MSK, NPPs may only be sited with specific restrictions. However, Czech regulations do not specify how to achieve maximum calculated earthquake intensities.

For the assessment of whether or not the Czech approach conforms to *“state of the art”* and *“current practice”* a review of the national regulations valid in Germany, France and the USA has been performed. Review shows that on the one hand, the state of science and technology is codified, to some part, in regulations (e.g., IAEA Regulations and Tecdocs). On the other hand, some regulations account for the continuous development as new scientific results and methods become available (e.g., the German KTA Regulations).

The German basic seismic regulations of the Nuclear Safety Standards Commission (KTA-Standards, 2201 series, dating back to 1990–1992) definitely refer to state of the art methods. They are considered as providing a general framework for the application of up-to-date methods. When assessing the current state-of-the-art in Germany, a compilation and evaluation of the current practice is of foremost importance. Seismic site assessments performed within the last few years can serve as characterization of the current state.

French standards are in accordance to IAEA regulations and are more specific in some points than IAEA regulations. Here, the *Règle fondamentale de Sureté RFS 2001-01* attempts to integrate the progress in the seismologic field, which has occurred in the last twenty years into the codified safety rules. This regulation is particular importance for assessing the current seismic state-of-the-art in France.

US regulations are more specific in seismic design e.g. *ASCE 4-86/4-98, USNRC 10 CFR part0 and 100, NUREG/CR-0098, EPRINP-6041-SL*. A detailed discussion of German and French regulations is included in **ANNEX D** (Hirsch et al.)

2.2 Seismic Site Re-evaluation

2.2.1 Standards for the Seismic Evaluation of Existing Nuclear Power Plants

The IAEA nuclear safety standards publications address the site evaluation and the design of new nuclear power plants (NPPs), including seismic hazard assessment and save seismic design, at the level of the safety requirements as well as the level of dedicated safety guides. It rapidly became apparent that the existing nuclear safety standards documents were not adequate for handling specific issues in the seismic evaluation of existing NPPs and that a dedicated document was necessary. For this purpose IAEA has published the safety reports series No. 28 “Seismic Evaluation of Existing Nuclear Power Plants”. This report is written in the spirit of the nuclear safety standards and can be regarded as guidance for the interpretation for their intent.

Worldwide experience shows that an assessment of the seismic capacity of an existing operating facility can be prompted for the following

1. Evidence of a greater seismic hazard at the site then expected before, owing to new or additional data and / or to new methods.
2. Regulatory requirements, such as periodic safety reviews, to ensure that the plant has adequate margins for seismic loads.
3. Lack of anti-seismic design or poor anti-seismic design.
4. New technical finding such as vulnerability of some structures or equipment, other feedback and new experience from real earthquakes (it is referred to the findings of the Kobe Earthquake 1995 and the Kozaeli Earthquake 2001, as well as the ChiChi Earthquake 2001).

Post construction evaluation programs evaluate the current capability of the plant (i.e. the plant “as is”) to withstand the seismic concern and identify any necessary upgrades or changes in operating procedures. Seismic qualification is distinguished from seismic evaluation. The seismic qualification is intended to be performed at the design stage of a plant. The seismic evaluation is intended to be applied after the plant has been constructed.

Also some guidelines do exist for the evaluation of existing NPPs, these are not established at the level of a regulatory guide or its equivalent. Nevertheless a number of existing NPPs throughout the world has been and are being subjected to review of their seismic safety. Rational feasible criteria for resolving the main issues have been developed in some member states, particular in the U.S.A. These criteria have in some instances been adapted for the specific conditions in western and eastern European countries.

2.2.2 Seismic Re-Evaluation of NPP Temelín

The seismic evaluation was used as basis for seismic design up to 1986. The re-evaluation was done since the approval of seismic design in 1987.

The results of the Czech re-evaluation are mainly discussed in Simunek (1995), following the first IAEA’s Site Safety Review Mission (1990).

Based on the review of the available documents the Austrian Expert Team concludes that all re-evaluations tend to confirm 0,1 g (e.g., “expert system”), for which the NPP originally was designed.

However in the case of the NPP Temelín the Austrian Expert Team considered the situation as follows:

1. There is evidence of a greater seismic hazard than expected before (refer particularly to chapter 2.4)
2. IAEA regulatory requirements have changed with respect to the requirements existent at the time of design
3. A lack of antiseismic design has been identified. Measures of seismic upgrading were recommended by IAEA Site Safety Review Missions (see Annex B).
4. Experience from new technologies (refer chapter 2.4.3) suggest that a higher risk for this particular site should be considered

Seismic safety evaluation programs should contain 3 important parts:

1. The assessment of the seismic hazard as an external event, specific to the seismotectonic and soil conditions of the site, and of the associated input motion.
2. The safety analysis of the NPP resulting in an identification of the selected structures, systems and components (SSSCs) appropriate for dealing with a seismic event with the objective of a save shutdown.
3. The evaluation of the plant specific seismic capacity to withstand the loads generated by such an event, possibly resulting in upgrading.

The scope of this report mainly concentrates on item 1. The other items are covered within another project in the Melk Process, namely PN8, Seismic Design.

It is recognised that the final judgement of the safety of an existing NPP should integrate the information about the level of input motion, the analysis methodology and a capacity assessment criteria. A lower level of input motion may be compensated for by more capacity assessment criteria. Therefore the philosophy of the assessment within the Melk Process had to be integrated over the separate projects. It is expected that this approach will lead to examination of the possible non-linear behaviour of some SSSCs and therefore result in a deeper investigation of the features of the NPP Temelín in a better understanding of failure modes and available margins.

The assessment of the seismic hazard of the site should be divided into 2 tasks:

1. Evaluation of the geological stability of the site, for example the absence of any capable fault that could produce differential ground displacement phenomena underneath or in the close vicinity of buildings and structures important to nuclear safety. This question is particular referred to in this report.
2. Determination of the diversity of the seismic ground motion at the site. The underlying principle is that the severity is similar to the one that would be calculated for a new NPP on the same site.

2.3 International Seismic Missions, Audits and Standards

2.3.1 State-of-the-art of Seismic Hazard Assessment in Western Europe

Starting point for the assessment of the seismic hazard potential and the seismic design of nuclear power plants is the determination of the seismic loads for the design basis earthquake and the parameters characterising this earthquake, in particular the seismic engineering data (maximum accelerations, duration of excitation, free field response spectra).

In **ANNEX D** (Seismic Hazard Assessment at Nuclear Power Plants: Current Practice and State of the art in Germany and France), a summarising account of the state of the art regarding the determination of those seismic loads and parameters is presented, supplemented by a brief discussion concerning seismic design and instrumentation.

It has to be taken into account that on the one hand, the state of science and technology is codified, to some part, in regulations; on the other hand, it is in continuous development as new scientific results and methods become available. Therefore, for individual issues, the exact state of science and technology cannot always be determined in unambiguous manner.

With respect to codification today, there are significant differences between Germany and France. In Germany, the basic seismic regulations of the Nuclear Safety Standards Commission (KTA-Standards, 2201 series) date back to the early 1990s (1990 – 1992, with one exception, on seismic instrumentation, from 1996). They are considered as providing a general framework for the application of up-to-date methods. Therefore, when assessing the current state-of-the-art in Germany, a compilation and evaluation of the current practice is of foremost importance. Seismic site assessments performed within the last few years can serve as characterization of the current state.

On the other hand, a new basic safety rule on seismic hazards was published in May 2001 in France (Règle fondamentale de Sureté *RFS 2001-01*). This regulation keeps the general approach developed in earlier regulations, but is more precise in several points. It attempts to integrate the progress in the seismic field which has occurred in the last twenty years into the codified safety rules. When assessing the current seismic state-of-the-art in France, therefore, the regulation *RFS 2001-01* is of particular importance.

IAEA regulations, in particular Safety Guide No *50-SG-S1* (IAEA 1991), as well as new regulations now under preparation (among others, Safety Guide No NS-G-3.3, superseding *50-SG-S1* (IAEA 2002a, 2002b), tend to be of a more general nature than German and French regulations and are not part of those regulations. They are not discussed further here. Also not discussed is the Eurocode 8 (concerning buildings in zones with significant earthquake risk) since it is stated explicitly that this code is not applicable to nuclear installations.

A comparison of the practice and state of the art in Germany and France with the evaluation of seismic hazards at the Temelín site in the Austrian Technical Position Paper (ATPP) of July 2001 indicates that, taking into account the information presented in the ATPP, neither German nor French requirements are fulfilled at Temelín. (ATPP was referred to in the call for tender of PN 6 for issues in discussion and open questions.)

For example, the following requirements appear not to be fulfilled at Temelín:

- Paleoseismic studies are part of the methodology to determine the design basis earthquake and have to be performed if possible, according to the current state of the art (Germany and France)
- Systematic analyses of bandwidths of uncertainty are required (Germany)
- Conservative determination of the design basis earthquake is aimed at by adding a safety margin of one unit MSK to the maximum historical earthquake (France)

Furthermore, as far as known to the authors, no information has been provided by the Czech side on the selection of fractiles for response spectra. Whereas in Germany, this selection is debated in scientific circles, with a tendency toward the 84%-fractile becoming apparent, this point appears to be neglected in connection with Temelín. It is, however, of great importance since the choice of the 84%-fractile rather than the 50%-fractile for a given intensity will generally increase the loads by as much or even more than adding one unit to the intensity would.

Another issue that might be of some relevance is that, as far as known to the authors, there is no consideration of pre- and aftershocks of an earthquake at Temelín. French regulations, on the other hand, require assumptions of pre- or aftershocks with an intensity equalling that of the maximum historical earthquake.

2.3.2 Site Safety Review Missions and Audits at NPP Temelín

The Austrian Expert Team checked the status of implementation of IAEA recommendations, in particular of site safety review missions and audits to the extent of available literature. For this purpose, access to the reports of the IAEA missions was requested.

Geological, seismological, hydrological investigations for the Temelín NPP site started in the 70ies. The Preliminary design of the Temelín NPP was approved in 1986 and the construction started in 1987. Significant IAEA and other international safety missions and audits started from 1990 (including those related to seismic issues). The following missions and audits were done (Details to this missions and audits can be found in: Masopust, R. & Prasil, M. 2003):

- 1990: IAEA Site Safety Review Mission
- 1990: IAEA Design Review Mission
- 1991: IAEA Site Safety Mission – Siting
- 1992: IAEA Site Safety Review Mission – Siting
- 1993: IAEA Follow-Up Review Mission – Siting
- 1994: IAEA Progress Review Mission – Siting
- 1996: IAEA Review of WWER-1000 Safety Issues Resolution at Temelín NPP
- 2001: IAEA Mission- Safety Review of the Temelín NPP External Hazard Issues
- 2003: IAEA Expert Mission – Seismic Hazard Assessment of the Temelín NPP

Two reports on the site safety review missions have been passed to the Austrian side. Presently, only the reports 1990 (Design) and 1991 (Siting) are not accessible to the Austrian Expert Team. Page 9 of the 1993-report is missing. The results of the IAEA reports are not fully integrated into this preliminary report but the reports are added as **ANNEX B**.

The team of IAEA Site Safety Review Mission 1990 received an earthquake catalogue from the Czech side beginning with an event of 1592, thus avoiding a discussion on the maximum historical earthquake, 1590 Neulengbach. This mission report contains critical remarks and recommendations like investigations that permit dating of recent tectonic activity and never were carried out. A comparison between IAEA standards, statements and recommendations in the IAEA site safety review mission report 1990 and the Czech report (Simunek, 1995) is presented in chapter 5 of the Austrian Technical Position Paper - Safety Aspects of Temelín Nuclear Power Plant (2001).

The latest IAEA Site Safety Review Mission 2003 *"Report of the Expert Mission to Assist the Czech Republic in Seismic Hazard Assessment of Temelín NPP to Temelín, Czech Republic 3-7 February 2003; Seismic Safety Review Services conducted under IAEA Technical Co-operation Project RER/9/066: Strengthening safety assessment capabilities of NPPs" is* mainly based on the Seismic Issues Background Document Volume 1,2 by Stevenson & Associates (2002) that in turn refers to the Energoprůzkum report (Simunek et al.1995). The Seismic Issues Background Document was not available to the Austrian side. From the statements of the IAEA and therein-quoted literature the Austrian Expert Team concludes, that a big part of information (Seismic Hazard Assessment of Temelín NPP Site, March 27-28, 2003) originates from this background document.

The IAEA Report (IAEA Site Safety Review Mission 2003) contains main conclusions and 5 issue reports. There are three key areas: the earthquake catalogue, the seismic hazard methodology, and the geomorphological studies.

2.4 Geological Investigations

2.4.1 Geological Overview of the Temelín Area

The NPP Temelín is situated on a flat to undulated peneplain at about 500-600 m above sea level northeast of the Cheske Budejovice-Basin in the Bohemian Massif.

In terms of regional tectonics, Temelín its situated in the Moldanubian Unit, which is part of the East-European branch of the Variscan Belt (Figure 2.4.1). The Moldanubian Region mainly comprises paragneissic, granitic, granulitic and migmatitic rocks of probable Late Proterozoic to Early Paleozoic age, intrusive, metabasic rocks, all of them comprising different stages of metamorphism. The ages of the pre-metamorphic, sedimentary, and magmatic rocks range from Upper-Proterozoic to Silurian. Relictic garnet and disthene provide documentary evidence for an older regional metamorphism in the Moldanubian (Acadic or Caledonian). The end of the dominating low pressure/ high temperature metamorphism is dated with 330-320 ma (mica and monazite).

The České Budejovice Basin shortly south of Temelín is a multi-phase sedimentary basin within the Modanubian basement. The basin shows a protracted history of subsidence and sedimentation with major phases of sedimentation during the Cretaceous, the Miocene and the Pliocene. Subsidence mostly was related to active movements along major faults bounding the basin to the north (e.g., the Hluboca fault) and south.

With respect to geomorphology, the crystalline units of the inner part of the Bohemian Massif were formed to a flat and undulated peneplain, interrupted by hills, basins and valleys. The most significant first-order morphological feature south of Temelín is the České Budějovice Basin showing up as large morphological lowland with very flat topography, numerous wetlands, marshes and lakes. This present lowland roughly corresponds to the former Cretaceous sedimentary basin. The northern topographical boundary of the basin roughly coincides with the Hluboka fault.

The largest rivers of the Bohemian Massif are the Elbe and Vltava (Moldau) (435 km length). The Vltava River rises in south-western Bohemia from two headstreams in the Bohemian Forest. It crosses the Cseske Budejovice Basin close to the Temelín site then flowing north across Bohemia to empty into the Elbe River.

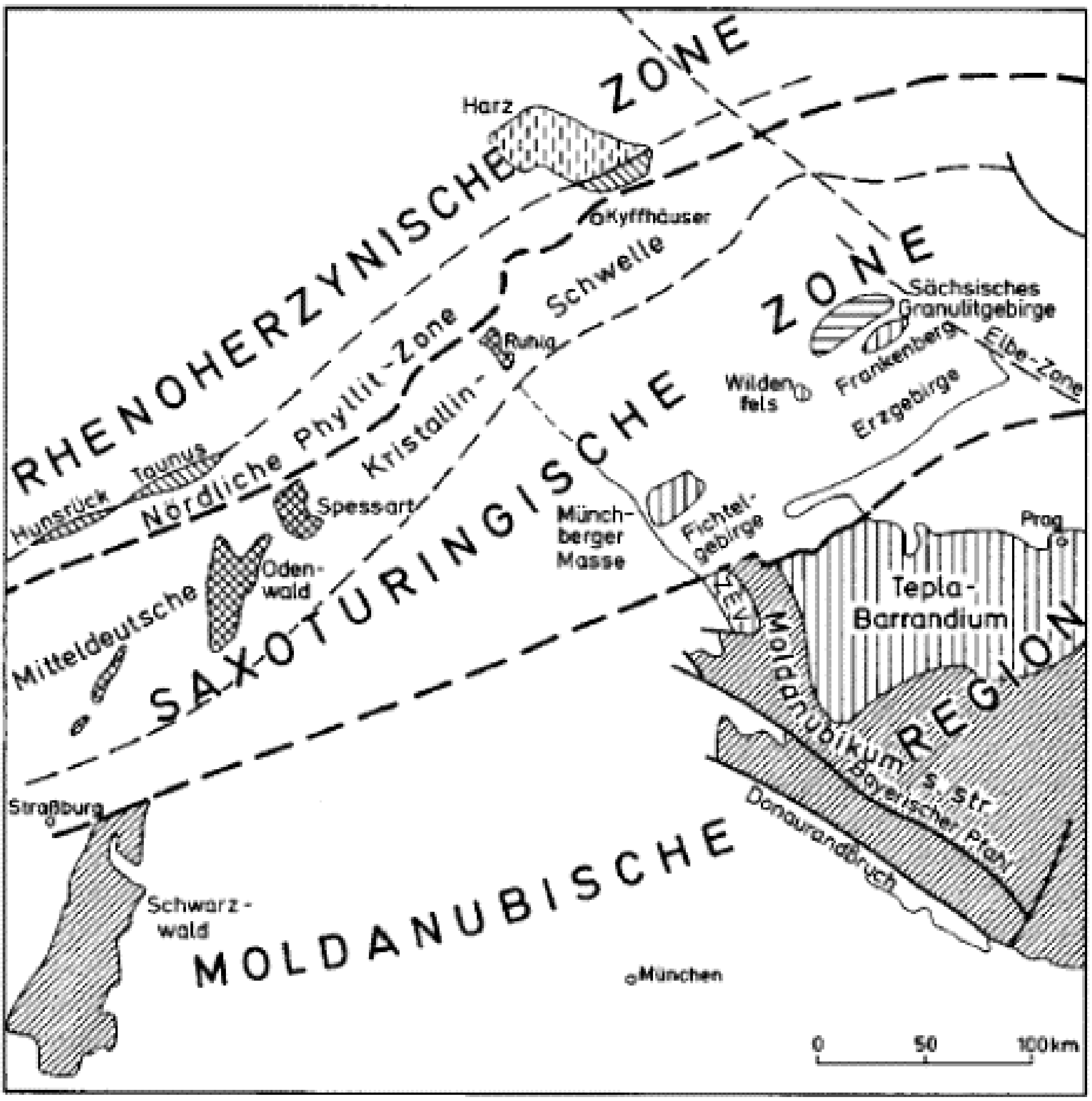


Figure 2.4.1: Geological overview: Major tectonic units of the Variscan Belt in Central Europe.

2.4.2 Review of Regional and Near-Regional Geologic Data – Application of Remote Sensing Techniques

Apart from the pure review process of information provided by the Czech experts the Austrian Expert Team approached questions about the tectonic setting of the power plant by a remote sensing investigation (complete report is contained in the **ANNEX C**). This was done to backup the Austrian Expert Team with important information for the review process and the discussions in Prague meeting.

Satellite images in combination with geophysical and geomorphological data, like the digital terrain model serve as independent evaluation of tectonic maps handed over by the Czech experts, and for the evaluation of tectonic geomorphology, which could be the basis for specific questioning of the trenching results of the Energopruzkum 1995 report. The aim was to map structural features visible on satellite imageries from the area of Temelín in order to investigate the tectonic setting and to detect surface traces of fractures and fault zones.

The analysis of remote sensing data focused on possible tectonic features. Linear features visible on remote sensing data from the investigation area were systematically mapped and significant features delineated by integrated interpretation of the datasets using geographic information systems. The evaluations were compared, correlated and combined with available geological and geophysical data. The lineament maps contain information on the tectonic pattern of the investigation area, especially concerning the position of fracture zones and faults (see Figure 2.4.2)

NW-SE-, NNE-SSW-, SW-NE- striking faults are distributed throughout the study area. The most outstanding fault system in the south of Temelín is the Hluboká fault striking NW-SE. Between Hrdějovice and Munice the Hluboká fault looks like just one large fault, whose SW fault side is at present sunk more than 300 m. Here the Hluboká fault is actually a boundary fault of the Budějovice basin and it limits the deepest block of the Upper Cretaceous sediments. This length of the Hluboká fault is bordered by the transverse Munice fault of NNE-SSW direction. Prachar (2003) stated that since the latest Riss (0,3 million years) no tectonic movements had occurred along the Hluboká fault. As the Alpine compression of the area is continuing – as proved by geodetic and GPS measurements and the occurrence of numerous micro-earthquakes – this statement must be doubted and further investigations are required.

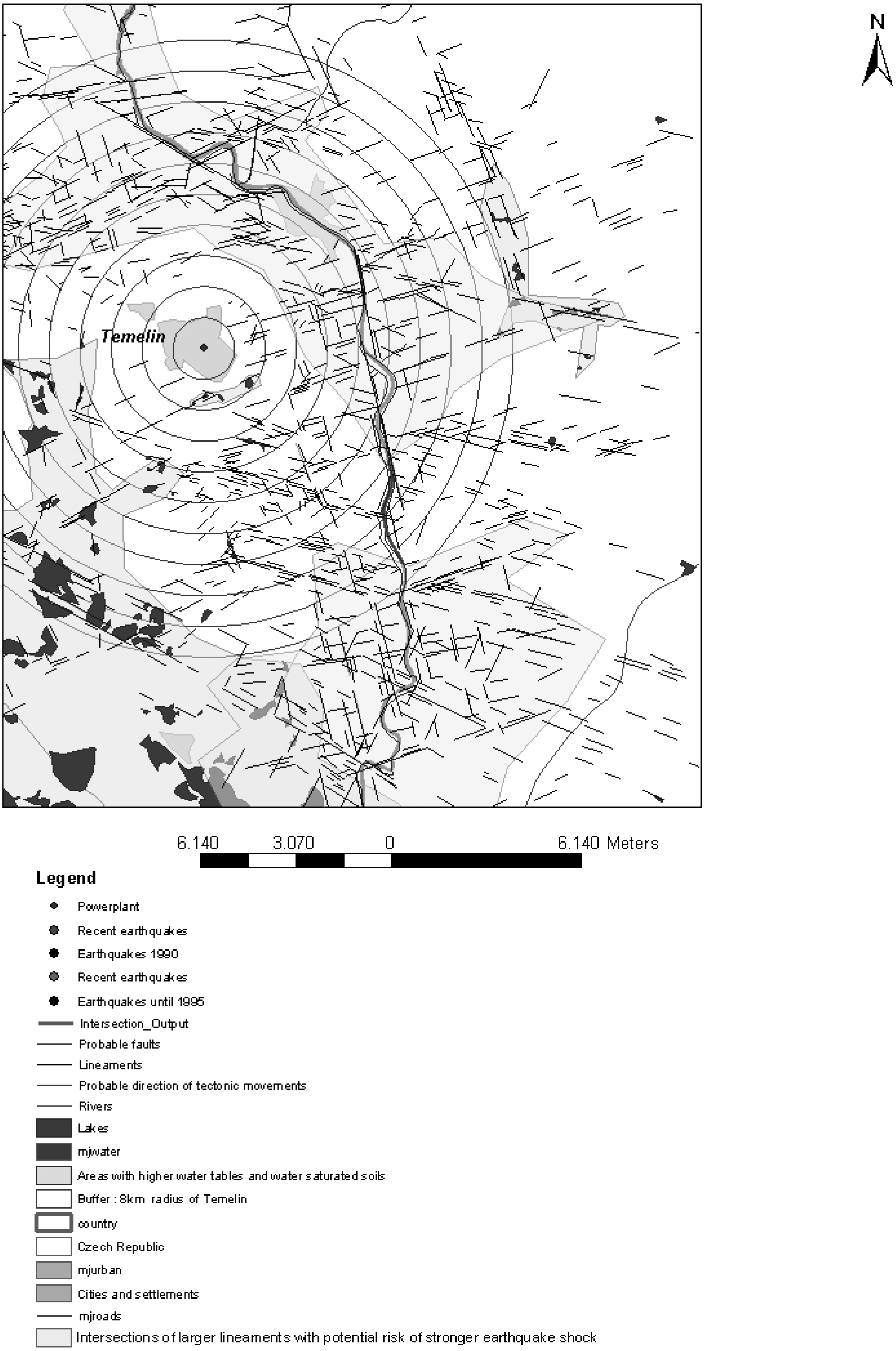


Figure 2.4.2: Local site conditions in the area of Temelín; each circle represents 1km of distance

The fault zones, especially the areas with intersecting fault zones, are traced at the surface by numerous lakes, swamps and the drainage network. The present slope SE of Hluboká nad Vltavou even if it is related to the Hluboká fault, is not the fault plane. Pronounced morphological slope, originally of the fault origin, receded as a result of Vltava river erosion activity during the Quaternary (before the Riss*)*. Quaternary volcanism and neotectonic movements indicate active crustal deformations in north-western Bohemia, combined with deep reaching faults and rifts as the Ohre (Eger)-rift.

Recent tectonic, vertical movements are reported from the river terraces near Marianske Lazne in NW-Bohemia that obviously are still ongoing. These terraces are affected by only very little erosion (Bankwitz, 1994). In addition there are GPS measurements indicating recent movements in the NE Czech Republic. Thus, within a radius of 100 to 150 km there are documented recent tectonic movements.

The question remains, whether continuously measured geodetic data, GPS data or radar interferometry over a longer time period of time (decades) could prove crustal deformations in the Temelín area as horizontal shear movements along the Hluboka-fault zone, or vertical height changes. Further investigations are recommended.

- Many of the distinct lineaments visible on the satellite imageries could be verified as fault zones. Others seem to trace yet unknown fault zones or cannot be interpreted without field check. Such structures should be investigated by detailed ground control (e.g., by geological and geomorphological mapping). The indications on tectonic structures achieved with this investigation point toward the presence of significant faults vicinity of the NPP Temelín, which are not included in the tectonic maps serving as basis for the seismic hazard analyses. It is suggested to further investigate the mapped structures with state-of-the-art methods in order to assess their tectonic significance, the age of faults, and their eventual seismic potential.

2.4.3 Hydrogeological Investigations in the Site Vicinity and Site Area of Temelín

Some of the background studies could be seen during inspection of the POSAR. These documentations of hydrogeological investigations depict some concern about fault activity. Hydrogeological investigations were carried out carefully due to concerns for the safety of Prague waterworks. Some questions by the Austrian Expert Team were raised during the UVP (environmental impact assessment), e.g. on water transport in fractured rock. Some tectonic information on faults was accessible for the Austrian side only in these documents on hydrogeological investigations.

2.4.4 Engineering Geological and Geotechnical Background Documents

The foundation ground of the individual buildings of the Temelín nuclear power plant is formed by solid hard rocks. Detailed geological maps and documentations of the open construction pit show that the main buildings of the power plant are situated on crystalline rocks with only minor discontinuities (fissures). Appropriate documentations have been shown by the Czech Experts. All facilities and buildings of the Temelín NPP are founded on bedrock of Moldanubic metamorphic rocks. These are sillimanitic and biotitic para-gneisses and migmatites, which are sometimes penetrated with veins and irregular bodies of granitoid rocks. Weathered zones were removed to a certain extent and zones of weakness filled with concrete. These bedrocks of Temelín have been intensively investigated.

The presented documentations of the foundation works during the workshop in Prague are sound and convincing.

2.5 Seismological Data

2.5.1 Review of Historical Earthquake Data

Data on historical earthquakes with relation to Temelín site have been reported by several authors e.g. Grünthal et al. (1985, 998), Gutdeutsch et al. (2001), Gutdeutsch et al. (1987), Hammerl et al. (1987), Karnik et al. (1957), Karnik (1968 a, 1968 b), Karnik et al. (1984), Karnik (1996), Lenhardt (2000), Procházkova et al. (1994), Procházková & Šimůnek (1998), Rudajev et al. (1998), Simunek (1995), Zatopek (1948), and Buben et al. (1999). Graphs of the earthquakes compiled by Schenkova, Karnik & Schenk (1976) and Prochazkova et al. (1994) are shown in Figure 2.5.1.

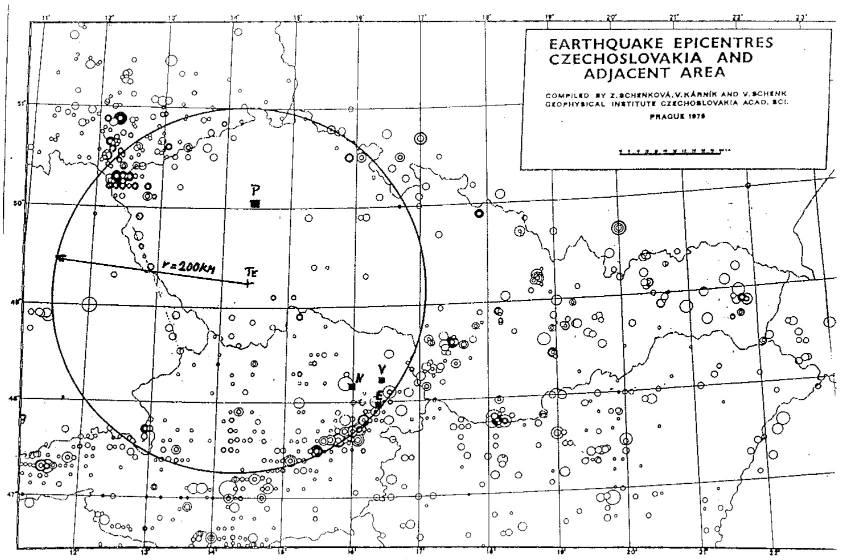


Figure 2.5.1 a

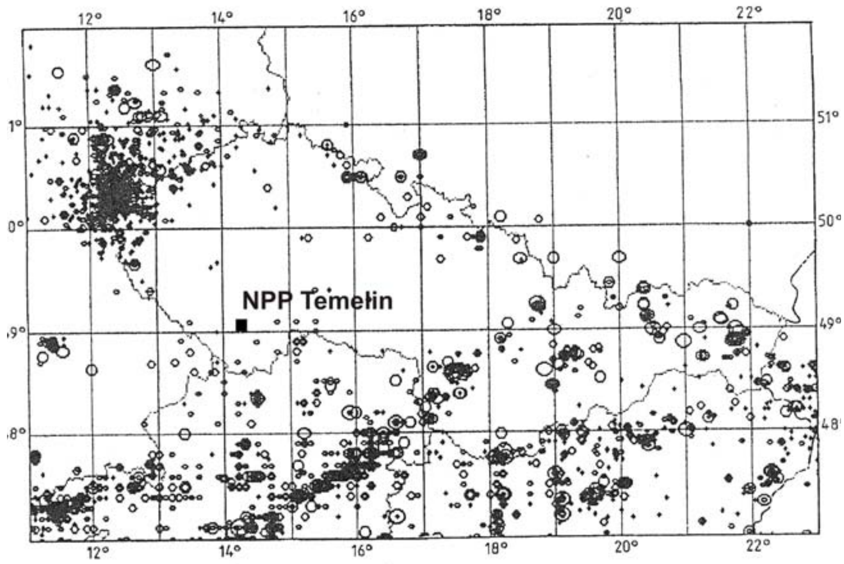


Figure 2.5.1 b

Figure 2.5.1: Maps of earthquakes with epicentral intensities I ≥ 3 for former Czechoslovakia and the adjacent regions from Schenková, Kárník, Schenk 1976 (Figure 2.5.1 a) and Prohaskova et al. 1994 (Figure 2.5.1 b). Note that the lower map depicts a number of epicenters, which are not included in the upper map (compare regions between 49° - 50° N and 13° - 18° E) indicating marked differences in the earthquake catalogues used.

The amount of information that has been presented on the Czech earthquake catalogue is limited and could be improved. The Austrian Expert Team has seen only fragmentary documents, and no supporting information about historical data and methodologies used to derive parametric datasets. This contrasts unfavourably with, for example, the new Swiss earthquake catalogue (ECOS) where all procedures are transparent and the historical data can be scrutinised online.

The basic earthquake data are a fundamental input to seismic hazard analysis, and the quality of these input data needs to be reviewed to ensure that the earthquake catalogue is as good as can be achieved within the constraints of historical data reporting. In addition, how these data are used in hazard analysis needs to be scrutinized. The Austrian Expert Team has the impression that there are some shortcomings in both areas that need to be addressed.

2.5.2 Catalogue Completeness

The latest version of Temelín seismic hazard assessment is based on an earthquake catalogue by Buben, Vencovsky & Rudajev (1999). The completeness of this catalogue has been addressed by Rudajev (Workshop at SUJB Praha, 2003) and Procházková & Šimůnek (1998). The supposed completeness of catalogued intensity classes (especially for I = VI and I = VII) seems to be significantly overestimated when compared to completeness analyses of comparable Central European countries (compare Figure 2.5.2 and Figure 2.5.3; note the assumed completeness for I_0 6 to 8, where the Czech data claim to be significantly more reliable than for all the other listed countries).

The cited catalogue presently is not available to the Austrian Expert Team and its reliability and completeness therefore cannot be checked directly. Cursory comparisons of accessible seismicity maps (compare Figure 2.5.1 a, b); however, show up marked differences between different Czech earthquake databases, which have not been resolved so far. This is illustrated by the seismicity map in compare Figure 2.5.1 b depicting several epicentres around Temelín, which are not included in the other map (compare Figure 2.5.1 a). So far it remains unclear, whether the currently used database by Buben et al. (1999) includes these events or not.

A complete catalogue is a crucial prerequisite for the quality of probabilistic hazard assessment. The listed completeness therefore should be checked by comparing the dataset of Buben, Vencovsky & Rudajev (1999) with the recently compiled multi-national (Czech-Slovak-Hungarian-Austrian) ACORN database (W. Lenhardt, 2003) and by statistical tests as those applied by Grünthal et al. (1998) for the D-A-CH Countries. Critical comments on the catalogue are also found in the IAEA Expert Mission (2003): „(b) Seismological Database ... the seismological database is satisfactory, in spite a better care in compiling the catalogue would have appreciated.“ (Quoted by Masopust, Workshop at SÚJB Praha, 2003). In spite of detailed questions during the Workshop, it remained unclear whether some effort has been put into systematic search for historical sources on earthquakes. Systematic historical research going back to chronicles, historical documents etc. is common practice in other European countries (e.g., U.K., Italy, Switzerland, Austria). As previously agreed, the Czech Experts are asked to provide a digital copy of the used catalogue to enable an independent check of its quality and completeness. A careful review of the Czech historical earthquake catalogue with its supporting datasets is recommended.

Presupposed completeness of historical earthquake catalogue

(According to Procházková D., Šimůnek P., 1998: *Fundamental Data for Determining Seismic Hazard in Central Europe, Ed. Gradus ISBN 80-238-2661-1*)

Epicentre intensity I_0 [MSK-64]	Completeness of data Century
$I_0 \geq 8^0$	Since about the 13th century
$I_0 \geq 7^0$	Since about the 14th century
$I_0 \geq 6^0$	Since about the beginning the 16th century
$I_0 \geq 5^0$	Since middle of the 19th century
$I_0 \geq 4^0$	In the 20th century

Figure 2.5.2: Assumed completeness of the catalogue of historical and instrumental earthquakes used for probabilistic seismic hazard assessment (from Rudajev, Workshop at SÚJB Praha, 2003).

I_0	IV	V	VI	VII	VIII	IX
Austria	1900	1900	1850	1670	1550	1200
Switzerland	1875	1875	1650	1575	1300	1300
Northern Italy	1875	1875	1750	1600	1200	1200
Areas adjacent to the Rhine	1875	1825	1775	1500	1250	1250
Germany: Sachsen / Thüringen	1850	1770	1700	1400		
Germany: Remaining areas	1925	1875	1875	1750	1625	
BENELUX-Countries	1925	1875	1825	1675	1330	
Southern Scandinavia	1880	1775	1775	1700		

Figure 2.5.3: Analyses of the completeness of catalogued intensity classes for intensities IV-IX for the gross zones of Germany, Austria and Switzerland (from Grünthal et al., 1998).

Historical earthquake catalogues are inadequate for the long-term seismological characterization of low seismicity areas such as the Bohemian Massif. Catalogue coverage of several hundred years is by factors 10 to 100 too short to cover seismic cycles, which are commonly observed for seismogenic structures (faults) in such areas. Probabilistic hazard computations for time windows more than ten times longer than the catalogue length become highly ambiguous. Limited earthquake catalogues (limited by the historical period) contain many uncertainties. The merit of modern PSHA studies is that they can model these uncertainties explicitly. The approach to the topic by Rudajev et al. (1998) is discussed in detail in the Paragraph 2.10.2.

Given that for any seismic source zone there must exist some set of parameters that represent the true, long term, seismic behaviour of the zone, it is possible, for any potential set of parameters, to estimate the probability that these are the true parameters. From this one can build up a probabilistic estimate of the earthquake hazard that takes into account the poorness of the data and the uncertainties that result. This is one of the reasons why the probabilistic analysis undertaken by the Czechs fails to be state-of-the-art.

An example of state of the art calculations can be taken from Wiemer & Wyss (2002).

2.5.3 Focus on Relevant Historical Earthquakes and their Intensities

There is general agreement between all experts (see also list of references), that the site is located in a region of low seismicity. The highest seismic intensity reported for the region of Temelín was observed from the so-called "Neulengbach earthquake" of 1590 with the epicentre located in the vicinity of Neulengbach/ Alpine Foreland of Lower Austria. Most authors agree that the epicentral intensity of this earthquake has been I_0=9° on MSK scale (e.g. Gutdeutsch et al. 1987). Based on the attenuation by three degrees of intensity I_0=9° of the 1590 Neulengbach earthquake the highest intensity felt at the location of Temelín was at least I= 6° MSK. Other strong historical earthquakes like the event of Murau 1201 and events in Italy are more distant and have been felt with lower Intensity in the region of the site.

2.5.4 Review of Seismogenic Source Zone Models

The results of seismic hazard assessments significantly depend on the selection, arrangement and limits of seismic source zones, which are treated as seismological homogenous regions with earthquakes occurring with the same likeliness in every part of the source zone. In many seismic hazard studies the interpretation of seismic and tectonic data to formulate a model of seismogenic zones is a key point, in that the definition of alternative source zone geometries can significantly change the hazard value. To overcome this ambiguity different interpretations are often combined (e.g. in a logic tree) in order to capture the uncertainty from different interpretations. At the Workshop 2003 different zoning models have been presented, however this approach does not seem to have been followed within the final calculations.

Seismic hazard estimates for Temelín originally have been computed using the source zone model depicted in Figure 2.5.4. The Bohemian Massiv, which is regarded as a mostly homogenous Variscan intra-plate crystalline unit, is divided into seven source zones termed A to E and J (e.g., Šimůnek, 1995). These zones do not obviously relate to geological or tectonic sub-units. This is especially true for the delimination of source Zone A, which is obviously restricted to the close surrounding of Temelín. Its separation from Zone B is not justified by geological data. The placement of the NPP in a source zone of its own previously was heavily criticised. This zoning was not used in the later probabilistic model, but it remained unclear if it was still used for the derivation of the deterministic hazard assessment.

During the Workshop at Praha several alternate source zone models have been presented (Rudajev, Workshop at SÚJB Praha, 2003; Figure 2.5.5), which differ significantly from the originally used model. However, none of the models seems to relate to a reasonable tectonic or seismo-tectonic model (see discussion in Paragraph 2.7.2). According to Schenk (Workshop at SÚJB Praha, 2003), the MCE / SL2 magnitude was calculated for a zone of diffuse seismicity using Gumbel's statistics for a region including entire Bohemia. According to Schenk, this computation confirms the previous results. Rudajev et al. (1998) based their probabilistic analyses on the source zone model depicted in Figure 2.5.5 b.

After the Workshop it remains still unclear whether all the shown models have been used for hazard computations. The effects of changing source zone models on the computed seismic hazard have not been specified. The effects of different source zone models for Bohemia on seismic hazard assessment could only be quantified by re-computation, which could be done with reasonable effort.

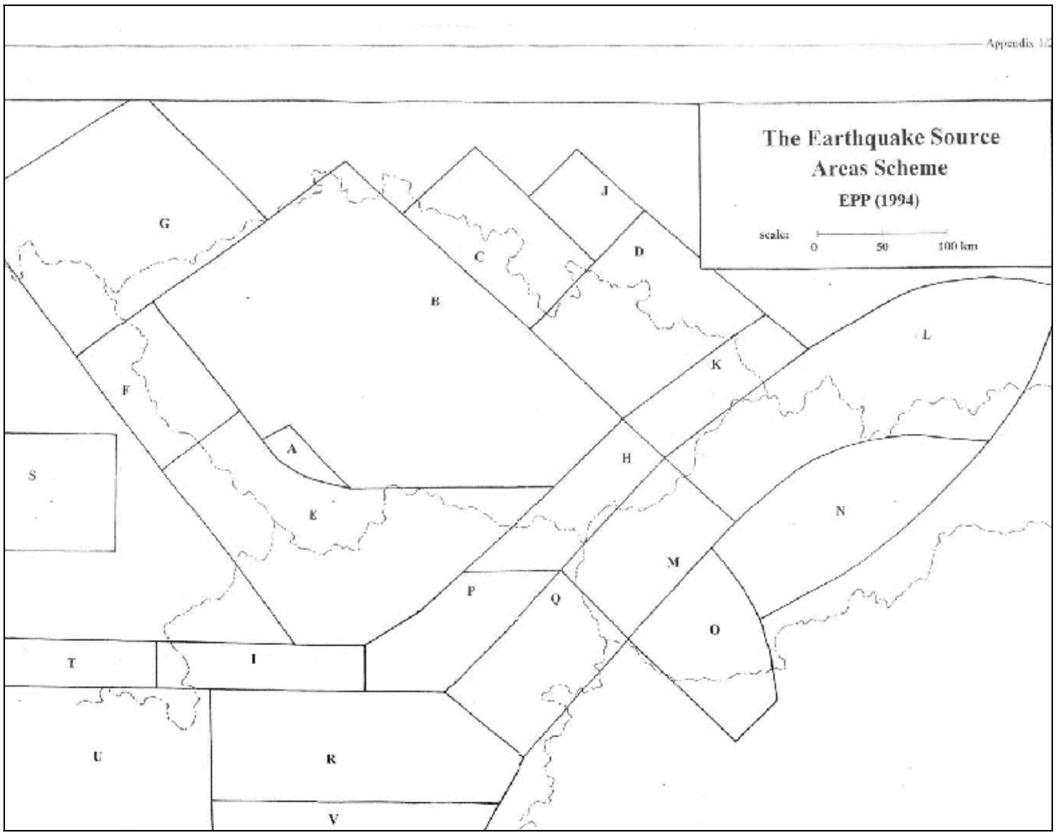
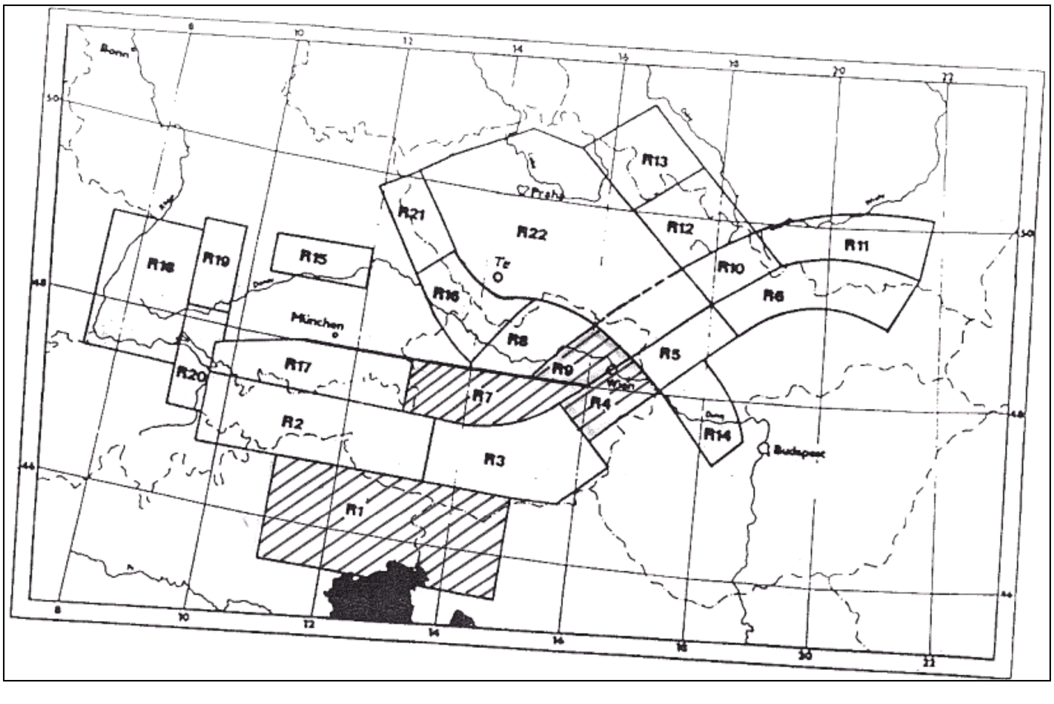


Figure 2.5.4: Seismic source zone model used for the first versions of seismic hazard assessment (Simunek, Energoprůzkum Report Part B, 1995)



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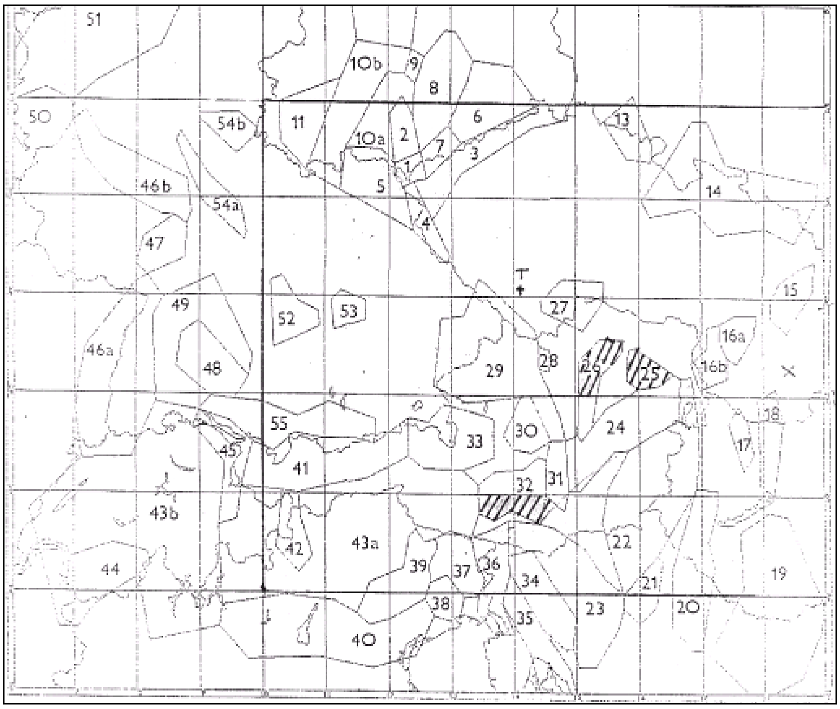

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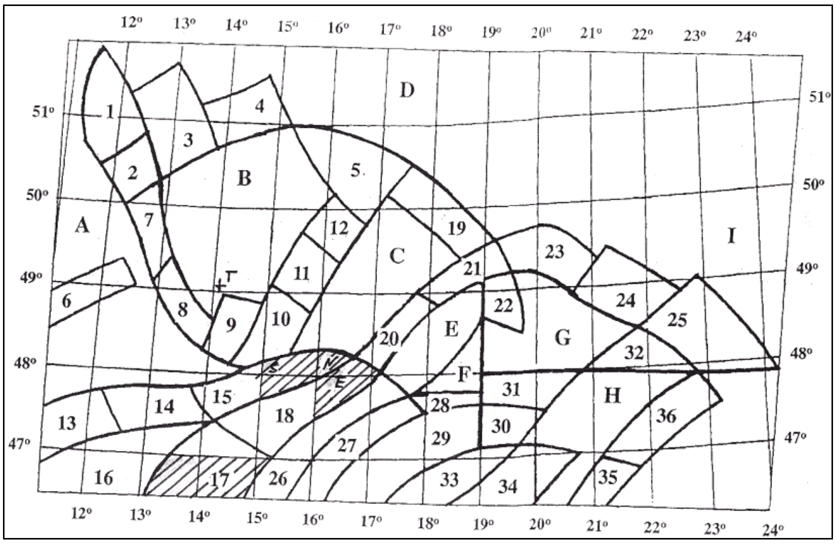


Figure 2.5.5 c

Figure 2.5.5: Alternative seismic source zone models for Bohemia and the surrounding regions presented by Rudajev during the Workshop at SÚJB Praha, 2003.

2.5.5 Identification of Seismogenic Structures as Input for Probabilistic Hazard Assessment

The identification of seismogenic structures is one of the key points of probabilistic seismic hazard assessment. The implementation of seismogenic structures is guided by Chapter 4.11 of IAEA Regulatory Guide No. NS-G-3.3, which reads as follows: "*The identification of seismogenic structures is made on the basis of geological, geophysical and seismological data providing direct or indirect evidence that these structures have been the source of earthquakes under current tectonic conditions. The correlation of historical and instrumental recordings of earthquakes with geological and geophysical features is particularly important in identifying seismogenic structures. A lack of correlation does not necessarily indicate that a structure is not seismogenic".*

Comparisons of seismicity maps with geological and tectonic maps highlight some prominent seismogenic features in the distance of the Temelín site such as the Mur-Mürz-line, and the Vienna Basin fault system. However, these structures were only used for deterministic assessments, not for probabilistic analyses. A correlation between geological features and seismicity for the eastern part of the West European Platform was given by Grünthal et al. (1985). A more detailed discussion on the capability of faults was presented by Prochazkova and Šimůnek (1994) and by Šimůnek (1995). However, some of these estimates are strongly model-driven rather than relaying on tectonic and seismologic data. Clear data based seismotectonic models both for the far region (< 200 km around the Temelín site: Alpine-Carpathian foreland and Bohemian Massif) and the near region of the site (Bohemian Massif around the Budejovice Basin) are presently not available (see paragraph 2.7.3). The only seismogenic structures, which have been defined as such for the Temelín seismic hazard assessment are those located in the Eastern Alps (Mur-Mürz Fault, Vienna Basin Fault System), all located at distances between 150 and 200 km from the NPP. The Czech probabilistic hazard assessments seem to only refer to regions of diffuse seismicity without properly defining seismogenic structures.

A cursory review of micro-earthquakes (Figure 2.5.6) indicates that micro-seismicity around the Temelín site may be related to NE-striking geological structures paralleling the elongated Budejovice Basin. As far as it can be judged from the available documents, the depicted patterns of micro-seismicity have not been explored in order to identify potentially active and seismogenic fault zones.

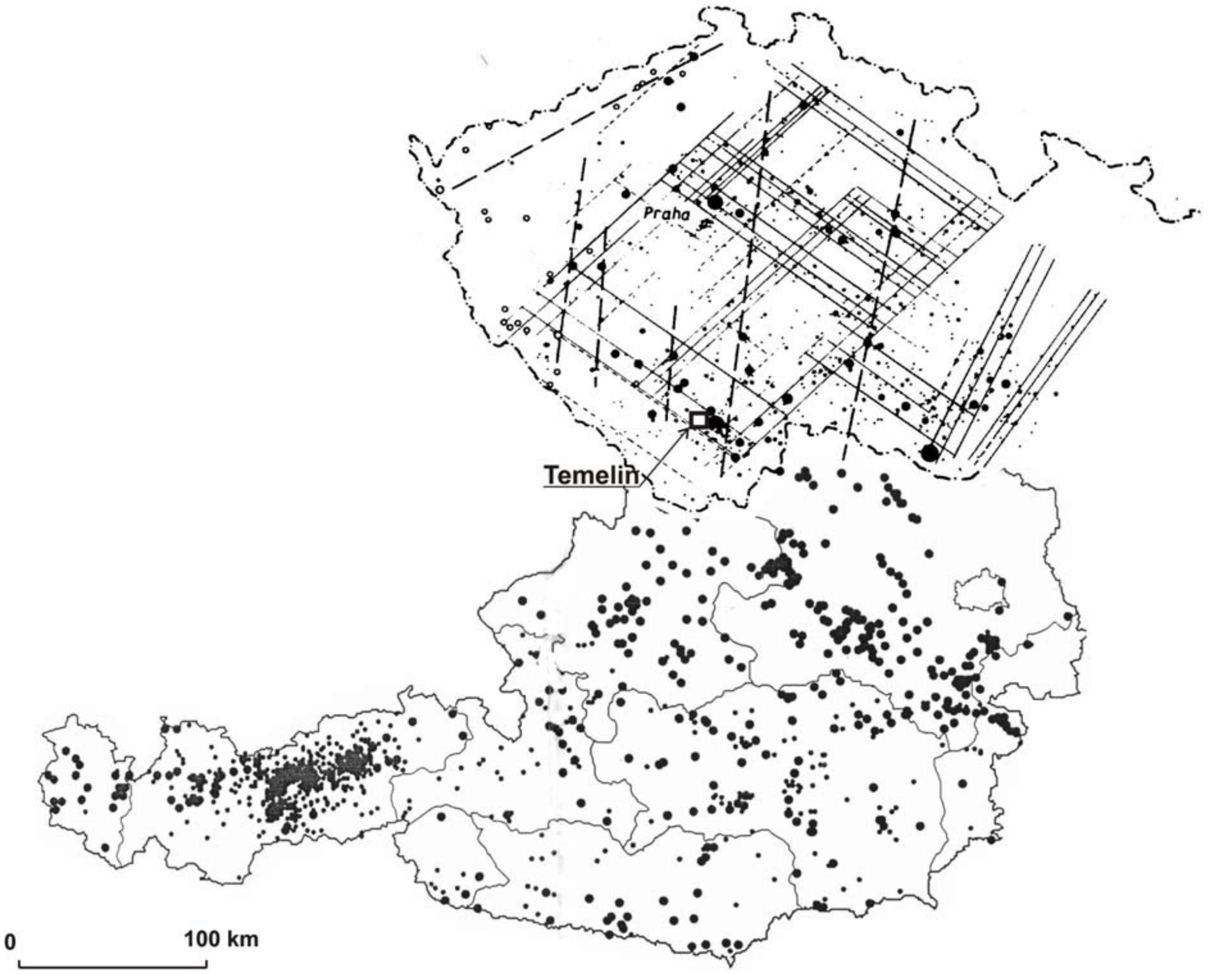


Figure 2.5.6: Distribution of micro earthquakes in Austria (ZAMG, 2000) and the Czech Republic (data by Zatobek, 1948; map published by Kutina, 1974).

2.5.6 Derivation of Magnitudes and Intensity Attenuation Relations

In a classic probabilistic seismic hazard assessment, as used in the USA and elsewhere, an earthquake catalogue (with magnitudes) is prepared; the parameters of each seismogenic zone in terms of magnitude frequency of occurrence are assessed; an attenuation equation linking peak acceleration to magnitude and distance is applied, and from this the probability of different values of peak acceleration are arrived at. This is a robust procedure, and while there are problems in choosing an appropriate attenuation curve for regions where there are no local strong ground motion records, this is a topic, which is well addressed in the literature.

Sidestepping this issue and using intensity attenuation relations is not best practice. Intensity attenuation is of relatively limited use in hazard studies for engineering design purposes. An approach in which peak acceleration attenuation is used directly, however, requires an appropriate database of strong motion data. Such a database is not available for the Temelín site as only very few strong seismic events have been instrumentally recorded by the Temelín Seismic Monitoring System yet.

The Czech experts used both approaches for computing attenuation relations. These are discussed in the following context.

Intensity-Magnitude Conversions. From the reports available to the Austrian Expert Team appears that magnitudes (M_{max}) have been derived from epicentral intensity (I_0) by the relation:

$$M_{max} = 0.63\ I_0 + 0.5 \qquad (3)$$

(E.g. Buben et al., 1999, taken from Karnik et al., 1968) without giving error bars and neglecting the influence of hypocenter depths. However, intensity distribution maps for the Czech area show clearly that the same epicentral intensity may result from a small magnitude, shallow event that affects only a restricted area, and a much larger, deeper-focus event that affects a wide area.

It is well established, that intensity / magnitude conversions give only rough estimates for the magnitudes and that the big uncertainties connected with this formula should be accounted for probabilistic analyses or proper safety margins (e.g., for the U.S. the standard relation used is $M_{max} = 2/3\ I_0 + 1$). The uncertainties of the relation can be judged well by Figure 2.5.8 correlating observed magnitudes and measured intensities for earthquakes, which occurred within a region of 200 x 200 km centred at Temelín site (data taken from Karnik, 1996). The intensity / magnitude plots are compared with the relation by Karnik (1968). The standard deviation (σ) of the plotted data from Karnik's relation was calculated to be 0.43. This uncertainty is not accounted for by the available hazard assessment and by the present estimate for M_{max} (Figure 2.5.7). The Austrian Expert Team concludes, that the present estimate **M_{max} does not** contain any safety margin (the last statement on page 7, Report by Simunek, Prague 2003, cannot be correct).

M_{MAX} ~ ($M_{MAX} = 0{,}63 * I_0 + 0{,}5$ - Kárník et al., 1968)

$I_0 - \Delta I = I_{Site}$ [° MSK-64].

M_{MAX} is value incl. safety margin of ≈ 0,5 unit of magnitude

Figure 2.5.7: (from the presentation by Simunek, Workshop at SÚJB Praha, 2003)

It is concluded that the used simple intensity-magnitude conversion is not adequate and may only be used under consideration of the big uncertainties connected with the formula. This could be done by adopting probability functions, or by using a more “conservative” conversion such as the one shown in Figure 2.5.8.

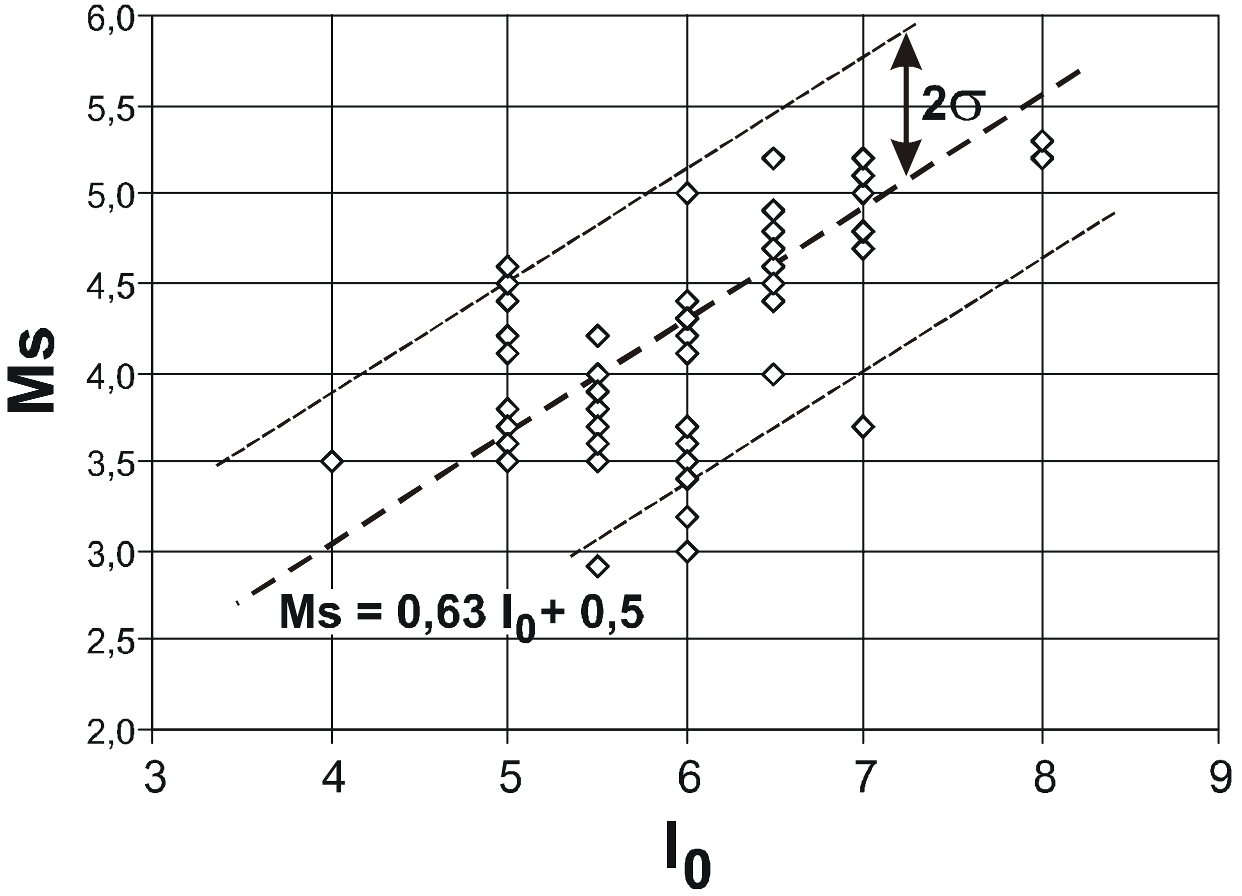


Figure 2.5.8: Correlation between epicentral intensity (I_0) and surface wave magnitude (Ms) for instrumentally recorded earthquakes, which occurred within a distance of 200 km of the Temelín NPP (data from Karnik, 1996). Karnik's (1968) linear function for deriving magnitudes from intensity is shown as dashed bold line. Note the significant variance of data points showing that the same intensity may result from events, which differ by more than one magnitude (e.g., for I_0 = 5 Ms can be read between 3,5 and 4,6). The graph shows that the conversion function is not conservative as it underestimates Ms for a large number of events. The upper dashed line (Ms = 0,63 I_0 + 2σ = 0,63 I_0 + 0.85) could serve as a conservative conversion function.

Intensity Attenuation Relations. Intensity attenuation relations on historical earthquakes for the location of NPP Temelín have been compiled by Šimůnek (1995). The procedure used by Šimůnek (1995) evaluates different attenuations for different source locations. This compares well with other approaches where directional variations are not considered. However, the attenuation calculations are not clearly defined: Where as the graphs showing Intensities versus distance seem to be correct we would calculate different attenuations for some locations.

Most authors agree that the epicentral intensity of the “Neulengbach” earthquake has been Io=9 MSK. The assessment of the intensity of this event felt at Temelín site varies between I=5 and I=6 by different authors. From the Austrian side arguments have been found that the intensity has been at least I=5.5 or 6.0 and that even I=6.5 could not be totally excluded. The arguments rely on the data of Šimůnek (1995) in Energoprůzkum-report and are contained in the report of Gutdeutsch et al. (2001).

Figure 2.5.1 a and b show strong earthquakes with a significant number of events occurring along a line that extends from about 14°E, 47°N to 18°E, 49° N (including the Semmering area and the extension to the little Carpathians). This seismic source zone corresponds to a major active fault referred to as Mur-Mürz-Vienna Basin fault (or Mur-Mürz-Leitha line; Decker et al., in press; Hinsch & Decker, 2003).

At the Prague presentation the Figure 2.5.9 was presented (Rudajev, Workshop at SÚJB Praha 2003):

Intensities in the site of NPP Temelín from individual seismoactive zones

I_0 [MSK-64]	R [km]	ΔI [^{0}]	I_s [^{0}]	$I_s + 1$ [^{0}]	λ [^{0}]	φ [^{0}]	locality	Year	Month	Region
10^0	290	4.8	5.2	**6.2**	13.8	46.6	Villach	1348	1	R 1
10^0	344	5.1	4.9	**5.9**	14.0	46.1	Kobarid	1511	3	R 1
9.5^0	339	5.0	4.5	**5.5**	13.4	46.2	Kobarid	1511	3	R 1
9^0	176	3.7	5.3	**6.3**	16.1	48.1	Neulengbach	1590	9	R 9
8^0	158	3.6	4.4	**5.4**	15.9	48.2	Neulengbach	1590	9	R 9
$7{,}5^0$	146	3.0	4.5	**5.5**	15.2	48.0	Scheibbs	1876	7	R 7
8^0	190	3.2	4.8	**5.8**						R4
7^0 *)	190	3.2	3.8	**4.8**	16.2	47.9	Ebrerichsdorf	2000	7	R 4

Figure 2.5.9: Within this table for the Neulengbach I_0 = 9 event an attenuation of ΔI=3.7 is drawn.

The isoseists compiled in Šimůnek (1995) show, that the attenuation of strong historical earthquakes located on the Mur-Mürz line near Vienna to Temelín site is 3° to 3.5° MSK, depending on the event. This is also confirmed by the isoseists drawn for the "Neulengbach" earthquake of 1590 by Gutdeutsch et al. (1987) and by more recent events. The earthquake of Ebreichsdorf (2000) occurred to the SE and at a greater distance from the Temelín site than Neulengbach. For this event the attenuation is drawn with ΔI=3.2. This is also in accordance with

Figure 2.5.10 (compiled by Šimůnek, 2003) showing attenuations and maximum intensities to be expected from important seismic events along seismically active faults located in Austria.

seismotectonic line	M_{MAX}	I_0	distance km	attenuation ΔI	I_{SITE} ° MSK-64
Mur - Mürz	6,0-6,4	9,0°	191	3,0°	6,0°
Semmering	6,5	9,5°	200	3,0°	6,5°
Leitha	6,0-6,4	9,0°	205	3,5°	5,5°

Figure 2.5.10: Attenuation of intensities for earthquakes occurring along active faults in eastern Austria (Šimůnek, 2003). I_0=I_p maximum potential intensity on the seismotectonic line; M_{max} maximum potential magnitude calculated from I_0 by the relation (3); ΔI= Attenuation of intensities from the seismotectonic line to the site.

It is concluded that a conservative assessment of the attenuation of earthquakes occurring in the Eastern Alps or in the Alpine foreland to the Temelín site should be based on a value of 3° MSK. The historically already felt intensity in this region is 6° on MSK scale.

2.5.7 Review of Calculations Regarding Ground Accelerations from Intensities

The calculation of ground accelerations from intensities is a critical point. Intensities are not directly related to ground accelerations. Relations can only be established in a statistical sense and should be based on regional observations. Because historical earthquakes are only characterized by intensities some relations must be used to obtain accelerations from intensities, however a big amount on uncertainties must be taken in consideration

While there appear to be issues regarding the choice of an appropriate intensity to acceleration conversion table, the real issue is that all such conversions are practically worthless because of the enormous scatter in any plot of intensity against acceleration. It is notorious that these two parameters are almost uncorrelated: accelerations of 1g and over have been recorded for which the intensity was around 5 EMS (European Macroseismic Scale). The use of such conversion tables is now very outdated, and cannot be recommended at all.

The Austrian Expert Team would like to see a conventional PSHA study of the Temelín site in which such conversions are not used.

2.5.8 General Focus on Uncertainties in All Calculations

It is widely recognised today that any hazard study for sensitive structures needs to take into account to the fullest the uncertainties in the input parameters. This is addressed by IAEA-TECDOC-724 chapter 3.2.4 as follows:

"The main contributors to the uncertainty of the hazard curve are: the boundaries of seismogenic structures and provinces; the geometrical parameters of seismic sources; the specification of the seismic activity of the sources; the choice of attenuation relationships; the choice of the stochastic model. An important source of uncertainty is the calculation of magnitude from intensity and transformation into acceleration or other vibratory ground motion parameter."

Modern probabilistic methods provide tools for handling: uncertainties in the true seismicity values due to the limitations of the earthquake catalogue; uncertainties in the seismic model due to different possible interpretations of features; uncertainties in the attenuation. It is critical for any study to be able to demonstrate that it has taken these uncertainties into account. From the available documents it could not be judged if all uncertainties have been included in the full sense of IAEA recommendations. E.g. the uncertainties in defining the source regions seem not to be included and the uncertainties within the relation of intensities and peak ground acceleration may be biased in the Czech calculations.

In conclusion the calculations may lack of a general probabilistic hazard study, which allows for a consideration of uncertainties in the sense of IAEA recommendations. This point cannot be judged from the Austrian side without having full insight into the calculation procedure.

2.6 Microearthquake Monitoring

Monitoring has become an issue of increasing importance worldwide. The benefits are obvious considering the increased capacity of data processing and the quality of raw data received through today's instruments. There is rapid development going on to improve the knowledge in transfer functions, damage detection and system identification technologies. These innovative approaches allow analysis of structures or components from real data. The most used and already well established technologies are those of system identification, where from a given input (i.e. shaker) or ambient vibrations (i.e. considered to be white noise) the real properties of a system are identified, that allows an assessment of a constructed system on "as is" conditions. This becomes particular important when very stiff and complex structures are to be assessed.

For the particular assessment of the effects an earthquake would have on a nuclear power plant micro earthquake monitoring could be very helpful. Any event, also of very low magnitude, reveals the characteristic of the site to some extent. The quality of the assessment will be increased with the number of events recorded. The final target could be a neural network that learns with every event and improves the prediction overtime. It was understood that such a micro earthquake monitoring system has been installed by external sources (University Brno), but there is no direct link to the internal monitoring system. Such a link would provide the possibility to establish transfer functions between the basements to floor levels within the plant. Transfer functions based on real data could be calculated. This would improve a quality of the assessment process considerably.

2.7 Seismotectonic Investigations

2.7.1 General Tectonic Framework

The tectonic evolution of the southern part of the Bohemian Massif is rather complex including three major orogenic evolutions referred to as Cadomian, Variscan and Alpine. The Moldanubian Zone at the SE margin of the Bohemian Massif is characterized by Variscan W directed nappe thrusting, followed by E directed back thrusting and S-N directed shortening in a transpressional deformation regime leading to large scale folding (Hrouda & Ullemeyer, 2001).

The intensive segmentation of the Bohemian Massif by brittle faults started during the late Variscian to Post-Variscian area, approximately from 320 ma ago.

The main faults of the Bohemian Massif are characterized by multistage evolutions. During the Upper Carboniferous / Lower Permian the area was affected by large-scale block tectonics involving faults with vertical offsets of several hundred metres up to some kilometres. According to Meyer (1989) the basement was probably uplifted even 4 to 5 km during the Lower Permian. Repeated vertical block movements up to several kilometres can be correlated with horizontal compression (Peterek et al. 1994), which is related to Mediterranean plate tectonics. Compressive deformation and reactivation of the Hercynian structural elements is the consequence of Alpine collision south of the Bohemian Massiv, which commenced during the Eocene (Vosserbäumer 1985; Ziegler 1987) and resulted in significant movements along fault zones (Skacelova & Havir, 1998). N-S to NW-SE-directed compression in the Alpine foreland resulted in uplift and the in the reactivation of existing fault zones. The movements took place predominantly along N-S, NNE-SSW and NW-SE striking shear zones. Such faults also are outstanding features in the surrounding of Temelín.

As convergence in the Alpine Belt is still continuing, the most recent movements documented in several parts of the Bohemian Massif extend to the Quaternary (e.g., Schröder 1976, 1990). Recent and ongoing vertical movements have been reported from fluvial terraces near Marianske Lazne in NW-Bohemia (Bankwitz, 1994). In addition there are GPS measurements indicating recent movements in the NE Czech Republic. Thus, within a radius of 100 to 150 km there are documented recent tectonic movements.

2.7.2 Discussion of a Regional Seismotectonic Model

Czech data include several geological maps showing tectonic faults in the southern Bohemian Massif and the region near the NPP site (Figure 2.7.1 and Figure 2.7.2). Several of these faults in the Bohemian Massif have been treated as potential seismic sources by applying an “expert system” for the definition of the maximum credible earthquake (MCE). The youngest tectonic movements on the faults in the southern Bohemian Massif including the basin of České Budejovice are said to be Middle to Late Pliocene (c. 5 – 2,6 Ma before present; Workshop at SÚJB Praha, 2003; Energoprůzkum, Report Part 2, 1995). According to these interpretations, Pliocene faulting mostly should have occurred in the eastern part of the basin of Budweis Basin. The last vertical movements in the southern part of the Bohemian Massif are referred to as Early Pleistocene (< 1,8 Ma before present). Younger movements (Middle to Late Pleistocene, Holocene) are excluded by the presented expertise (Simunek, 1995).

This interpretation is not consistent with additional geological and geodetical data presented by the Czech experts, which are indicative for presently non-understood Quaternary deformation in the Bohemian Massif. These data include the post-Pliocene tilting of southern Bohemian Massif, severe re-organisations of drainage systems including the cut-off of drainage to the Danube and the change of drainage to north-flowing rivers, westward tilting of river terraces, and geodetic data proving evidence for differential movements of parts of the Bohemian Massif near Budweis with rates up to 2 mm/year (Vyskocil, 1975), and micro-seismicity recorded both by the Temelín Seismic Monitoring System and Kutina (1974). None of the listed phenomena has been studied in detail.

Additional evidence for young faulting activity in the Bohemian Massif comes from offset of Quaternary sediments along the Hluboka fault, which is included in the fault database used for MCE computation. Although some of the Czech experts are aware of these young regional vertical movements, this is not accounted for in an appropriate tectonic model.

Severe deficits in defining a proper seismo-tectonic model are further evidenced by the facts that no recent stress data were incorporated into geological models, although such data are available for the northern Czech Republic on the public domain (World Stress Map, 2003). Available data conform to the regional stress pattern for stable Central Europe with maximum compression (σ_{Hmax}) oriented WNW-NW, i.e., in a very favourable orientation for the re-activation of NW- and NNE-striking faults depicted in Figure. Furthermore, no attempts were made to connect earthquakes (both felt ones and micro-earthquakes) or geodetically determined vertical movements with mapped faults. According to Schenk (Workshop at SÚJB Praha, 2003), the correlation of earthquakes with faults failed due to inaccurately determined epicentres of historical earthquakes.

The Austrian expert team concluded that neither convincing seismotectonic model, nor even the outline of a reasonable model for Pliocene to Quaternary deformation in the Bohemian Massif is available to backup seismic hazard assessments. Specifically, no state of the art data are available to constrain the Pliocene to Quaternary tectonic history of the region (age dating, analysis of Quaternary landforms, river terrace analyses, pedological and sedimentological analyses). Such data are listed as standard data for seismic hazard assessments in intraplate regions requirements by IAEA (IAEA Safety Guide No. NS-G-3.3, Paragraph 2.10). The lack of a seismotectonic model has also been mentioned in several previous IAEA Expert

Missions including the latest mission report (IAEA Expert Mission, February 3-7, 2003: *„Seismological Database...It was also recommended to clarify in more details the presentation of these seismotectonic models and the way they were used in seismic hazard assessment of the site“:* statement cited at the Workshop at SÚJB Praha, 2003).

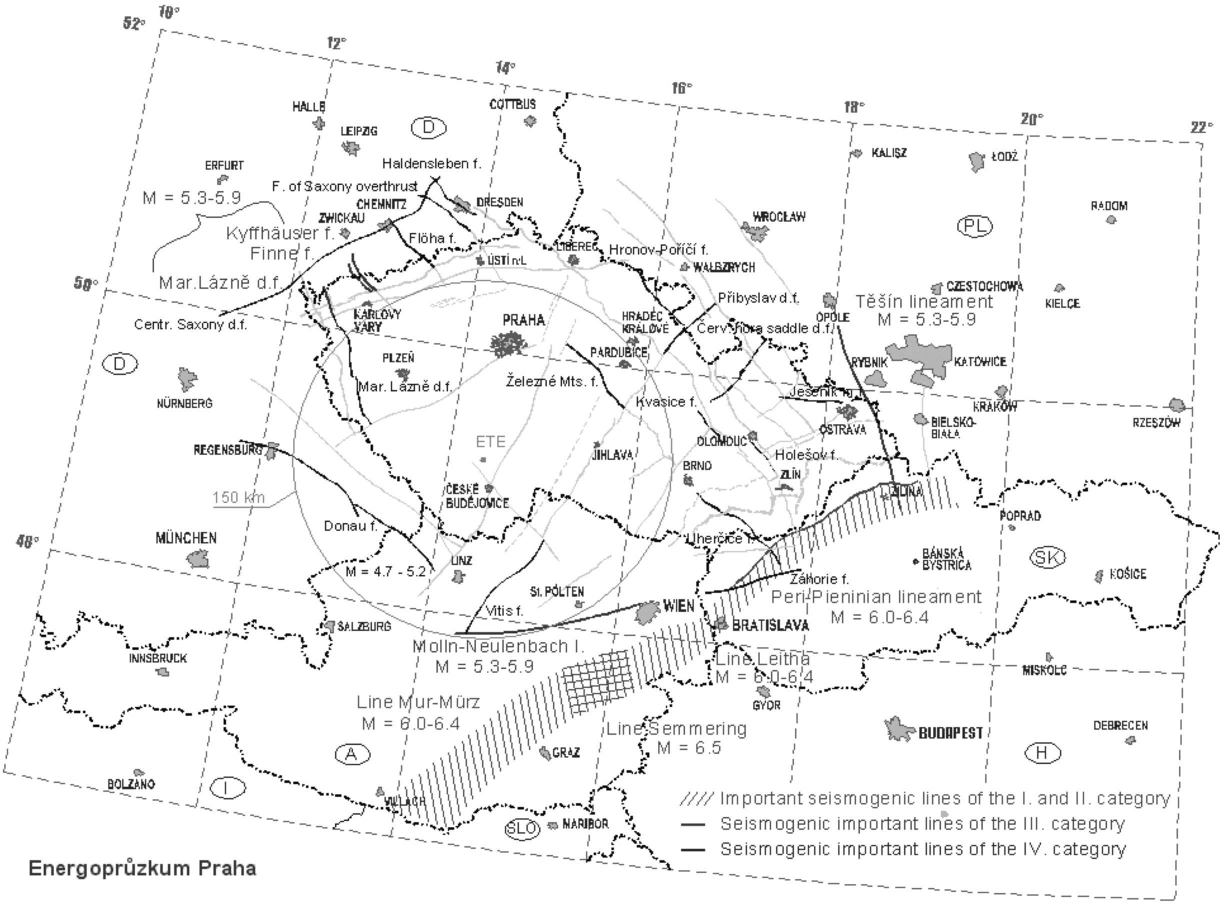


Figure 2.7.1: Regional tectonic map of the Bohemian Massif and adjacent regions highlighting faults, which are treated as potential seismic sources (from Simunek, 1995).

2.7.3 Determination of Seismogenic Structures

Seismic hazard estimates are based on a fault database (faults, which are regarded potential seismic sources: “Map of the Potential Earthquake Occurrence Zones”, Figure 2.7.2), and the source zone model depicted in Figure 2.7.3.

Two maps of potential seismogenic faults are shown in the accessible material (Figure 2.7.2, Figure 2.7.3). The maps differ in a remarkable detail concerning the faults named as Fault 1.5 (Jachymov Fault) and Fault 1.2.1 (Kaplice Fault) shortly south of the NPP (Figure 2.7.2). In the map on Figure 2.7.2, which is used for the computation of MCE’s for each of the depicted faults by an Expert System (see Paragraph 2.10.1), the faults terminate about 25 km SSE of the NPP. The map in Figure 2.7.3 shows Fault 1.2.1 passing about 10 km E of Temelín and Fault 1.5 terminating at a distance close to the power plant. Both maps depict no other faults in the near region of the NPP, although several major faults in the near-region exist (compare the map in Figure 2.7.4). Also, both maps do not include the boundary faults of the Cretaceous basin of České Budejovice shortly south of the Temelín site.

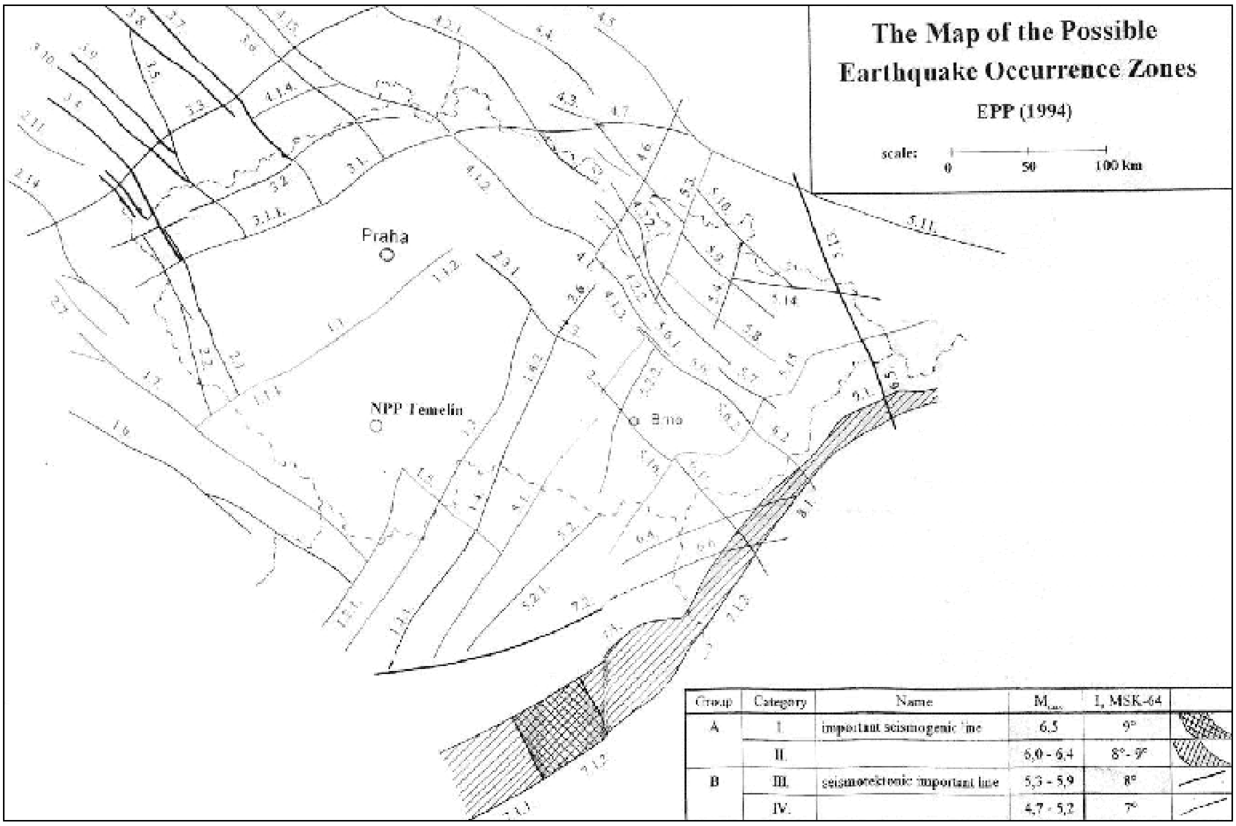


Figure 2.7.2: Map of potential seismic sources (Simunek, Report Part B, 1995).

The presented maps of potential seismogenic zones are not consistent with each other. The selection of potentially active faults, which are accounted for by hazard assessment, seems highly arbitrary as all faults in the near-region of the NPP (Figure 2.7.3) are deleted from the database without discussion or justification. This seems most problematical for the Hluboka Fault (the northern boundary fault of the Budweis Basin), as Czech geological data may be indicative for Quaternary movements along this particular fault (Paragraph 2.7.5.1).

The seismic potential of structures in the near vicinity of the site has also been assessed by Buben et al. (1999). The presented map showed several structures to the south of the site (Figure 2.7.3). The map is remarkable different from other maps of potentially seismogenic faults in the near-regions. Maximum possible magnitudes of earthquakes (mmM) were derived for six faults drawn in this figure on the basis of the fault length L by the formula:

mmM = (1.7+-0.1) log L + (1.0 +-0.5) (km) (1)

taken from Suvilova (1982). This formula differs considerably from the well-known investigation of Wells and Coppersmith (1994):

$M_w = 5.08 + 1.16 \log (SRL)$ (2)

with M_w = moment-magnitude ($M_s=1.5M_w-3$) and SRL=surface rupture length in km. The latter relation gives by far higher magnitudes than that obtained from Suvilova's relation. Maximum potential magnitudes are considered to be near 8 (see also Ward, 1997).

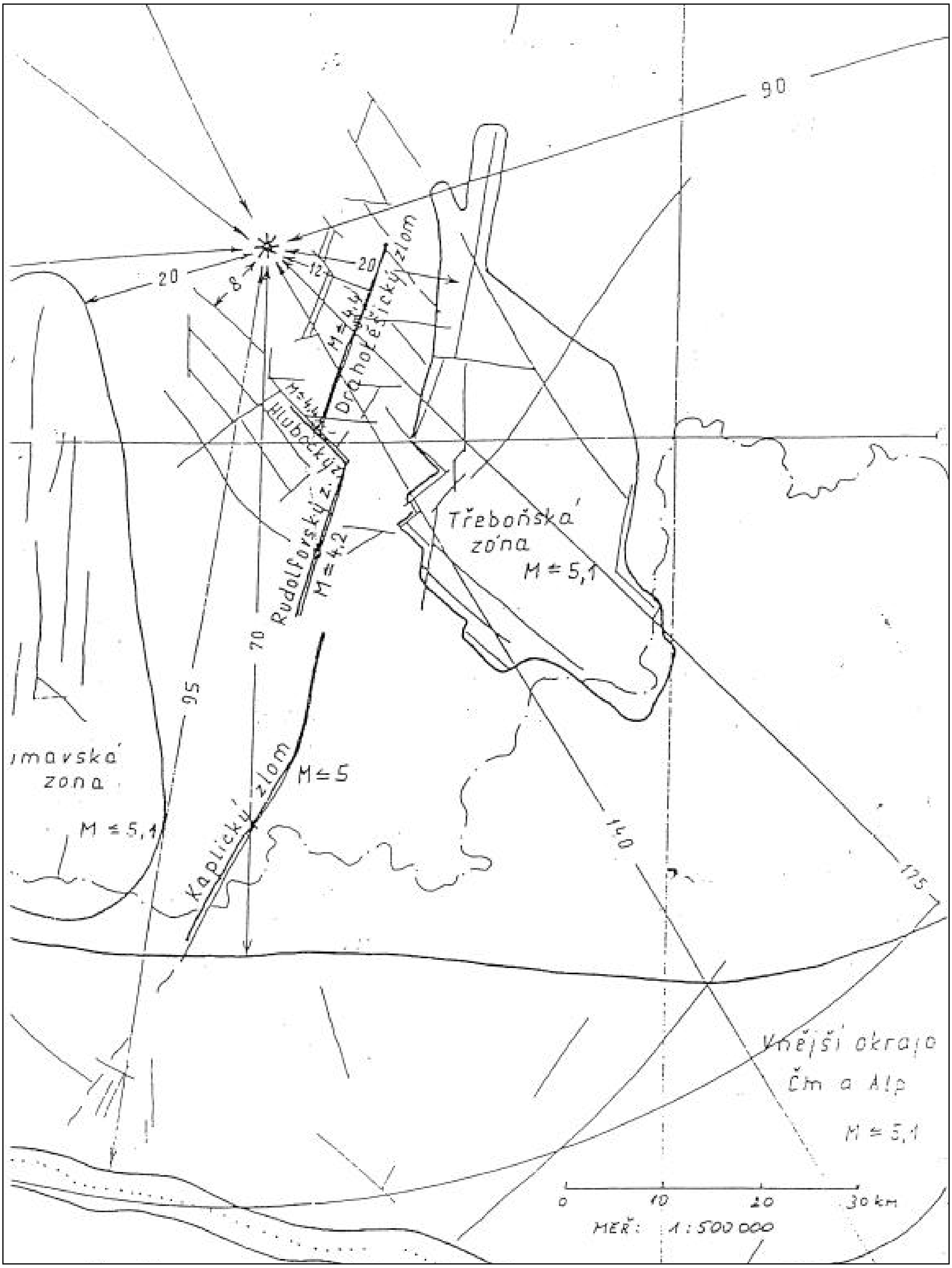


Figure 2.7.3: Map of faults in the near-region of the Temelín NPP (Buben et al., 1999).

2.7.4 Investigation of the Main Fault Systems

Geological and geophysical investigations addressed analyses of a number of faults in the near region of the NPP. A tectonic map of the area depicts 12 faults (Figure 2.7.4; Prachar at Workshop at SÚJB Praha, 2003). According to the Workshop presentations and to background information obtained during discussions, only three faults out of these 12 were studied in detail (Figure 2.7.5). These are the Hluboka fault (studied by boreholes and geoelectrics), Vodnany mylonite zone (trenching) and the Lysnice mylonite zone alias „Podrezany ditch“ (geoelectrics, trenching). These data are regarded to be mostly sound. The remaining faults shown in the near-site maps (Zbudov, Haklovy Dvory, Dubne, Vlavy, Munice, Hrdejovice, Rudolfov, Drahotesice and Blanice fault) have not been investigated, although all faults are traced to distances < 20 km from the NPP site.

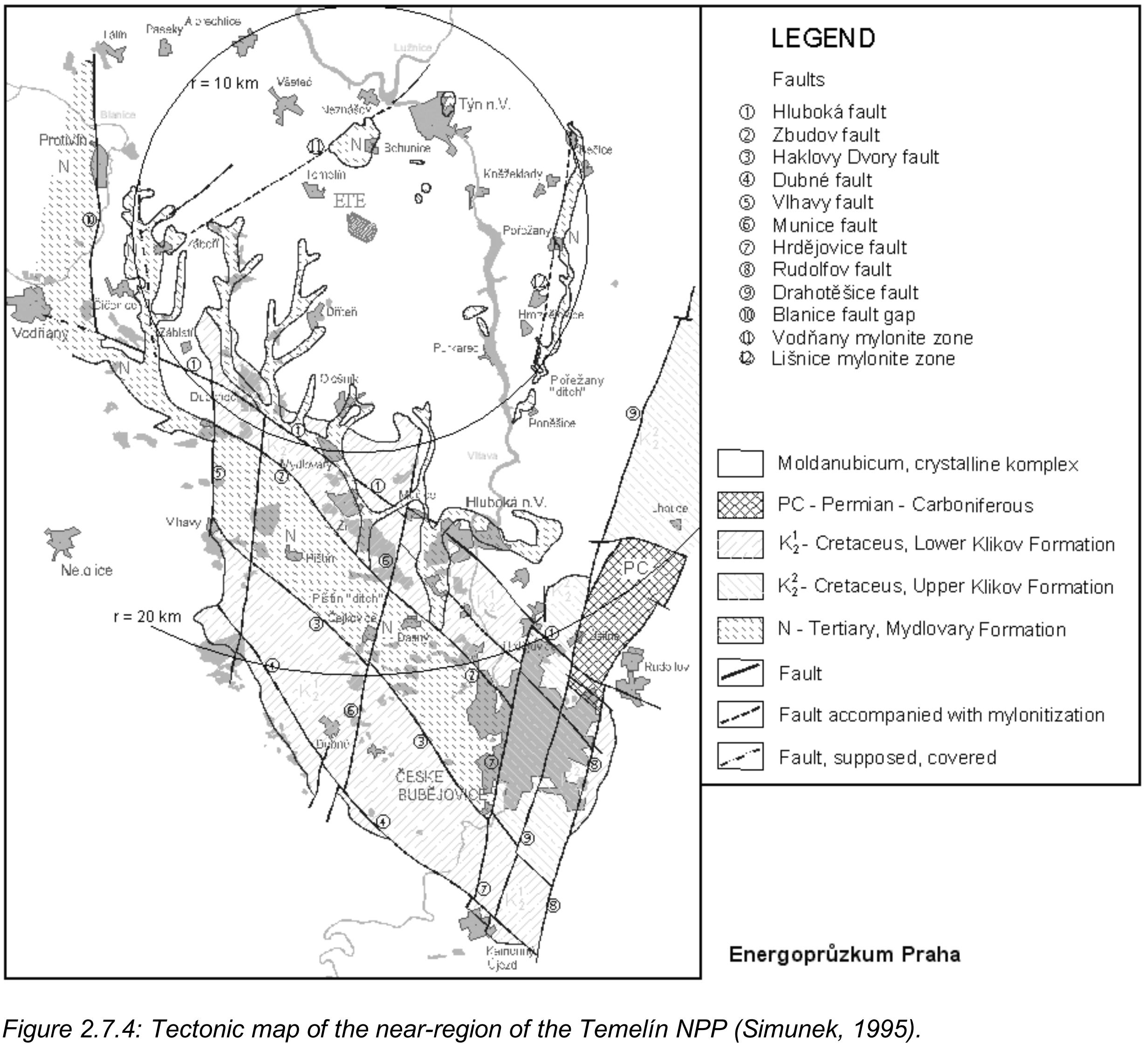


Figure 2.7.4: Tectonic map of the near-region of the Temelín NPP (Simunek, 1995).

	FAULT	RESEARCH PERFORMED
1	Hluboka Fault	4 Boreholes 5 Geoelectric Profiles
2	Zbudov Fault	-- no research evident --
3	Haklovy Dvory Fault	-- no research evident --
4	Dubné Fault	-- no research evident --
5	Vlhavy Fault	-- no research evident --
6	Munice Fault	-- no research evident --
7	Hrdejovice Fault	-- no research evident --
8	Rudolfov Fault	-- no research evident --
9	Drahotesice Fault	-- no research evident --
10	Blanice Fault Gap	-- no research evident --
11	Vodnany Mylonite Zone	Short Trench
12	Lisnize Mylonite Zone (“Podrezany Ditch”)	Geoelectric Profile Short Trench

Figure 2.7.5: Faults in the near region of the Temelín NPP and geological / geophysical investigations performed for seismic hazard assessment Compiled from Simunek (Report Part A, 1995).

The following shortcomings are regarded as the most severe ones in the seismic hazard assessment of the Temelín NPP:

1. Geological data only exist from a small selection of faults cropping out in the near-region of the NPP. The existing data for the Hluboka fault (one section based on 3 boreholes) are insufficient to date the youngest fault activity. For the other faults listed above, obviously *no* data are available to constrain the age of youngest fault activity. This has also been criticized by the latest IAEA Expert Mission (February 3-7, 2003) stating that *„Geological Investigations and Database...: ... Geophysical profiles and trenches were carried out in order to verify whether SOME SPECIFIC geological structures should be regarded as faults and to check the possible activity.... ...It was recommended to make some additional effort on view of a more useful and convincing synthesis of the available data.“* (Cited by Masopust, Workshop at SÚJB Praha, 2003).
2. The Austrian Expert Team agreed that the geological investigation of near-regional faults did not follow state of the art or common practice. The performed investigations are by far not sufficient in addressing only a small selection of faults (3 out of 12 mapped near-regional faults). The following particular points are raised:
   a. With the exception of geoelectrics no high-resolution geophysics (high resolution seismic profiling, geo-radar profiling) were applied to locate and map near-surface faults.
   b. Dating of Quaternary sediments and landforms only rely on doubtful regional correlations to the Alpine glacial record. No biostratigraphic data (e.g., terrestrial gastropods, mamal biostratigraphy, pollen) or absolute age data are visible (14C, OSL, thermoluminescence, etc.).
   c. The tectonic geomorphology techniques, which were applied, are not state of the art, although they seem to be approved by an IAEA Expert Mission, (Masopust, Workshop at SÚJB Praha, 2003). The Hluboka Fault in particular, shows geomorphologic features, which are regarded as strong indications of Holocene fault movements (see chapter 2.7.3.).

d. No geodetic data have been incorporated into the regional and near regional scenario, although such data are available from published literature (Vyskocil, 1975).

e. It is further state of the art and recommended by IAEA guidelines and the site safety review mission 1990 to apply paleoseismological methods including dating of the latest movements of faults. The question of the largest possible event in the near-site area (no matter how low the probability of its occurring is) has to be addressed in a robust way. At present, the lack of such discussion is a weakness in the studies conducted to date.

2.7.5 Determination of Recent Tectonic Activity of Major Faults

As stated in the previous paragraph, the accessible Czech data and reports do not include reliable datings of the youngest fault activity for the faults mapped in the near region. The inadequacy of previous investigations is shown by a review of data available from the Hluboká Fault and Vodňany Mylonite Zone, which are the most extensively discussed faults in the report by Simunek (Report Part A, chapter 3.1. and pp. 31-39, 1995) and IAEA. Data included in the report are summarised in Figure 2.7.6. The faults have been surveyed during a reconnaissance field trip by the Austrian expert team.

2.7.5.1 Assessment of the Hluboká Fault

Cursory field surveys by the Austrian Expert Team and a review of the data provided in the Simunek 1995 report shows that the Hluboká (Raininger) Fault separating the Budweis Basin from the crystalline units to the N is marked by distinct morphological features, which may indicate Quaternary and active normal faulting along the fault and continued subsidence of the Budweis Basin.

Boreholes
Borehole TSv-7, NVr-1 (Malecha, 1994): Tab. 3.1 (p. v)
Borehole H-1, H-2, H-3: Fig. 4 (p. A36); P3.1. (p. viii – x)
Borehole HL-3: P3.1.2 (p. xi)
Borehole M-1, M-2: P3.1.3 (p. xii-xiii)
Geoelectrics
Geo-electrical profiles Munice A, B, C (Supp. 4, p. xxv) *[Munice A not depicted; no location map]*
Geo-electrical profiles Hluboka 17, 18 (Supp. 4, p. xxiii – xxv)
Compilations of previously existing borehole data (mostly without location maps) and geological maps

Figure 2.7.6: Geological and geophysical data for the assessment of the Hluboká Fault (Simunek, 1995).

Based on a profile constrained by only three boreholes (H-1 to H-3), Energoprůzkum regards the fault not active since at least the Riss (c. 300.000 y). This is deduced from the non-coincidence of the fault trace with the morphological scarp SE of Hluboka, and from the supposed age of the fluvial terrace of the Vlatva adjacent to the scarp (age data for the terrace are not provided). The morphological scarp is interpreted as an erosional feature of the Vlatva River. Similar interpretations for the fault sector near Munice are based on two boreholes and one geo-electrical section. It is argued that the main fault does not coincide with a significant morphological scarp. According to the boreholes H1, H2 and H3 located immediately west of the scarp the basement rock (crystalline) is reached at 15 depth and at a about 50 m height east of the scarp toe (within a distance of 30 – 40 m); this difference in height cannot be explained as only due to a destructive (erosional) process and additional boreholes may indicate the exact location of the Hluboka Fault and its relation to young deposits.

Previous research on the fault system is regarded to be insufficient for dating the latest fault movements, for ruling out Quaternary and active movements, and for excluding the fault as a potential source for earthquakes.

Surveying the NE boundary of the Budějovice Basin between Hrdějovice (north of České Budějovice) and Nákři showed a marked change in morphology across the boundary faults between the Cretaceous / Neogene basin and the crystalline basement units. The flat morphology of the Budějovice Basin with abundant lakes and wetlands strongly contrasts from the hilly areas NE of it. According to the geological map 1:50.000 and the data shown by Energoprůzkum the basin boundary is controlled by a series of faults rather than by a singular main fault. Geomorphological features indicative for possibly young or ongoing deformation include marked linear morphological scarps paralleling the fault system, a segmented fan indicative for possible uplift of the scarp, disturbed Quaternary river terraces of the Vlatva River, the general appearance of the Budějovice Basin as an area of wetlands indicative for continuous subsidence, and published geodetic data indicating continued subsidence of the basin with about 0,7 mm/yr (Vyskocil, 1975). Several fault sectors obviously show marked morphological expressions, which could be controlled by young or active tectonics:

Hluboká - Hrdějovice. The most conspicuous scarp occurs SE of Hluboká (Figure 2.7.7). Features pointing to tectonically controlled topography include the rectilinear trend of the scarp and the morphology of a small fan in front of the scarp (Figure 2.7.8); the location S of Hozin “Nad kamenem” is also shown in the Simunek Report, his Figure 3.5). This fan seems to be segmented in comprising slope segments that are relatively linear and that are characterized by abrupt transitions in slope. The relatively steep fanhead with an abrupt down-fan transition to a lower gradient surface could indicate an actively uplifting hinterland of the fan, i.e., active uplift along the Hluboká scarp.

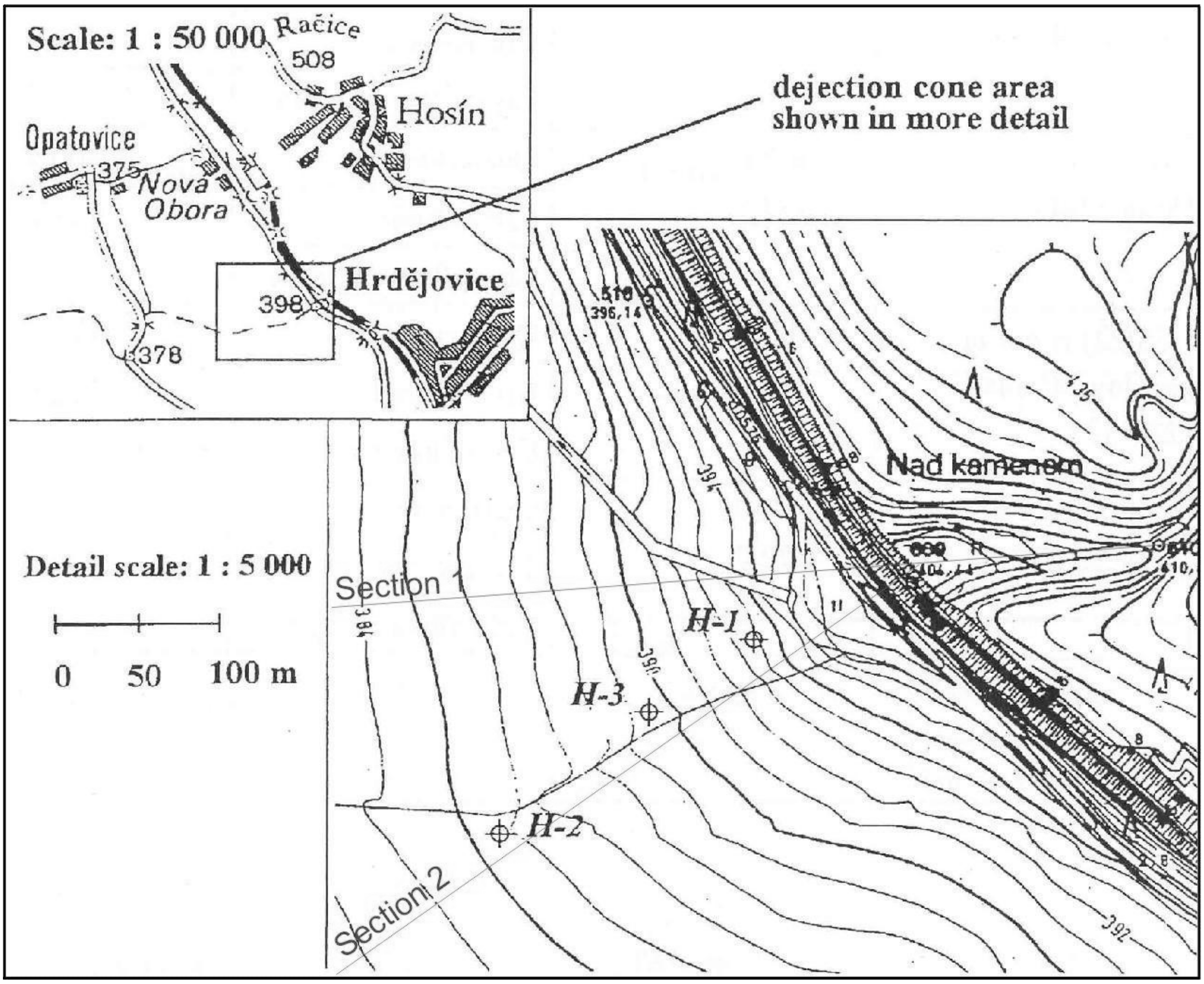


Figure 2.7.7: Detailed topography of the suspected fault scarp of the Hluboká Fault (SE of Hluboká) and a fan adjacent to the scarp. H-1 to H-3 are exploration boreholes. The topographic sections (Section 1 and 2) are shown in Figure 2.7.8. (scanned from Simuek 1995, Fig. 3.5, p. viii).

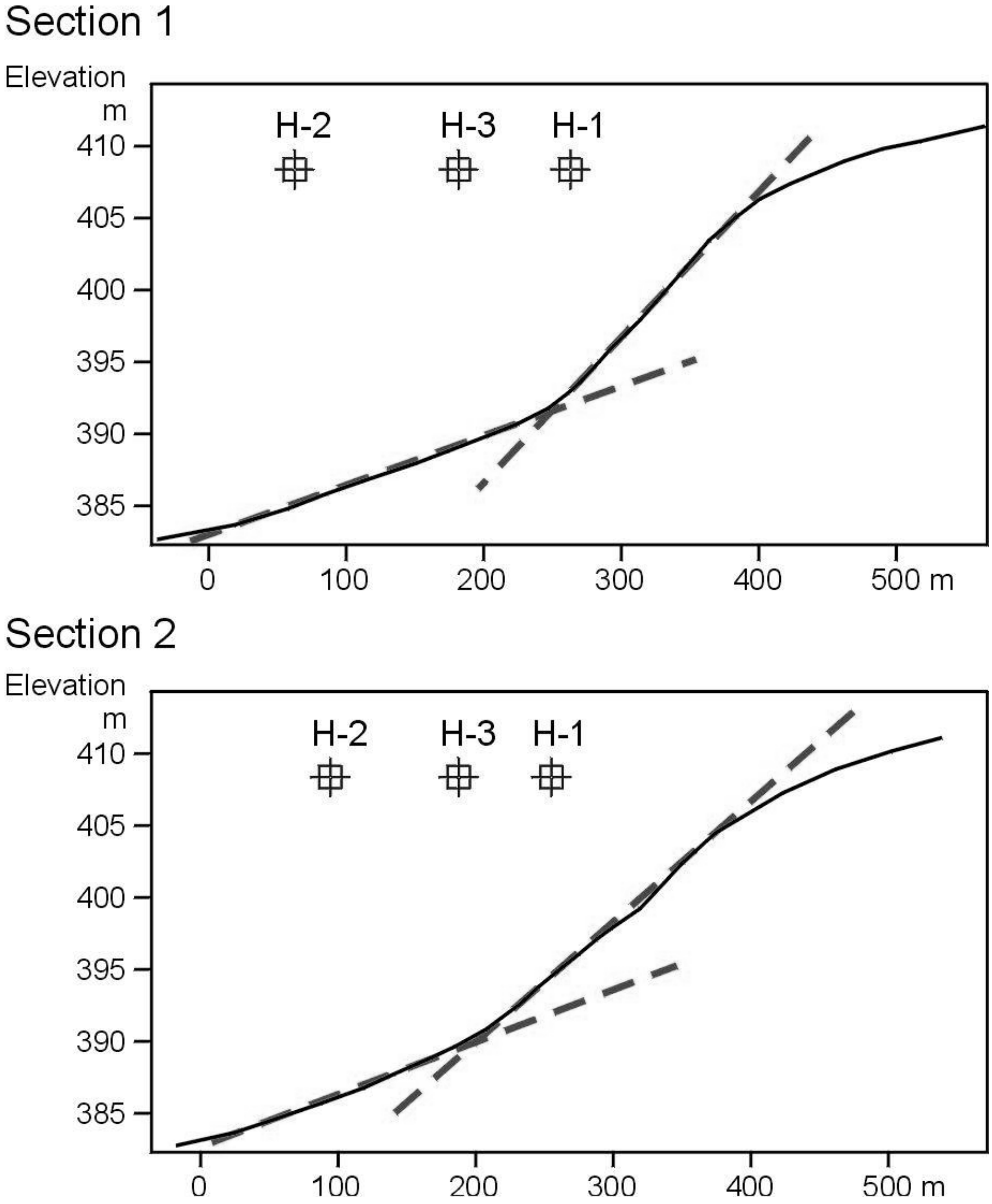


Figure 2.7.8: Topographic sections across a fan adjacent to the suspected Hluboká fault scarp (SE of Hluboká) constructed from the map shown Figure 2.7.7. Note the obvious segmentation of the fan with low linear gradients at the lower fan and steeper linear slopes at the fanhead. Features denote a segmented fan, which may be indicative for active uplift along the scarp.

Olešnický v. The survey indicates that the NW-SE-striking fault-controlled boundary between Cretaceous sediments and crystalline units (marked by wet ground caused by the Cretaceous aquitards) corresponds to a gentle increase of slope (Figure 2.7.92.7.9). A small valley crossing the fault shows a steepening valley floor resembling so-called “hanging valleys”, which are indicative for active vertical movements across the fault. The fault sector has not been investigated.

Nákři – Olešnik. Inspection of the continuation of the Hluboká fault zone revealed a possible NW continuation of the gently sloping scarp seen at Olešnický hill (Figure 2.7.92.7.9). Several small valleys entering the Budějovice Basin from the NE interrupt the scarp. The possible extension of the apparently linear scarp between Olešnický hill and Nákři is about 4 km. The fault sector has not been investigated.

Figure 2.7.9 a

Hluboká. Morphological scarp along the Hluboká Fault SW of the village Hosin.

Figure 2.7.9 b

Olešnický v. Gentle linear scarp marking the NW-SE-striking fault boundary between Cretaceous sediments and crystalline units. The gentle valley in the center of the picture shows a valley floor steepening across the scarp.

Figure 2.7.9 c

Nákři – Olešnik. Morphological scarp in the NW continuation of the scarp at Olešnický v.

Figure 2.7.9: Pictures of morphological scarps at the Hluboka fault NW of České Budejovice.

Assessment of the Quaternary river terraces of the Vlatva. Energoprůzkum provides detailed data on the correlation of Quaternary and Pliocene terraces along the course of the Moldau/Vlatva River, which crosses both the Budweis Basin and the Hluboká fault zone. The authors conclude that no significant vertical movements disturbed the terraces, which they correlate to the youngest Alpine glaciations of Mindel, Riss and Wuerm. They therefore definitely exclude tectonic movements in the last 600 ky (Energoprůzkum 1995, p. A80).

From the geomorphological point of view the drainage pattern of the Budweis Basin is quite peculiar since the Vltava River flows against the Hluboka scarp. The schematic profile along the Vlatva River (Figure 2.7.10; figure 11 in the report by Simunek, 1995) shows an apparent uplift of the Mindel and Riss terrace in the area north of the Budweis Basin. Both terraces show upward convex topography at the crossing of the Hluboká fault, which may be indicative for the relative uplift. In addition, the detailed sections (Fig. 5.1 in the Energoprůzkum report part A, Simunek, 1995) depict a number of river terraces, which are restricted to the area N of the Budweis Basin and which cannot be traced upstream. Both features, the apparent uplift of terraces and the increase of the number of terraces formed, may be related to Quaternary tectonics and the relative uplift of the region N of the Budweis Basin along the Hluboká fault. Both geomorphological features are not addressed in the report. An additional severe weakness of the assessment provided by Energoprůzkum (1995) is the entire lack of appropriate age data for the Quaternary sediments.

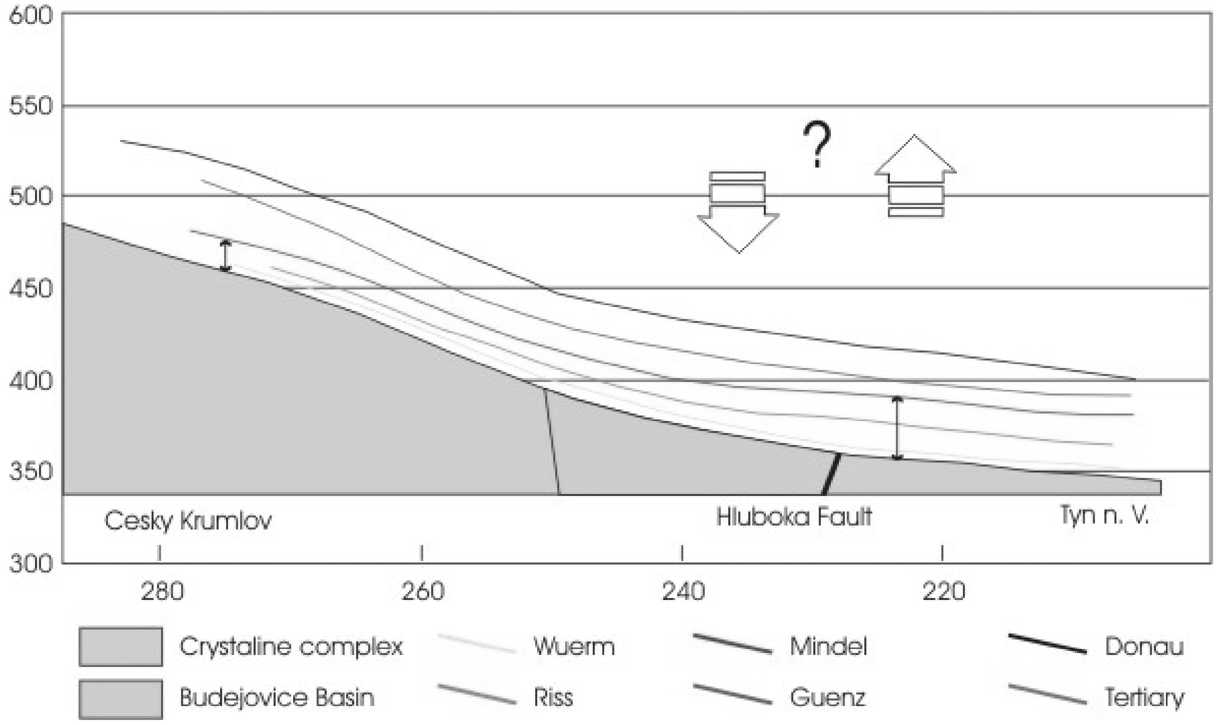


Figure 2.7.10: Schematic profile of the Quaternary terraces along the Vlatva River across the Budějovice Basin (redrawn from Energoprůzkum 1995, figure 11, page A 81). Note the change of elevation of the Mindel and Riss terraces above the actual river across the Hluboká fault zone as well as the convex-up topography of these terraces adjacent to the fault. Features may indicate Quaternary uplift of the area N of the Hluboká fault (to the right of the fault in the diagram).

The key result of the survey by the Austrian Expert Team is the suggestion that the Hluboká Fault should be investigated in much more detail in order to assess or exclude its seismic potential. The minimum distance between the fault and the NPP is c. 9 km. Additional geological and geophysical exploration should focus on this fault rather than on the other faults within the near-site of the NPP. Investigations, which deem necessary for emending the assessment to current practice, are shortly outlined in Paragraph 5 of this report.

2.7.5.2 Assessment of the Zbudov-, Lišnice- and Vodnany Fault

Short additional surveys covered several locations along the Zbudov Fault and the Lišnice Mylonie Zone ("Porežany Ditch"). The expert agreed that these faults, which have been investigated by Energoprůzkum in some detail, seem to be of minor concern compared to the Hluboká fault.

The Vodòany Mylonite Zone is located c. 3-5 km NW of the power plant and dips to the SE below the power plant. The structure is regarded to be of Miocene age separating Miocene sediments and crystalline basement units. Due to its location, geometry and the possible association with micro-earthquakes it may have crucial impact on the construction site. The Vodnany Mylonite Zone was explored by trenching (Simunek 1995, Report Part A, p. A44, figures 3.8 and 3.9, Photo 8, 9 therein). Based on the results of trenching this report states that the morphological scarp, paralleling the fault close to the location Fanfiry, is not related to a fault. The documented 25 m long trench, however, is regarded to be insufficient for such conclusions. The trench at the location Fanfiry did not recover any fault. Also, the expected contact between crystalline rocks and Miocene strata was not recovered. The selection of the trench site has not been based on high-precision locations of the fault zone (by geoelectrics, seismic or ground penetrating radar). The described investigations are regarded insufficient for excluding Quaternary or Holocene movements along the Vodnany Fault.

2.7.6 Investigation of Tertiary Sedimentation and Quaternary Influence of the Relief

Investigations on Tertiary sedimentation, Quaternary landforms and geomorphology are included in the chapters 4 and 5 of the Energoprůzkum report (Simunek, 1995). Assessments of these results are included in the paragraphs above.

2.7.7 Discussion on Application of Integrated Techniques as Recommended by IAEA (Neotectonics, Paleoseismology, Geomorphology, Sedimentology)

Both the amount and quality of data obtained from integrated geological, geophysical, and geomorphological methods are insufficient for the conclusions made. The shortcomings in the assessment of near-regional faults are regarded as the most severe ones in the seismic hazard assessment of the Temelín NPP.

Geological data only exist from a small selection of faults cropping out in the near-region of the NPP. For all faults, the existing data are regarded insufficient to date the youngest fault activity. A detailed assessment of the research performed is included in Paragraph 2.7.4, Investigation of the Main Fault Systems.

2.8 Seismic Monitoring System

The main objectives of seismic instrumentation are:

1. To provide data on the seismic motion parameters at selected locations to confirm or validate the design and evaluation basis
2. To help in the decision making process for the appropriate response in the case of earthquake occurrence.

The current situation of seismic instrumentation and scram systems at the plant, along with their operation and functions should be reviewed. The review of the existing instrumentation should consider the local seismological network at the near region around the site and the seismic instrumentation at the plant itself.

The main goals for monitoring systems at the site are not always very clear, as they can support different tasks:

- Support operator actions during an event
- Confirm design assumptions
- Support long-term periodical safety reviews.

In some cases they are safety related in accordance to such classification, responsibilities for data acquisition, processing and reporting should be defined.

In case of the nuclear power plant Temelín the post event operator actions related to concerns of earthquake protection should fulfill the following criteria:

- Determination of level, frequency and duration of earthquake activity at the NPP site (Note: in case of low seismic activity an automatic system is rarely justifiable).
- Seismic capacity of NPP structures, equipment and distribution systems: Particularly in case of seismic hazard re-evaluation, automatic systems could be useful.
- Safety considerations related to spurious scram in case of high ambient noise (i.e. quarry) also in used by other plant equipment (i.e. urban), it could be advisable to avoid any automatic system.
- Expected time of seismic scram and comparison of this time to the expected time to reach the strong motion part of the earthquake time history.
- Broad ranging safety issues related to the consequences of the state from shut down of the plant immediately following an earthquake.
- Level of operator confidence and reliability: In case of a non-automatic system the operator plays a major role in the decision of post earthquake actions.

For further details it shall be mentioned here that project PN 4 is devoted to seismic qualification of equipment and project PN8 if devoted to seismic design, which interact considerably with the results of the evaluation of site seismicity.

The monitoring system should consist of sensors located preferable at the free field and at the location of safety related equipment in the plant. These are (i.e. minimum amount of sensors usually installed at NPPs):

- One three axial strong motion recorder installed to register the free field motion time history.
- One three axial strong motion recorder installed to register the motion of the basemat of the reactor building.
- One three axial strong motion recorder installed on the most representative floor of the reactor building.

The trigger levels should be adapted to the location of the sensors in the plant, recording to the seismic design results. In case of multi-unit-sites, the scram logic should be coordinated among the different units. The control panel of the monitoring system should be located in control room for an easy access by the operator. In case of the NPP Temelín the monitoring system presented in the workshop, in Prague, fulfills the minimum requirement specified.

The Temelín micro-earthquake Monitoring system has been presented including several details. The system is several years old and it should be replaced by more modern and uniform equipment. Some of the recorded events could not be located exactly and focal solutions could not be presented. To overcome this problem additional stations should be placed with attention to events near the “Vodnany mylonitic zone”.

2.9 Earthquake Hazard Assessment: Comparison to Other Incidents

The Perry Nuclear Power Plant close to Cleveland in the US was affected by the Leroy earthquake with a magnitude 5 in 1986. The epicenter has been 18 km away from the NPP. The strong motion duration was only one second with a total earthquake duration of 2,7 seconds. The PGA at the site was 0,19g, higher than the design value of 0,15g. The CAV parameter registered a value of 0,08g sec. (a potential damage is usually associated to values of 0,3g or more). Relative displacement between basemat and containment shell was 0,1 cm while the design value was 0,36 cm.

There has been no damage found in the walk down and the lessons learned have been:

- PGA as damage indicator is not as suitable choice, while CAV or relative displacement confirmed their validity.
- Low energy earthquakes even if very close to their site induce low damage because of a short duration and high frequency content.

At the Humboldt Bay nuclear power plant in California an earthquake with magnitudes 7,0 of coast 120 km has been recorded in 1980. The free field PGA of site was 0.2-0,25 g (horizontal). The plant design original value was 0,25 g, upgraded in 1975 to 0,5g. Significant modifications were implemented to structural steel and lateral restraint to piping. No visible damage was recorded at structures, systems and components.

The lessons learned have been that upgraded structures can withstand events higher than the original design bases. It is further concluded, that maximum peak ground acceleration as the only design parameter is not a confident measure of safety.

For the Temelín site the following conclusions may be drawn. The Czech position is that a hazard figure of 0.10 g is acceptable for low hazard cases according to the IAEA guidelines. This may be true, but national experience in France and the UK is that regulators would still insist on higher values being used.

2.10 Earthquake Hazard Assessment: Comparison of the IAEA Regulations with the Czech Approach

Seismic hazard assessment may be carried out under observation of different regulations. Within this section a comparison is made between IAEA regulations No. NS-G-3.3 and the Czech approach. The comparison is not complete and will only include those aspects, where the Czech approach differs from IAEA regulations. The assessment of the SL-2 level earthquake in accordance to IAEA Regulation No. NS-G-3.3 should be performed in several steps. Some important steps can be enumerated as follows.

- *Step 1:* Establish a geological, geophysical and geotechnical database (see Paragraph 2.4 of this report).
- *Step 2:* Establish a seismological database. This topic is addressed in Paragraph 2.5.
- *Step 3:* Construction of a regional seismotectonic model. See Paragraph 2.7.2 for details.
- *Step 4:* The evaluation of ground motion hazard. Evaluation of ground motion hazard will be considered in Paragraph 2.11.

IAEA regulatory guide No. NS-G-3.3 allows for two different models for hazard calculation referred to as the deterministic and the probabilistic method. Hazard calculations using both methods have been presented by the Czech side. Finally both methods serve to scale appropriate ground response spectra.

2.10.1 Deterministic Seismic Hazard Assessment

The deterministic methods are described in IAEA NS-G-3.3 (2002, Chapter 5.14) and will not be repeated here in detail. The following paragraphs review the Czech approach to the three major steps *(1) – (3)* prescribed by the IAEA Regulation:

(1) "Dividing the seismotectonic model into seismotectonic provinces corresponding to zones of diffuse seismicity and seismogenic structures".

A clear seismotectonic model was not presented or described in detail, and no satisfactory effort was undertaken to define seismogenic structures. Instead, several seismic source zone models shown. To date it is not clear which of the models finally has been used for deterministic hazard assessment. It is concluded, that the model of Šimůnek (1995) has been used with some modifications. The validity of this model has been discussed in Paragraph 2.7.

(2) "Identifying the maximum potential earthquake associated with each seismogenic structure and with each seismotectonic province".

Czech data include several maps showing tectonic faults in the southern Bohemian Massif and the region near the NPP site (Figure 2.7.1 and Figure 2.7.2). Several of these faults in the Bohemian Massif have been regarded potential seismic sources and magnitudes of maximum credible earthquakes (MCE, comparable to the SL2 earthquake) have been estimated using a semi-quantitative „Expert System" for fault classification and seismic hazard assessment (Energoprůzkum Report Part 1, Simunek 1995; Simunek, Workshop at SÚJB Praha, 2003). The approach strongly deviates from internationally used standard approaches for deriving MCE magnitudes for certain faults (e.g., Wells & Coppersmith, 1994; Vakov, 1996; Schmidt, 2003: PEGASOS – Re-evaluation of Swiss NPP's). It is suspected that the application of the cited correlations would result in significantly higher estimates for MCE's for individual faults in the Bohemian Massif than the values provided in the report by Energoprůzkum (Report Part 1, Simunek, 1995).

The most obvious shortcoming of the approach is that MCE magnitudes have not been computed for faults in the near region (i.e., at distances < 25 km) of the NPP, which partly were investigated by cursory geological investigations (see Paragraph 2.7.4). Despite of distinct geological evidence some of the faults, for which MCE's have been computed, are not traced into the near region (compare Figure 2.7.4 and Figure 2.7.2).

It is concluded that the employed Expert System for estimating MCE values is not satisfactory explained and severely deviates from internationally used approaches. Also, the selection of faults, which are treated as potential seismic sources and for which MCE's are estimated, seems highly arbitrary and not related to geophysical or geological data. This is especially true for the exclusion of the near-regional faults (at distances < 25 km from the NPP) from MCE computations.

MCE estimates for remote seismic sources in the Eastern Alps and their foreland seem more reasonable. The maximum potential earthquake for the Mur-Mürz Fault has been quantified with 9.5° MSK (Table of PSHA; Workshop at SÚJB Praha, 2003; Šimůnek, 1995). Details to this assessment such as fault length, fault area, stress drop a.s.o. were not given. The division of this zone into three parts was not explained. For a conservative assessment this division may not be accepted and the whole zone may be regarded as belonging to one seismogenic structure with seismically active faults. The maximum observed intensities in this zone is I_0=9°MSK. Using standard practise the maximum potential intensity for this region will be I_0 (observed)+1°, that is Imax=9°+1°=10° MSK. This applies as well for the "Neulengbach" region where we evaluate also a maximum potential earthquake of I_0=10°.

(3) "Performing the Evaluation"

The review of the performed evaluation concentrates on the earthquake of Neulengbach (1590) and the Mur-Mürz-Leitha seismogenic structures. According to the previous discussion the attenuation from these structures to the site is ΔI=3°MSK. The maximum potential earthquake for the Mur-Mürz-Leitha structure and the "Neulengbach-region" can be estimated as $I_{observed}$+1=10°. The maximum expected potential intensity at the site is Ip =10°-3°=7°MSK. So we can state that the SL-2 level earthquake should be at least 7°MSK.
This contradicts the results presented by Šimůnek (Workshop at SÚJB Praha 2003) where the maximum potential Intensity (*including* one degree of safety margin) at the site was denoted as I_{max} = 6.5. The magnitudes calculated are not conservative.

2.10.2 Probabilistic Seismic Hazard Assessment

The IAEA Regulation NS-G-3.3 (2002, chapter 5.17), lists the following steps, which again are compared to the practice of the Temelín hazard assessment.

(1) "Evaluation of the seismotectonic model for the site region in terms of seismic sources, including uncertainty in source boundaries".

The evaluation of the seismotectonic model has already been discussed in a previous chapter. Rudajev et al (1998) use only the source zone model of Schenk et al (1989). Distinct seismic sources are not differentiated. So the calculations are based on diffuse seismic zones only and do not include fault zones. According to the available documents and information obtained during the Workshop at SÚJB Praha (2003) the uncertainty in the source boundaries was not properly addressed. The additional error caused by different source models is not given.

(2) "For each source, evaluation of the maximum earthquake magnitude, rate of earthquake recurrence and earthquake recurrence model, together with the uncertainty associated with each evaluation".

Earthquake magnitudes have not been calculated. Instead maximum possible Intensities I_p were taken from Schenk et al. (1989). The authors of that publication used Gumble III statistics and maximum observed values for estimating I_p. The use of extreme value statistics is not recommended by the IAEA NS-G-3.3 (2002) publication. The reason is that it is not conservative.

(The literature shows examples with actually observed higher values for I_o than the extreme values calculated by statistics). Estimating the maximum possible earthquake equal to the maximum observed earthquake obviously is not conservative. In addition it is not stated which of the two methods has been applied at the different zones. In any case both methods do not regard the demands of chapter 4.17 of the NS-G-3.3 (2002).

The authors of the report Rudajev et al (1998) have been well aware of this point. However they could act only on basis of available literature. Establishing a new seismotectonic model as requested by the IAEA was out of their scope.

The evaluation of the earthquake recurrence and the recurrence model parameters were carried out using the Poisson model (Gutenberg Richer relation) by a program written by Malek and Buben. This method has been applied to the seismic source zonation of Schenk et al (1989). Zone 22 of this model was excluded from the computation without giving reasons. For the near site region in addition 11 faults have been considered, with maximum potential Intensity I_p varying from 5° to 7° MSK.

To adapt the incompleteness and the possible non-stationary of the time series of the catalog a homogenization of the catalog has been carried out.

The same program was used to evaluate the uncertainty of the calculations. For that purpose the b parameters of the relation

$\log N=a-b*I$

(N=average annual cumulative number of events with epicentral Intensity I, ($I_L \leq I \leq I_U$)) have been varied. The variation of b was taken as 5 linear steps ranging from $0.8*b_0$ to $1.2*b_0$. This implies a boxcar distribution of the parameter b around a mean value b_0. This clearly does not represent a reasonable stochastic model. The standard deviation in Poisson processes is rather large ($s^2=\mu$; μ=mean), and the uncertainty in b strongly depends on the number of data used in each zone. Therefore this kind of error calculation will not give statistically relevant error estimates.

(3) "Evaluation of the attenuation of earthquake ground motion for the site region, and assessment of the uncertainty in both the mean attenuation and the variability of the motion about the mean as a function of earthquake magnitude and source distance".

This step should be considered in more detail and cannot conclusively judge with the information given during the Workshop at SÚJB Praha (2003). The points in question are the relation between Intensity and acceleration and the attenuation between the seismogenic structure and the Temelín site. Some intensity acceleration relations taken from the literature are compared in Figure2.10.1. The relations used for the probabilistic method presented in Prague (2003) are summarized in Figure 2.10.2.

The attenuation ΔI was calculated by Rudajev et al. (1998) by the well-known relation

$\Delta I=k*\log(D/H)$

With H= depth to the focus, D=focal distance and k =constant, depending on the source area. Unknown H-values of historical earthquakes were taken as typical values from Prochazkova (1982). The attenuation coefficients k was taken individually for each source zone. The individual values were not contained in the publication, however during the Prague presentation it was declared, that they have been taken from Schenkova et al. (1981) The attenuations calculated in this publications are mean values not minimum values and therefore lead to non conservative estimates (high) values of attenuation. For instance the attenuation from Neulengbach region is 3.7 in the table of Rudajev (2003) and 3.0 in the table of Simunek (2003). Similar to the procedure with b-values also the variation of k-values was considered by Rudajev et al. (1998). A rectangular distribution starting with 0.9*k and ending with 1.1*k was applied. This variation will not cover the real spread of the intensities to the opinion of the Austrian Expert Team.

The correlation between intensity and mean ground acceleration is comparatively low and depends strongly on the region. For different relations have been used by Rudajev et al. (1998), see Figure 2.10.1.

Relation	Author	Value of A [m/s²] at I=7° MSK
$\log A=0.45*I_s-1.3$	Drimmel (1985)	0.71
$\log A= 0.33*I_s-0.5$	Gutenberg & Richter(1956)	0.64
$\log A= 0.30*I_s+0.014$	Trifunac (1975)	1.30
$\log A= 0.19*I_s+0.62$	Schenk (1985)	0.89

Figure 2.10.1: Calculation of accelerations from intensities used with the Czech approach.

Further intensity acceleration relations taken from the literature are compared in Figure 2.10.2. The relations used for the probabilistic method presented in Prague (2003) are summarized in Figure 2.10.1.

Relations between intensities and horizontal peak ground accelerations				
Reference	Peak ground accelerations [m/sec^2]			
	Intensity MSK-64			
	6	7	8	9
Old Soviet practice	0.25 - 0.5	0.5-1.0	1.0-2.0	2.0-4.0
PNAE G7-002-86	0.9	1.9	3.8	7.5
French SCSIN (including additional safety)		2.5	4.0	6.0
old KTA	0.3-0.9	0.7-2.2	1.5-3.0	3.0-7.0
NUREG/CR-0098 el Centro	0.4	0.8	1.7	3.4
DOE/NE-0086 (1989) California		1.25	2.5	5.0
Murphy (1977) S-Europe	1.0	1.8	3.1	5.4
Murphy (1977) World	0.6	1.0	1.8	3.2
Drimmel (1985) Austria	0.3	0.7	2.0	5.6
Schenk (1981) U.S.+Japan	0.4 - 1.0	0.6-1.6	0.9-2.5	1.4-3.9
Eurosafe (1999)		1.0		

Figure 2.10.2: Relations between intensities and horizontal peak ground accelerations

Comparison of the two tables gives the impression, that the relations used for the probabilistic method are biased toward lower accelerations. As far as was understood by the Austrian expert team the variation caused by different zonings was not considered by the probabilistic hazard assessment.

All together it is concluded by the Austrian Expert Team, that the probabilistic hazard assessment is an important contribution to objectify hazard assessments, but it underestimates the hazard at Temelín site. The method itself seems to be correct, but some input data and parameters should be improved.

2.11 Seismic Design Base

2.11.1 Review of the Seismic Design Basis (SL1 Level)

A comparison of requirements inferred from international standards and regulations (especially *IAEA 50-SG-S1* and *IAEA NS-G-3.3* (2002)) with implementations at Temelín NPP shows that some regulations have been observed only partially. One special topic is the use of site-specific response spectra as explained in the following context:

In accordance to *IAEA NS-G-3.3* (2002) design basis ground motions should be expressed in terms of response spectra having a range of damping values and compatible time histories.

Site-specific response spectra could not be attained for NPP Temelín, because of lack of data. It was not communicated to the Austrian side which response spectra have been used during the early design of the NPP. In the Posar and in Šimůnek (1995) special designed response spectra have been presented. These spectra have been compared with site independent spectra from Russian standards in the POSAR and the Austrian Expert Team expects that they have been used for checking the facilities of the NPP against possible seismic failure.

Figur 2.11.1, taken from Šimůnek (1995) compares the design spectra used with a spectrum (cited as standard spectrum) that connects the corner points from USRG 1.60 /1973 with 0.5% damping by straight lines. This spectrum (the cited standard-spectrum) is well above the USRG spectrum at the other frequencies (see also Figure 2.11.2).

The spectra are taken from near distance earthquakes of Intensity I_0 = 7 and I_0 =8. Such spectra do not compare with spectra of large earthquakes (Intensity 9) at far distance from the site, even when they have the same intensity on the site, because large earthquakes have longer duration and lower centre-frequency at far distances. So the IAEA request for site specific spectra or comparable spectra seems not to be fulfilled, because the main thread for Temelín site is expected to be inferred from far distance Austrian earthquakes similar to the 1590 Neulengbach earthquake (Gutdeutsch et al., 1987).

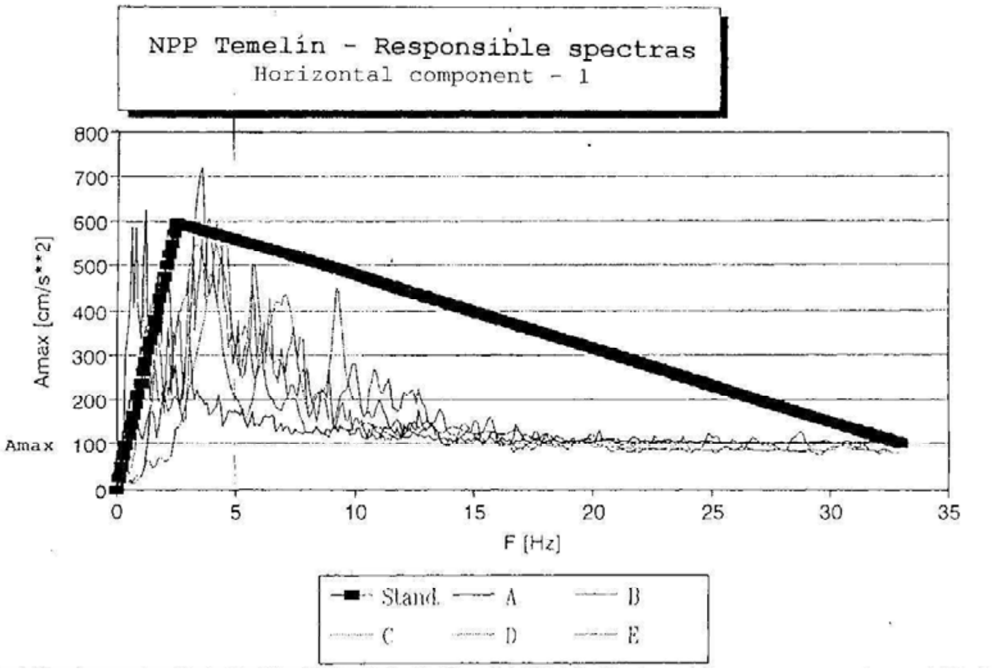


Figure 2.11.1: Design spectra compared to a simplified spectrum from USRG 1.60 /1973 with 0.5% damping

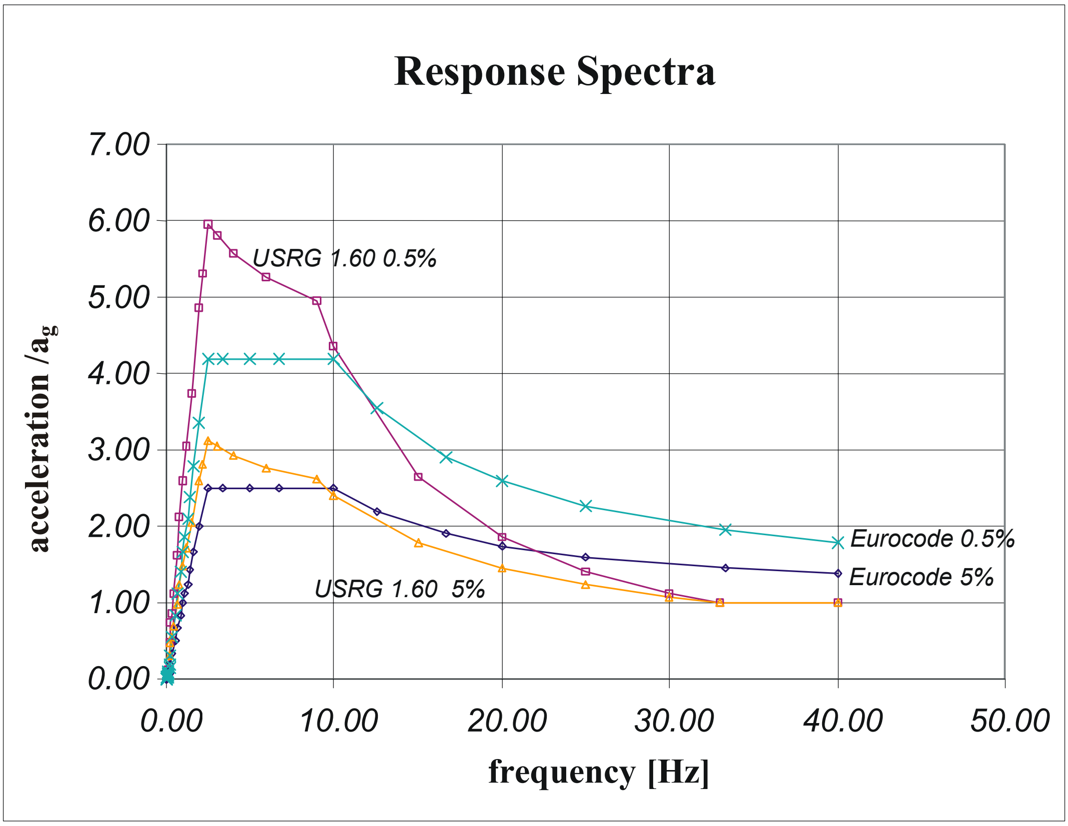


Figure 2.11.2: Response spectra of USRG 1.60 compared with spectra from Eurocode 8 at damping of 0.5% and 5%.

3 THE INFORMATION RECEIVED FROM CZECH SIDE

This chapter summarizes - according to the Verifiable Line Items (please refer to Annex E) the information that has been provided by the Czech side during the Workshop in Prague. Cross references are made to the items mentioned under chapter 2 (Topics of Relevance for the Seismicity Assessment). Conclusions are drawn in chapter 4 (Conclusions from the Monitoring Process).

3.1 Site Seismic Licensing Requirements

The legal frame of the Temelín NPP consists of the Czech Legislation Base, the Czech Atomic law and the IAEA Safety Related Publications.

The Czech Legislation Base consists of:

- Act No 18/1997, the Law on Peaceful Utilisation of Nuclear Energy and Ionising Radiation (the Atomic Law)
- Regulation No. 214/1997 on the Quality Assurance of Classified Items with regard to Nuclear Safety of the Nuclear Facilities
- Regulation No. 215/1997 Criteria for Siting Nuclear Facilities and Very Significant Ionisation Radiation Sources
- Regulation No. 195/1999 On Requirements on Nuclear Installations for Assurance of Nuclear Safety, Radiation Protection and Emergency Preparedness

The following IAEA Safety Related Publications have been used:

- IAEA Safety Standard 50-SG-S1: Earthquake and Associated Topics in relation to Nuclear Power Plant Siting (Rev.1)
- IAEA Safety Standard NS-G-3.3: Evaluation of Seismic Hazard for Nuclear Power Plants
- IAEA Safety Standard 50-SG-D15: Seismic Design and Qualification for Nuclear Power Plants
- TECDOC-343: Application of Microearthquake Surveys in Nuclear Power Plant Siting
- TECDOC-724: Probabilistic Safety Assessment for Seismic Events

3.2 Seismic Site Re-evaluation

The Workshop did not explicitly treat this issue. This item is subject to PN8 seismic design.

3.3 International Seismic Missions, Audits and Standards

Site investigations (geological, seismological, hydrological etc.) started in the 70ies. The Preliminary design of the Temelín NPP was approved in 1986 and the construction started in 1987. Significant IAEA and other international safety missions and audits started from 1990 (including those related to seismic issues).

The following missions and audits were done:

- 1990: IAEA Site Safety Review Mission
- 1990: IAEA Design Review Mission
- 1991: IAEA Site Safety Mission – Siting
- 1992: IAEA Site Safety Review Mission – Siting
- 1993: IAEA Follow-Up Review Mission – Siting
- 1994: IAEA Progress Review Mission – Siting
- 1996: IAEA Review of WWER-1000 Safety Issues Resolution at Temelín NPP
- 2000: Response to Austrian Open Questions on the Temelín NPP Related to Seismic Design and Seismic Hazard Analysis
- 2000: Response to Austrian Safety Issues No. 7 (Seismic Design and Seismic Hazard Assessment) and No. 19 (Environment and Seismic Qualification of Equipment)
- 2001: IAEA Mission- Safety Review of the Temelín NPP External Hazard Issues
- 2003: IAEA Expert Mission – Seismic Hazard Assessment of the Temelín NPP

3.4 Geological Investigations

The following maps published by the Czech Geological Survey show the tectonic models, (Figure 3.4.1) which are used by the Czech experts for the evaluation of the near region and the site vicinity of the Temelín NPP.

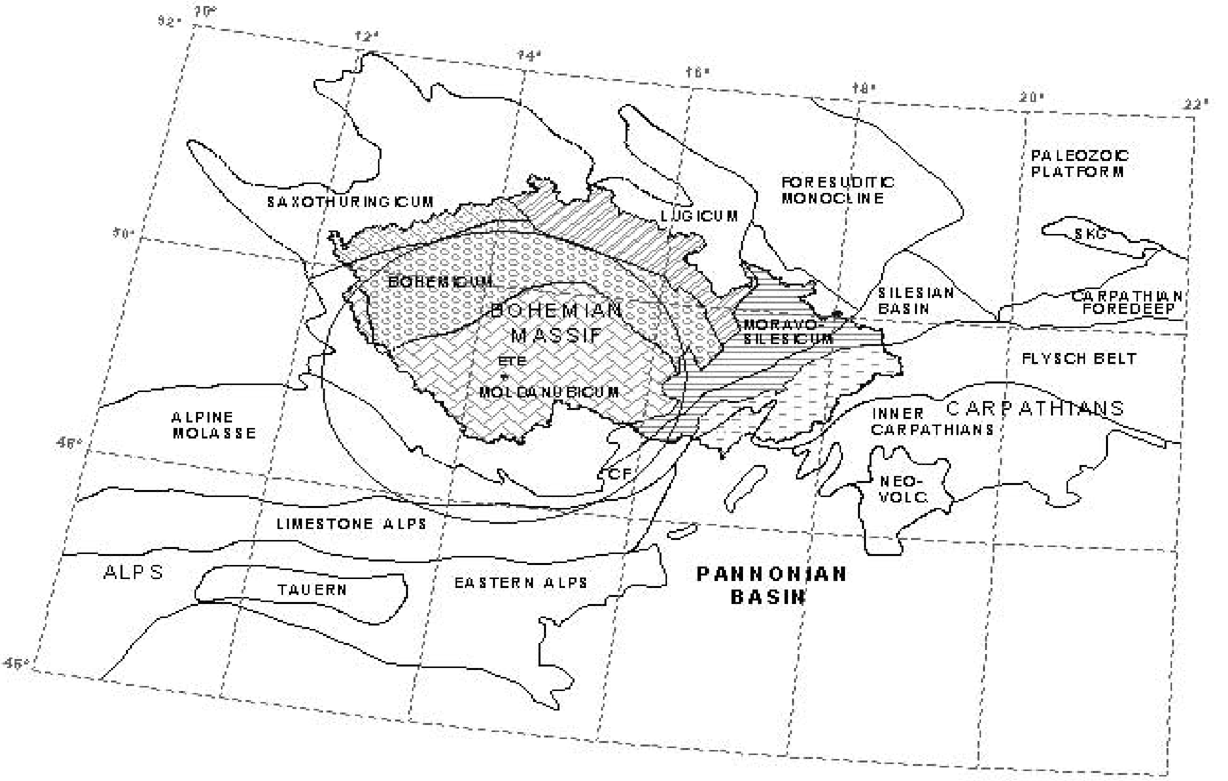


Figure 3.4.1: Region of the Temelín NPP – Geological Units of the Central Units

The bedrock of the buildings of the Temelín NPP is built on Moldanubic metamorphits of uniform series formed by a complex of sillimatic and biotitic para-gneisses and migmates that is sometimes penetrated with veins and irregular bodies of granitoid rocks.

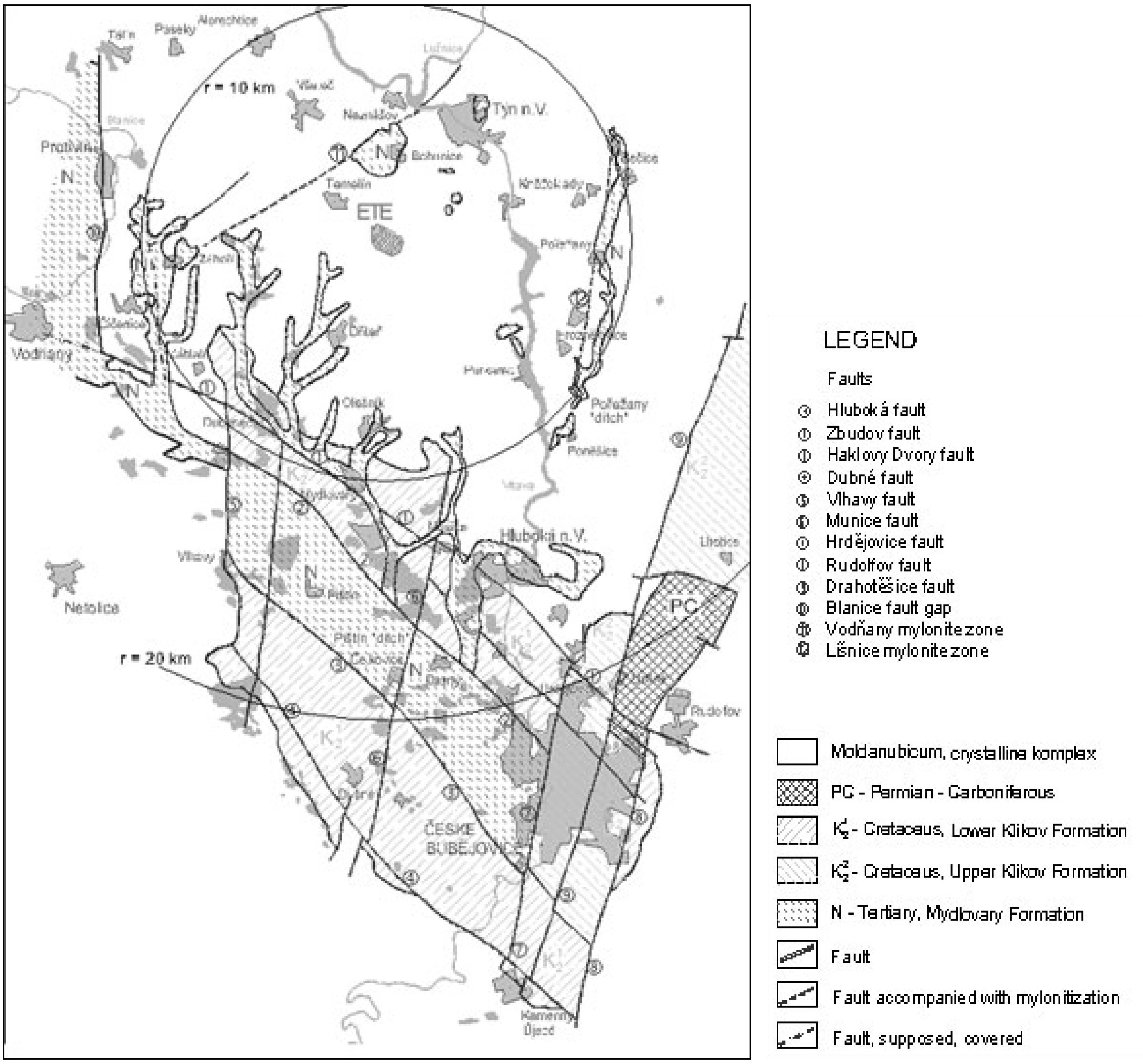


Figure 3.4.2: Tectonic Diagram of the Budweis Basin and its Periphery

The Czech experts conclude that with a high probability the latest vertical tectonic movements on the faults in South-Bohemian basins took place during the Middle up to Upper Pliocene. Tectonic activity concentrated predominately in the Eastern edge of the Budweis basin and into the Blanice fault gap area, with dominant role played by faults of NNE-SSW, N-S direction. In the Southern part of the Bohemian basin tectonic activity is still continued, however with decreasing intensity, in the Lower Pleistocene (Figure 3.4.2).

Non-interrupted course of terrace benches since the Mindel till Würm, fluvial network equalization, absence of active ravines and landslides, as well as this area relief’s general morphological character, give evidence on tectonic activity getting quiet in this area over the last 600 thousands years. Thus, the correctness of the Temelín NPP site selection, from the tectonic stability standpoint, can be verified.

3.5 Seismological Data – Earthquake Hazard Assessment

3.5.1 Historical Earthquake Catalogues

The following historical catalogues have been used by the Czech Experts:

- Kárník V., Michal E., Molnár A. (1957): Erdbebenkatalog der Tschechoslowakei bis zum Jahre 1956, Travaux Géophysiques No 69, Inst.Geophys. Czechoslovak Academy of Sciences, Prague
- Kárník V. (1968): Seismicity of European Area Part I, Ed. Academia, Prague
- Kárník V. (1968): Seismicity of European Area Part II, Ed. Academia, Prague
- Kárník V., Procházková D., Brouček I. (1984): Catalogue of Earthquakes for Territory of Czechoslovakia for the Period 1957-1980. Travaux Géophysiques No 555, Inst.Geophys. Czechoslovak Academy of Sciences, Prague
- Gutdeutch et al. (1987): Historical Earthquakes.
- Kárník V. (1996): Seismicity of Europe and Meditereranean, Geoph.Inst. of Acad. Sci., Prague
- Brouček I. (1983): Seismic hazard of NPP Mochovce, Expert’s Report,
- Procházková D., Šimůnek P. (1998): Fundamental data for determination of Seismic hazard of Localities in Central Europe, Ed.: Gradus, ISBN 80-238-2661-1. Prague
- Šimůnek P., Buben J. (1985): Seismic hazard to NPP Temelín, Expert’s Report EGP, Prague
- Toth - Hungary: http://georisk.seismology.hu
- Buben J., Vencovský M. (1999): Earthquake Catalogue Compiled by IRSM AS CR,

3.5.2 Probabilistic Hazard Assessment

According to (TEC DOC-274), seismic hazard to a building site is expressed by the probability P(A), that - in the course of one year - the PGAH value will not exceed a prescript level A. This probabilistic analysis is based on computing great number of individual curves P(A), using sets of alternative input data, models and relations. Subsequently, the obtained curves are generalized and expressed by means of statistics.

The calculation of individual P(A) curves is possible only when we accept following simplifying presumptions:

- Within each of assessed source zones, the distribution of future epicentres will be uniform, i.e. the probability of future epicentre site does not depend on its location inside a zone.
- Empirical parameters describing the seismicity are stationary i.e. the present day parameters will be valid in the far future (e.g.,10000 years), too.

The calculation of PSHC consists from following steps:

- Delimitation earthquake source zones: 28 source zones covering the region of NPP (Schenk et al.1989) were used. Each source zone was divided in a number N of elementary subareas of size (20x20) km2 area. By this procedure N=1724 source elements have been taken into account.
- Parameters of seismicity in each of zones: Calculation PSHC requires the extrapolation of the cumulative N(I) relation : $\log N(I) = a - b(I - I_{min} I)$. These empirical functions are truncated at the maximum historical epicentres intensities Io,max for each of source zones. The maximum possible values I p = 1o + I o,max and parameters a, b are given in the following table. The uncertainty of parameters b (see columns 3 and 7 in above table) was compensated by using values 0.8 * b, 0.9 * b, b, 1.1 * b and 1.2 * b.

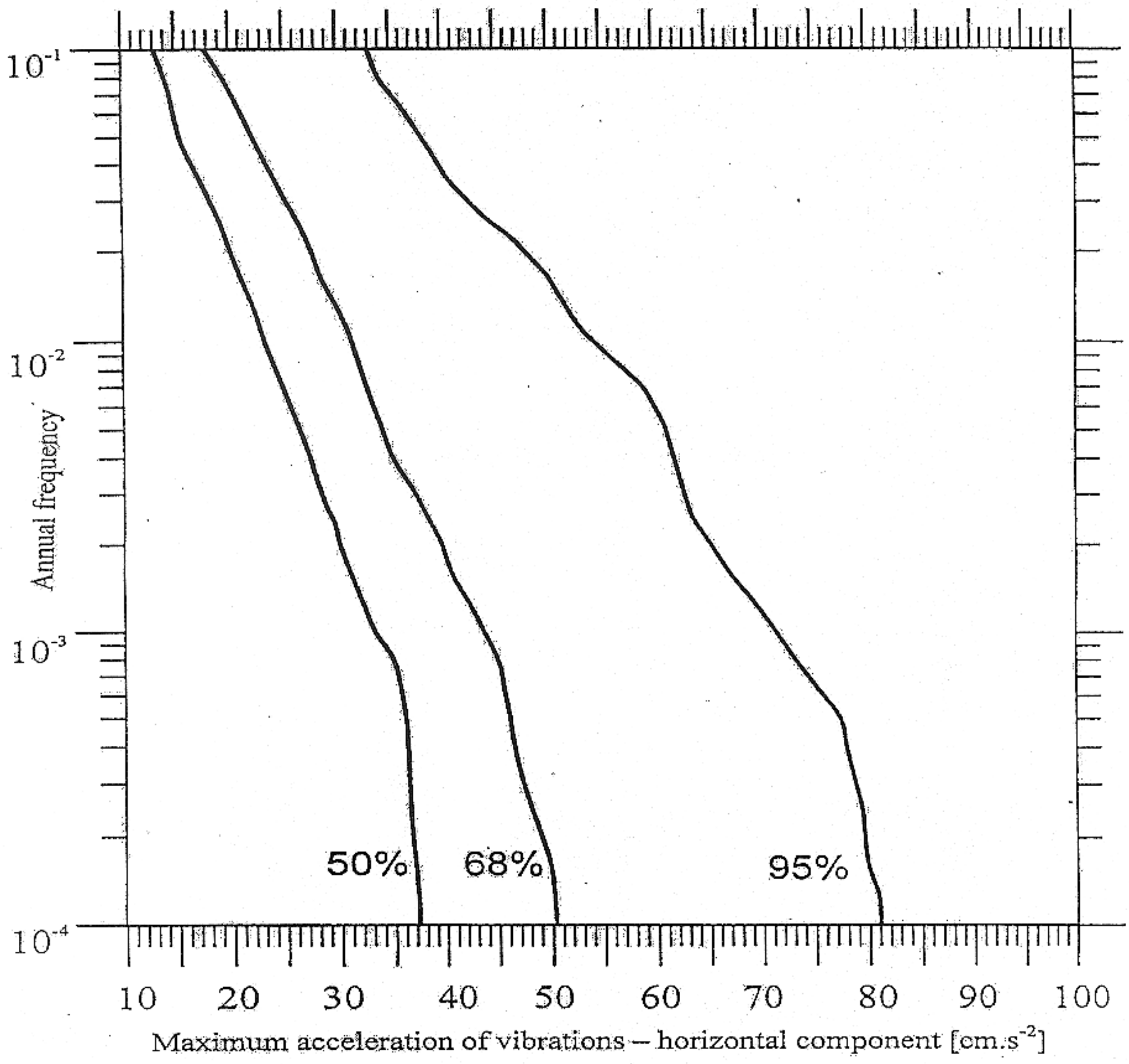


Figure 3.5.1: Probabilistic seismic hazard curves for NPP Temelín

The program calculates a great number of individual curves for all combinations of input data. In the next step, it calculates the distribution of individual curves and then draws resulting curves for various probabilities of not exceeding (ascribed to each curve, i.e. 50%; 68%; 95%) during the time interval one year (given in axis y). The corresponding values of acceleration are given on X- axis. The value of yearly probability e.g. 10^{-4} means that the most probable repeating period is 10000 years (which is the repeating period of the SL-2 earthquake).

The PSHC prove the value of SL-2 hazard. PGAH is 80 cm. s^{-2} at 95% probability of non-exceedance.

3.6 Microearthquake Monitoring

The general objectives of the microearthquake surveys in relation to NPP siting are:

- Identification of the location of a fault without surface expression near the site
- Contribution to reaching decisions regarding whether or not a known fault is active
- Identification of activity related to other geological features
- Identification of induced seismicity
- Determination of general background seismicity in the seismotectonic region of the site to help to correlate structures with earthquakes

The microearthquake monitoring network has 8 stations for 30x30 km area. The accuracy of the localisations is:

- Epicentre ±1 km, later ± 0.2 km
- Depth ± 5 km, later ± 1 km
- Origin time ± 0.5s, later ± 0.1s

The local Richter magnitude is calculated $M_L = \log((u*2800)/0.6325) + 0.1 + 1.4 * \log s$, for u is the maximum amplitude of ground displacement in mm and s is distance from hypocentre in km. This results in sensisvity of the network presented in the Figures below.

Station	Latitude	Longitude	H	Distance	Start of Operation	End of Operation
STRU	49.156	14.402	443	3.4	01.09.1991	in operation
HLAS	49.068	14.24	435	15.9	01.09.1991	in operation
PASE	49.262	14.289	479	11.0	01.09.1991	in operation NUZI
BIHU	49.155	14.305	429	5.8	01.09.1991	30.11.1994
JANE	49.069	14.445	450	13.4	01.09.1991	09.12.1992
JELM	49.029	14.559	514	21.5	10.12.1992	in operation
KOUB	49.127	14.126	558	19.1	01.09.1991	23.07.2001
HELF	49.138	14.018	568	26.5	24.07.2001	in operation

Figure 3.6.1: NPP Monitoring Stations

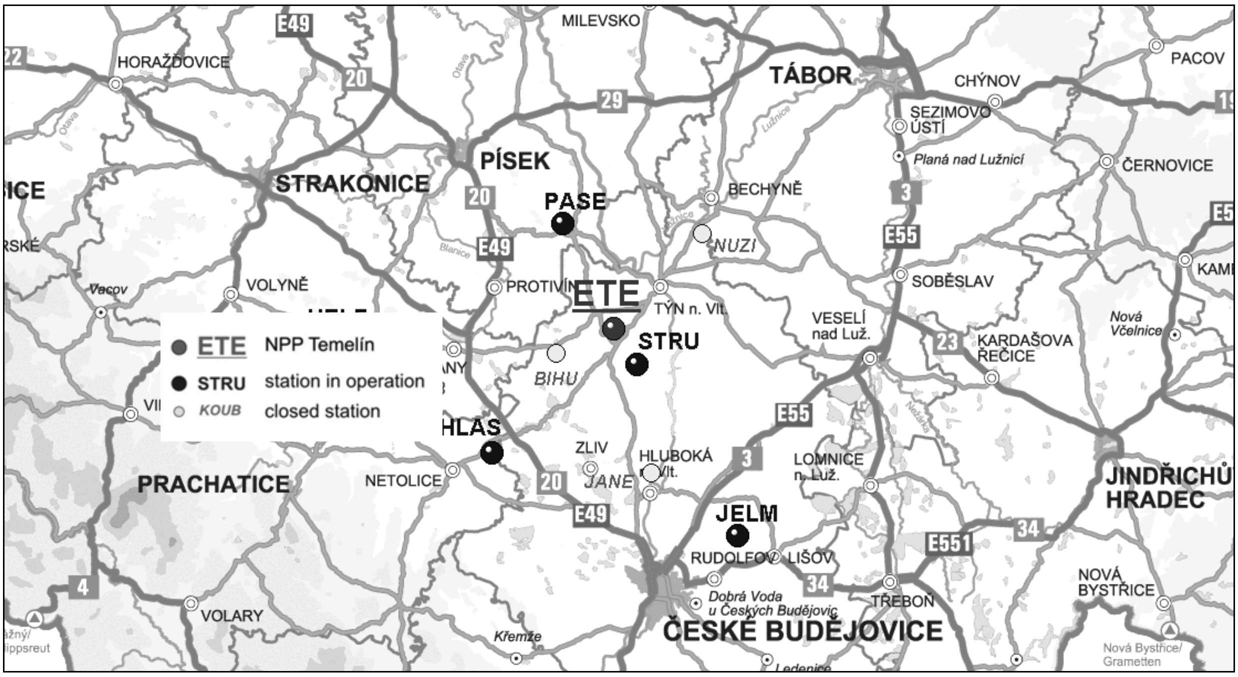


Figure 3.6.2: Map of stations of the NPP Temelín Microearthquake Monitoring Network

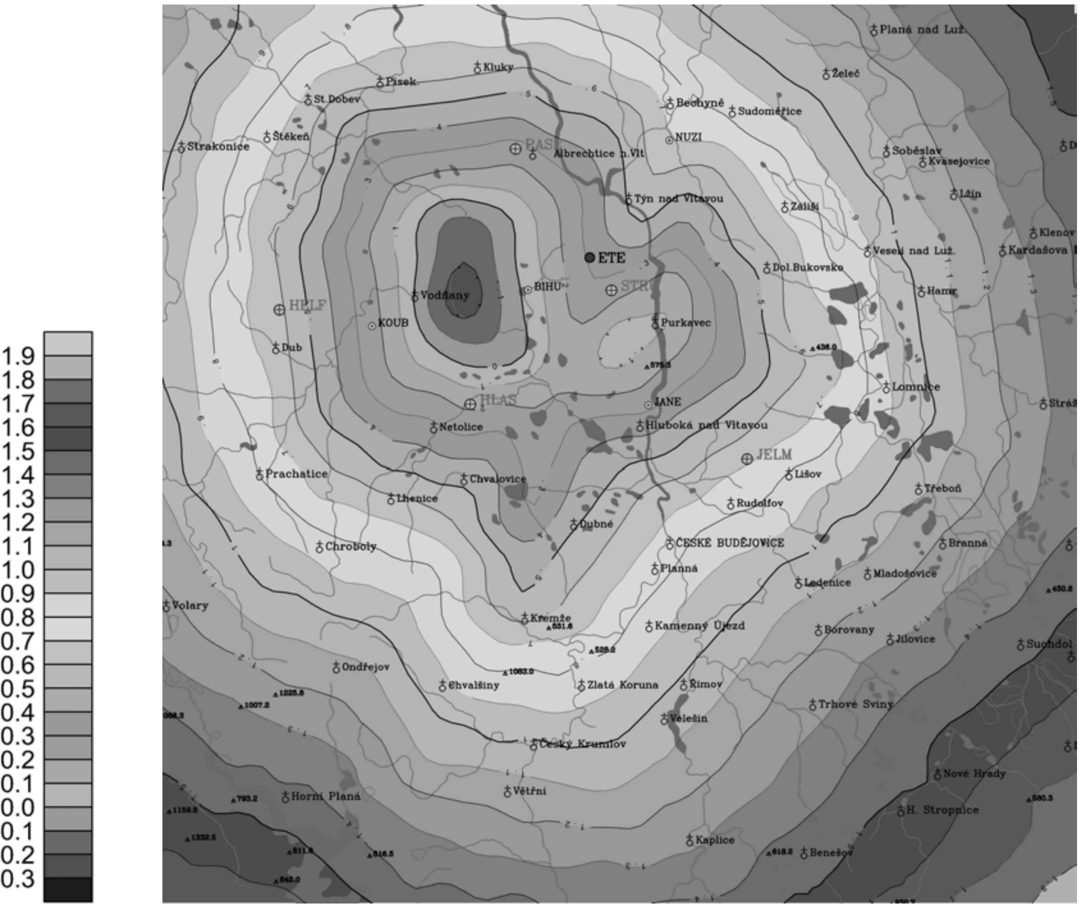


Figure 3.6.3: Sensitivity map of the monitoring network

Within 40 km of the NPP no event with magnitude greater than 1.0 occurred. Within a radius of 50 km only 3 events with magnitudes 1.0 – 2.0 and none with a greater magnitude were registered. The evaluation of quarry blasts in the locality has proved that the network is capable of reliable detection and location of shocks within the magnitude range 1 – 3 within 50 km of the NPP. The Czech experts dra the conclusion that the results show that the locality is an exceptionally quiet one.

For the quick information about earthquakes in the vicinity of the NPP and in the Alps region a Seismological Information Display is operated by the Institute of Physics of the Earth, Masaryk University, Brno, on demand of the State Office for Nuclear Safety (SÚJB). It is in operation since September 30, 2002. The following main sources are used:

- broadband stations of the Czech regional seismological network operated by IPE Brno – identification of occurrence of an earthquake greater than the threshold magnitude in the area of interest and localisation of the earthquake
- alert information issued by seismological organisations - RedPuma of SED, EMSC, ZAMG, NEIC of the USGS
- microearthquake monitoring network - IPE Brno, impact on the locality, readings of amplitudes in the NPP Temelín vicinity

Additional sources are used for a greater accuracy of the localisation. These sources comprise of:

- other stations of the Czech national seismological network - operated by Geophysical Institute of the Academy of Sciences of the CR, Prague
- other European stations - operated by ZAMG Austria, BGR Germany, SED Switzerland, INGV Italy etc.

3.7 Seismotectonic Investigations

To create the seismotectonic model the geological characteristics of the main units of the region´s geological structure, the seismotectonic characteristic of the region and the model of forces in the main geological units were evaluated. For the regional seismotectonic model there were used two models compiled according to the *IAEA 50-SG-S1* requirements (paragraphs 401 – 417):

- Focal provinces and provinces with diffuse seismicity
- Seismoactive (capable) parts of faults

Maximum earthquake potential was determined for each focal province, each province with diffuse seismicity and each seismoactive part of fault. The following map shows the provinces with diffuse seismicity.

The determination of the I_{SITE} value was done by the expression: $I_0 - \Delta I = I_{Site}$ [° MSK-64].

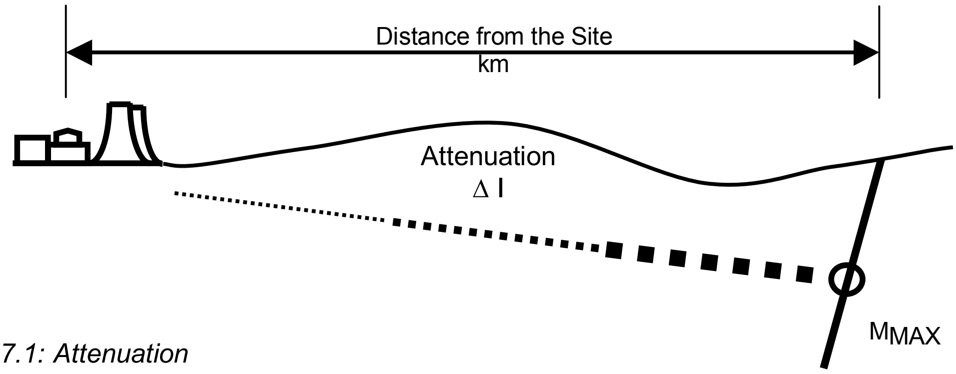


Figure 3.7.1: Attenuation

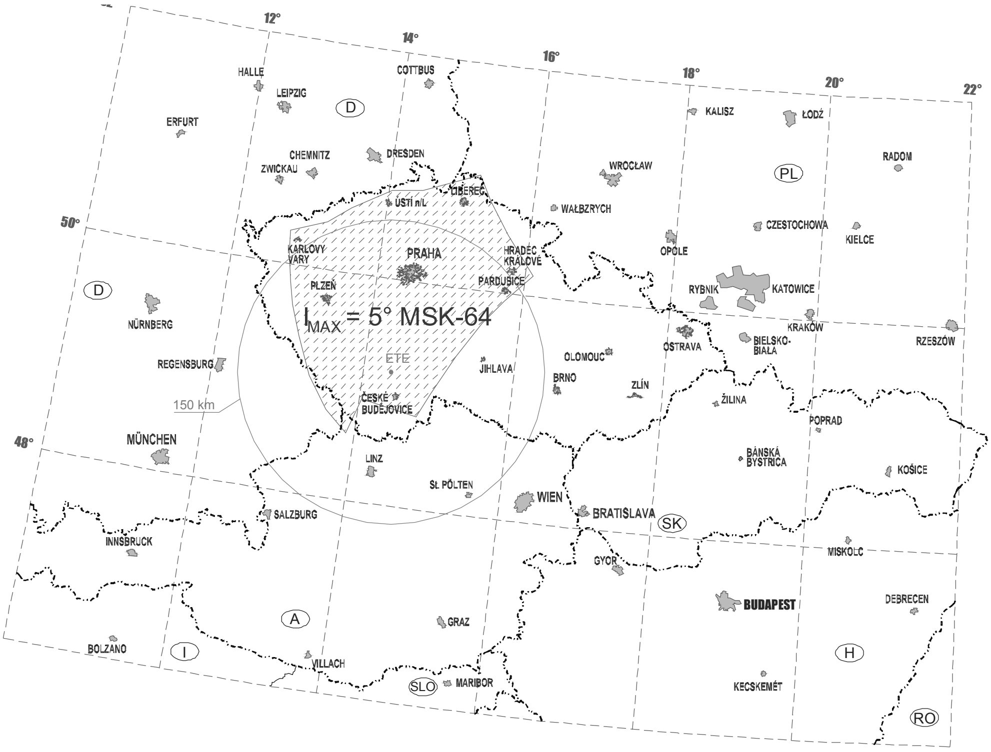


Figure 3.7.2: Provinces with diffuse seismicity

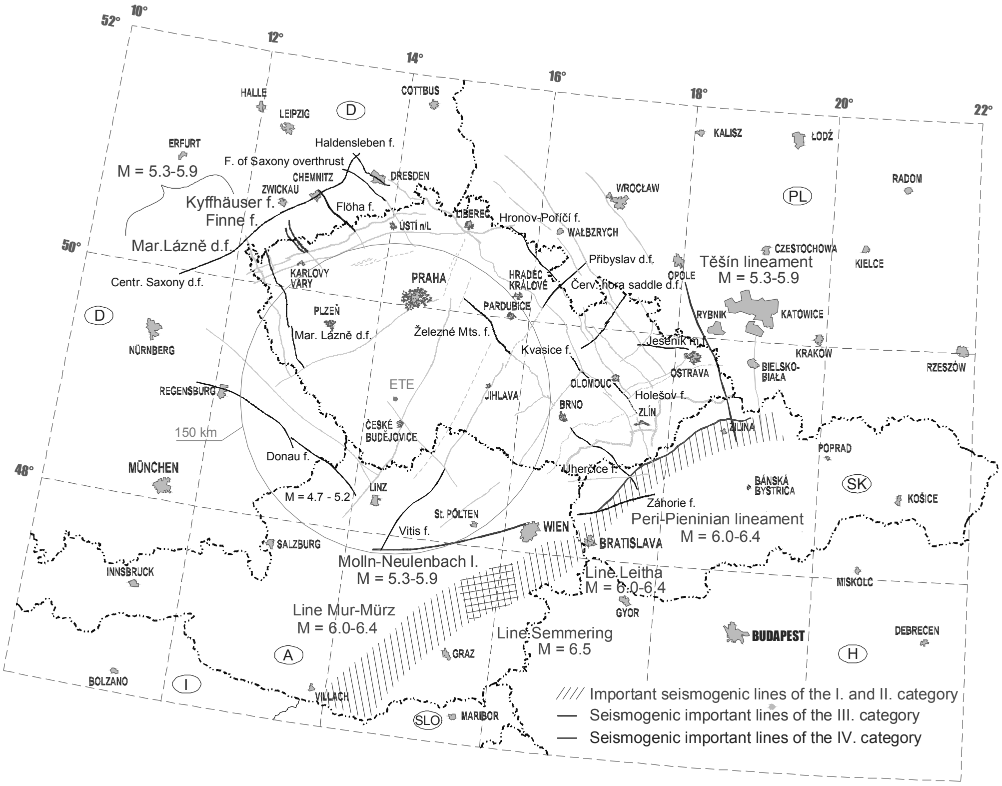


Figure 3.7.3: Map of seismogenic lines

The process and analysis of data express that the largest intensity of earthquakes in the Temelín NPP site for the time horizon of 10 000 years are:

Seismotectonic line	M_{MAX}	I_0	Distance	Attenuation	I_{SITE}
			km	ΔI	° MSK-64
Mur - Mürz	6,0-6,4	9,0°	191	3,0°	6,0°
Semmering	6,5	9,5°	200	3,0°	6,5°
Leitha	6,0-6,4	9,0°	205	3,5°	5,5°

Figure 3.7.4: Largest intensity earthquakes

The earthquake potential associated with seismogenic zones implies that based on the deterministic (seismotectonic) approach the maximum calculated (safe shutdown - SL-2) earthquake for the Temelín NPP site is 6,5° MSK-64 and the acceleration can not, in any case, be higher than 0,1 g.

Diffuse seismicity surroundings of the Temelín NPP site was calculated as follows:

zone	I_0	distance	attenuation	I_{SITE}	+ 1° as a
	° MSK-64	km	ΔI	° MSK-64	safety margin
B	5,0°	0	0°	5,0°	6,0°

Figure 3.7.5: Diffuse seismicity

Based on the deterministic (seismotectonic) approach the maximum calculated (safe shutdown - SL-2) earthquake for the Temelín NPP site is 6,5° MSK-64 and the acceleration can not be higher than 0,1 g.

3.8 Temelín Seismic Monitoring System

The Temelín Monitoring and Diagnostic System (TMDS) consist of a number of on-line diagnostic systems assuring timely information to personnel about the altered mechanical status of the primary circuit. The Temelín Seismic Monitoring System (SMS) is part of the Monitoring and Diagnostic System.

SIG SA in collaboration with Westinghouse Electric Corporation has developed a seismic monitoring system to meet existing and emerging ANS, NRC and IAEA guidance based on the simplified hardware. Because of the operation & maintenance cost savings associated with reduced analog hardware, and the potential for improved post-earthquake planning, utilities should consider an upgrade to their seismic monitoring systems to replace the traditional analog hardware with digital processing capability allowed by the emerging regulatory requirements.

The objective of seismic monitoring is to provide a warning to the control room operator indicating that the essential earthquake has occurred and that evaluation of the need for plant shutdown should begin. Integration of seismic monitoring output with post-earthquake action plans is critical to effectively assessing plant condition and the need to shut down.

OBE is exceeded if accelerations recorded in the free field are such that both the response spectrum check and the cumulative absolute velocity (cav) check are exceeded, i.e.:

- Response spectrum check: the 5% damped ground spectrum at frequencies between 2. and 10 Hz exceeds the OBE ff spectrum or 0.15 g's, whichever is greater.
- CAV check: the CAV (cumulative absolute velocity) is greater than 0.16 g. seconds

The following actions of operational staff have to be taken after alarm „start of seismic event recording":

- It must not be exceeded OBE level during plant operation
- if the OBE level is exceeded the plant shutdown into regime 6 must be started within 8 hours
- if the start of seismic event recording is activated and the OBE level is not exceeded during plant operation, the operational staff must take decisions from the point of view of possible plant operation within 4 hours. If it is not possible to operate the plant within 8 hours after the earthquake arising, the plant shutdown into regime 6 must be started.

The MCR operator must ensure before shutdown of the plant that there is no damage to the plant equipment. This has to be done according to the PEPDIS evaluation (evaluation of changes of selected I&C and TMDS data before and after a seismic event) and walk-down of the plant.

The Seismic Monitoring System (SMS) is a strong-motion multi-channel digital recorder system. Accelerometer packages are placed in remote locations and are connected to recorder through shielded cables. Recorder, control module and processing computer are rack mounted in a cabinet. By monitoring continuously the sensors, it detects seismic events, generates associated alarms and automatically processes the recorded data. Also it performs periodical test of the system.

The main features of the monitoring system are the triaxially mounted accelerometers in accordance with ANS, NRC, and IAEA requirements. They are seismically, EMC qualified and field hardened.

The basic system benefits are that it is more cost-effective from a life cycle cost point of view than traditional systems. It is specifically designed to address the emerging regulatory requirements and has a digital processing capability that increases the system flexibility. The elimination of excessive hardware improves the reliability. It is an upgradeable system for automatic data processing.

3.9 Supplementary Earthquake Hazard Assessment

Some alternative approaches for the assessment of earthquake hazard were followed up. This concerns the following topics:

- Examination of the applicability of abroad acceleration attenuation relations A(M,D) by comparison the calculated and the actually recorded values.
- Calculation of the values PGAH by means of empirical relations A(M,D) given the values of Io or M and the distances D [km] and comparison resulting values of hazard with that given in POSAR.
- Calculation of the SL-2 values of PGAH on the basis of historical earthquakes using the A(M,D) relations and a newly compiled list of earthquakes in the region.

It is fortunate that in abroad active zones operate dense nets of strong motion acceleration-recorders yet since some tens of years. Due to advanced technology and number of instruments and instrumental data obtained, the up date assessment of hazard must no more use the relations for intensity decrease and for conversion the site intensity IS to ground motion acceleration. The computation of ground motion acceleration from IS encumbered by uncertainty reaching up to two decade orders (Ambraseys, 1991).

In the nineties, the great number abroad acceleration recorders made possible to derive empirical acceleration attenuation relations A = A(M,D) describing the peak ground acceleration A [g] decrease with distance D [km] for various magnitude M of earthquakes. This avoids uncertainties inherent with formulas A(IS). The method based on authentic acceleration-records s treated as reliable and perspective (Labbe P. 2001).

Since 1998, one local acceleration- recorder STRUHA operates near to the NPP building site. In consequence of very low seismicity in the near region and of low-to- mediate seismicity of the far region in question, the necessary good sized volume of instrumental data could not be obtained up to now. Therefore we have as jet to use abroad attenuation formulae A = A(M,D). In this chapter, the empirical verification of most adequate formulae will be made by comparison of some few recorded acceleration records with the values calculated from abroad relations.

A number of empirical relations describing the attenuation of horizontal component of peak ground acceleration (PGAH) or velocity (PGVH), were published in (Cvijanovič C., Breška Z. 1989, Joyner W.B., and Boore D.M. 1981, Joyner W.B. and Boore D.M. 1988, Petrovski D. 1986, Kuk V. 1986, Sabetta F. and Pugliese A. 1996, Sadigh K., Egan J., Youngs R., 1986).

In this chapter, we will discuss following ten of them, denoted here as A1,A2…….A10. For all of them, the authors indicate the reliability of calculated values by the values of standard errors σ and the binary variable P. The value P=0 indicates the mean value μ (probability 0.5 of not exceeding) of regression curve. Value P=1 (probability 0.68) is calculated as μ±σ and P=2 (probability 0.95) as μ±2σ.

The used abroad relations overestimate the recorded values up to tenfold. Maximum overestimation yields the formula A7 – Petrovski.

Above statements concern only the right–hand parts of attenuation diagrams (distances D >120 km) and moderate magnitudes $M \leq 5$. No events with M >5.5 and D< 120 km have been recorded in STRUHA up to now.

The newest European attenuation formulae were recently referred by Fukushima, 2003. His attenuation relations go out from records of near and strong earthquakes, whereas our experimental data concerned only moderate events with more distant epicenters. Therefore here arose a chance for checking up our attenuation relations in the light of that prescribed for Europe. The acceleration attenuation curves of (Fukushima, 2003) are shown in the Figure below.

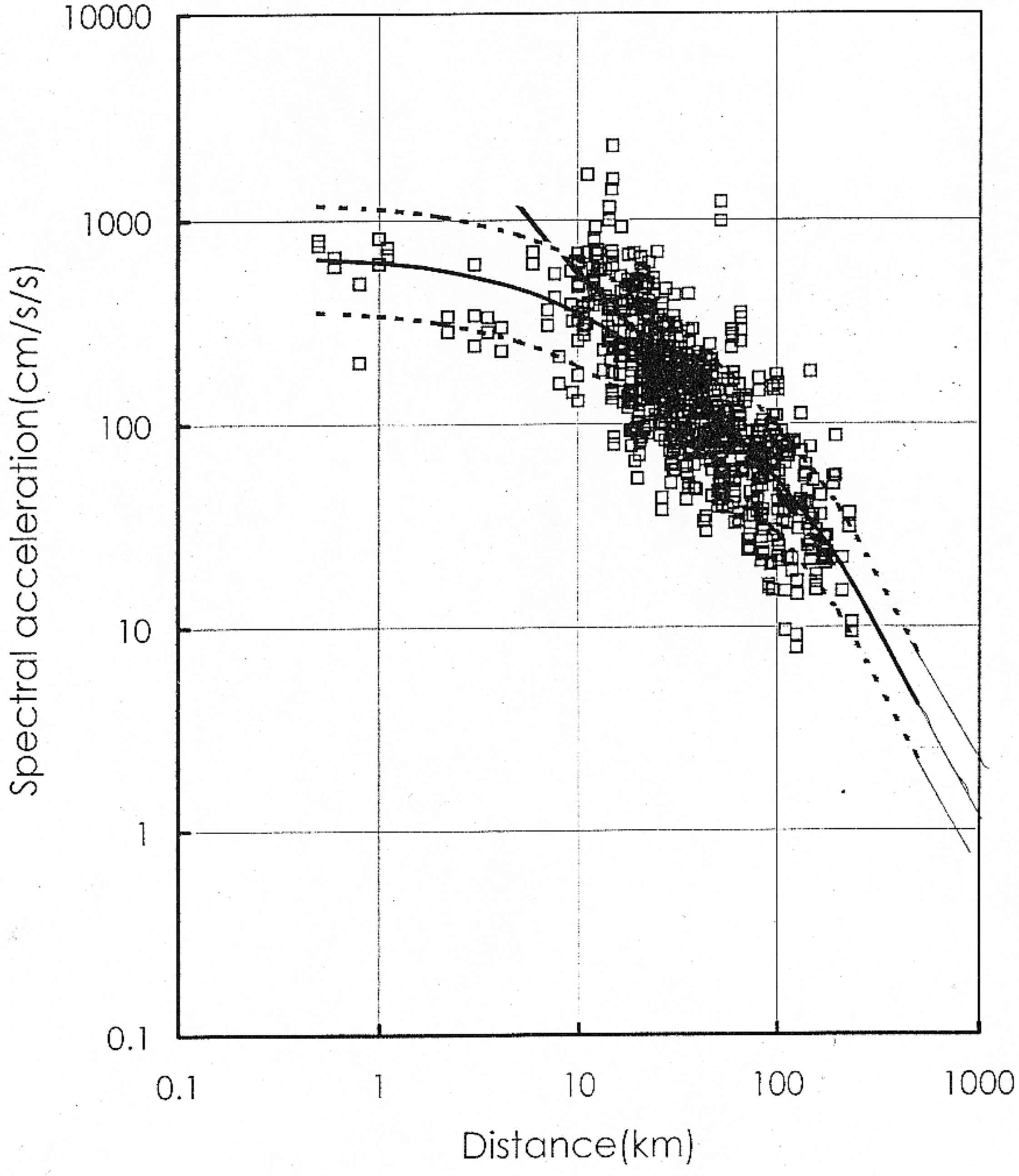


Fig. 3 Comparison between predicted spectral acceleration by derived attenuation relation and observed spectral acceleration. (a) M7.0 for frequency at 34 Hz. Observed data points are normalized to M7.0 and soil site. The observations are indicated by points. The prediction and standard error are indicated solid and dotted lines respectively. And RFS is indicated by broken lines.

Figure 3.9.1: Spectral acceleration

They concern the strong earthquakes (magnitudes $5.5<M<7.5$) in small distances (between 0 and 200 km) in Japan, Turkey and USA. Here, the observed data are normalized to $M=7$ and *soil* site (i.e. *not rock* as is in Temelín). The calculated mean values μ are indicated by solid line, the values $\mu-\sigma$ and $\mu+\sigma$ by dotted lines respectively. Points depict the recorded acceleration. The total number of evaluated records is 744 (Europe: 399, US: 162, Huogo-ken Nambu: 158 and Kocaeli: 25).

The A=A(M,D) relation for the mean value of A [cm.$^{s-2}$] reads

$$\text{Log } A = 0.42*M - \text{Log } [D + 0.025*e^{M}] - 0.0033*D + 1.22 + \sigma$$

Where the standard error $\sigma = 0.26$.

It is worth to take cognizance of small differences between values PGAH given by Fukushima's equation and both equations A4 and A8. Moreover, the dispersion of points indicates, that no from 744 recorded accelerations exceed the values $\mu + 2\sigma$, where the mean value μ is shown by a full line and the belts $\pm\sigma$ are indicated by broken lines.

3.9.1 Non-Zoning Method of Hazard Assessment

The values of seismic hazard calculated from intensity attenuation relations are to high due to uncertainties in input data, seismicity models and empirical relations. That original non-zoning method is in some respect analogous to that described in Frankel (1995) who used spatial smoothened distribution of historic earthquake foci. The non – zoning method suggests the following input data and models:

- Regional earthquake catalogue
- Verified acceleration attenuation relation for the region in question
- Assessment maximum calculating M and minimum calculating D based on the data in earthquake catalogue.

A special list of earthquakes was created using compiled catalog ÚSMH which includes 1488 events with Io >= 6° MSK-64. The main sources for compiled ÚSMH catalog are:

- Karnik's 1996 catalog consists of 456 events in the period 1800-1986.
- Toth's catalog involves events in the period 1005-1986.
- Catalog of Prochazková and Šimůnek (1998) consists of 370 earthquakes in the period 456-1996.

Evidently, the formats of above source catalogs are not identical, as they refer to various time periods. The data (intensity, geographic coordinates) in source catalogs, which relate to possibly identical events, differ considerably in many cases. An original program was written which facilitates the expert to decide which of differing input data could be most adequate. The mutual differences in geographic coordinates reach often up to 0.2° - 0.3° MSK-64.

The earthquake potential of focal zones is taken in account by introducing the so- called maximum calculation earthquakes Mc. The Mc values are assessed by increase the magnitude Mh of all (historic) earthquakes one unit more

$Mc = Mh + dM$, where $dM = 1$.

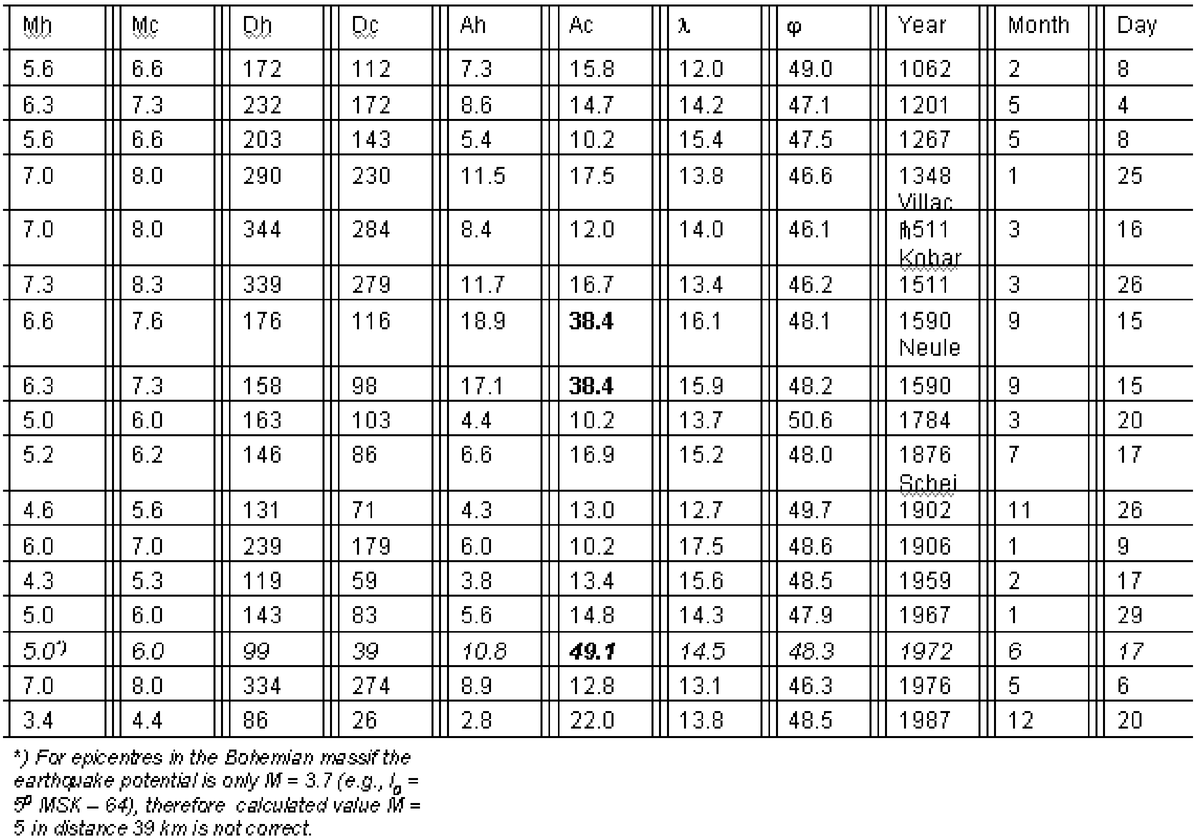
The maximum calculation magnitude Mc is no doubt conservative enough, the commonly used value being $dM = 0.5$ see the assessment seismic potential of a source zone) according to the seismo – statistic approach is $Mp = Mh + 0.5$, what corresponds to $I_p = I_{o,max} + 1$. Minimum calculation distances Dc are prescribed very conservative as well by the relation:

$Dc = Dh - 60$ km

The calculation of the PGAH values is performed for all historical data Mh and Dh as well as for calculation values Mc (increased) and Dc (decreased).

The resulting values are given in the Figure below, which contains only events that produce the acceleration PGAH ³ 10 cm.s^{-2}. The input data are given in columns 1 to 4. The calculated values Ah (historic) and Ac (calculation) values are given in the columns 5 and 6. The geographic coordinates are given in columns No 7 and 8. Earthquake time coordinates are given in the last three columns 9 to 11.

The earthquakes Villach (1348), Kobarid (1511), Neulengbach (1590) and Scheibbs (1876) have been often discussed as possible sources of hazard to Temelín. The values of contribution to entire hazard are highlighted with bolt font. The maximum contribution to entire hazard comes from event Neulengbach (Mh = 5.6, Mc = 6.6, Dh=176km, Dc=125km) calculated by the attenuation relations A4 and A8. The resulting values are 18 cm. s^{-2} according to A8, and 20 cm. s^{-2} according to A4.



Mh	Mc	Dh	Dc	Ah	Ac	λ	φ	Year	Month	Day
5.6	6.6	172	112	7.3	15.8	12.0	49.0	1062	2	8
6.3	7.3	232	172	8.6	14.7	14.2	47.1	1201	5	4
5.6	6.6	203	143	5.4	10.2	15.4	47.5	1267	5	8
7.0	8.0	290	230	11.5	17.5	13.8	46.6	1348 Villac	1	25
7.0	8.0	344	284	8.4	12.0	14.0	46.1	ɱ511 Kobar	3	16
7.3	8.3	339	279	11.7	16.7	13.4	46.2	1511	3	26
6.6	7.6	176	116	18.9	**38.4**	16.1	48.1	1590 Neule	9	15
6.3	7.3	158	98	17.1	**38.4**	15.9	48.2	1590	9	15
5.0	6.0	163	103	4.4	10.2	13.7	50.6	1784	3	20
5.2	6.2	146	86	6.6	16.9	15.2	48.0	1876 Schei	7	17
4.6	5.6	131	71	4.3	13.0	12.7	49.7	1902	11	26
6.0	7.0	239	179	6.0	10.2	17.5	48.6	1906	1	9
4.3	5.3	119	59	3.8	13.4	15.6	48.5	1959	2	17
5.0	6.0	143	83	5.6	14.8	14.3	47.9	1967	1	29
5.0)*	*6.0*	*99*	*39*	*10.8*	***49.1***	*14.5*	*48.3*	*1972*	*6*	*17*
7.0	8.0	334	274	8.9	12.8	13.1	46.3	1976	5	6
3.4	4.4	86	26	2.8	22.0	13.8	48.5	1987	12	20

**) For epicentres in the Bohemian massif the earthquake potential is only M = 3.7 (e.g., I_o = 5° MSK – 64), therefore calculated value $\bar{M}$ = 5 in distance 39 km is not correct.*

Figure 3.9.2: Magnitude of maxiumum calculation earthquakes (Mc), Magnitude of historic earthquakes (Mh), Maximum calculation distances (Dc), Distance of historic earthquakes (Dh)

Values of earthquake hazard to Temelín obtained by the non-zoning method do not reach the SL-2 level PGAH = 0.04 g.

The influence of relatively weak but near events, such as the 1972 M=5 earthquake, calculated from the A8 for hypothetical small distance Dc =39 km relation is not realistic. This opinion can be proved only on the basis of events recorded in local distances. Moreover the attenuation relations saturate in the range up to 20 km.

The most update attenuation relations of Fukushima were constructed on the basis of great number of strong earthquakes coming from near-region distances, too. Such relations can be used for verification the relations A1 to A10 in the domain of great accelerations, say up to 0.1g, where our records in SRUHA are not at hand.

As a first step to this end, J. Buben calculated from all A1 to A10 relations the PGAH values for two hypothetic values, i.e., M=6 and M=7 and hereafter stated the critical values of D_{cr} (M=6) and D_{cr} (M=7) for which the accelerations reach the value 0.1g.
By statistic evaluation J. Bube obtained D_{cr} (6) = 74 ±30 k
m and D_{cr} (7) = 130±73 km.

From relation of Fukushima goes out D_{cr} (6) = 89 km and D_{cr} (7) = 147km with 0.95 probability of not exceeding.

Due to consistent values obtained from all relations the Austrian Expert Team presumes to express the following thesis concerning the hazard to Temelín not regarding the time interval:

- No earthquake with magnitude $M \leq 7$ in distance greater than 150 km will cause a PGA of 0.1 g (with 95% probability of exceedance)
- No earthquake with magnitude $M \leq 6$ in distance greater than 90 km will cause a PGA of 0.1g (with 95% probability of exceedance)

3.10 Earthquake Hazard Assessment

The Czech Side did not identify a seismoactive fault in the vicinity of Temelín NPP. In this area only five microearthquakes were recorded during 10 years of observation. The Maximum microearthquake had a magnitude of M = 0.2. These microearthquakes cause the seismic background. The strongest earthquake recorded in a 50 km distance to Temelín achieved a magnitude of M = 1.8. The Czech Experts argue that the seismic foci in the Bohemian Massif have a diffusion character, which means that they do not cluster along any tectonic fault.

3.11 Seismic Design Basis

3.11.1 SL2 And SL1 Determination, Response Spectra, Accelerograms

Based on the results of seismological and geological investigations of the Czech Side, the following two earthquake levels are determined for the Temelín NPP:

1. SL2 (SSE) – the extreme ground motion level with probability of exceedance no more than 10^{-4} per year.
   - $PGA_{SL2, hor}$ = 0,10 g (as recommended in the IAEA Safety Guide 50-SG-S1, Rev. 1)
   - $PGA_{SL2, vert}$ = 0,07 g (approximately 2/3 of $PGA_{SL2, hor}$). The values correspond approximately to 7^{o} MSK-64.

   The SL2 ground response spectra (GRS):

   - Derived as enveloped curves calculated from a set of several natural accellerograms recorded in locations with similar geological and seismological conditions and scaled to PGA_{hor} = 0,10 g or to PGA_{vert} = 0,07 g
   - Standard broadband NUREG/CR-0098 (median + 1 sigma) spectra for rock sites

   These GRSs were compared with one another. No significant differences were found for them. These spectra were then used to generate synthetic accelerograms in the foundation base.

2. SL1 (OBE) – the design earthquake ground motion level with probability of exceedance no more than 10^{-2} per year.
   - $PGA_{SL1, hor}$ = 0,05 g (50% of $PGA_{SL2, hor}$)
   - $PGA_{SL1, vert}$ = 0,035 g (approximately 2/3 of $PGA_{SL1, hor}$)
     These values correspond approximately to 6^{o} MSK-64.

The SL1 ground response spectra (GRS) are of the same shape as for SL2, however multiplied by factor 0,5. When the accelerograms were generated using the program SPECTRA, the requirements regarding the minimum PSD as presented in the US NRC Standard Review Plan (Section 3.7.1, Appendix A) were respected. The rise time was 5 seconds, the duration of strong motion 15 seconds and the decay time again 5 seconds. These time periods are very conservative.

3.11.2 Ground Response Spectra

The Czech side presented a diagram with Ground Response Spectra during the expert discussions concerning Temelín site seismicity (Figure 3.11.1).

This diagram displays, at low frequencies, rather high values for the horizontal and vertical acceleration, considering that Temelín is generally regarded to be located at a site with low seismicity. Acceleration decreases markedly towards higher frequencies.

Horizontal acceleration reaches a peak value of about 4.25 m/s^2, in the frequency range of 2 to 5 Hz. Vertical acceleration is about 1.6 to 1.8 m/s^2 in this range. For the high frequencies, values are about 1.25 m/s^2 and 0.6 m/s^2, respectively.

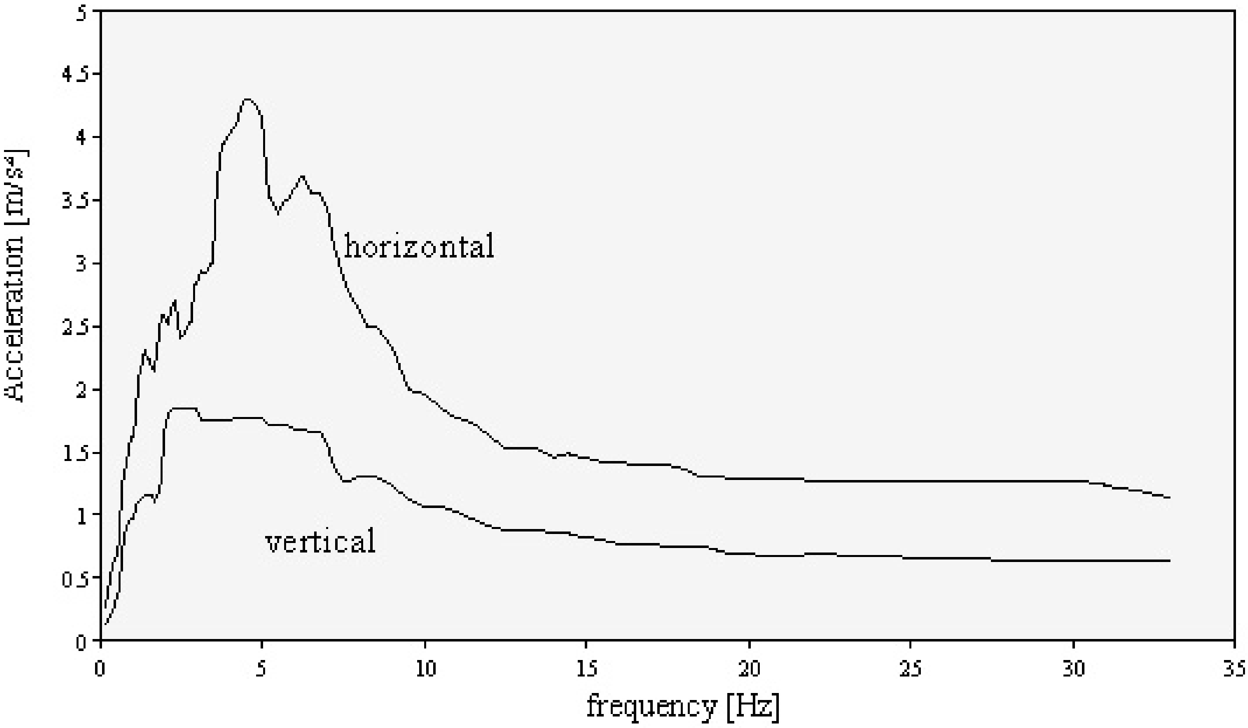


Figure 3.11.1: Response Spectra (enveloped curves calculated from selected natural accelerograms and for 5% damping).

In plausibility (full report is provided in **ANNEX D** (Comparison of Temelín Ground Response Spectra to Spectra for German Sites) of the Temelín Ground Response Spectra is investigated through comparison with spectra for German sites. Three sites in Germany have been selected for this purpose:

- Konrad (Lower Saxony, near Salzgitter; waste repository) – very low seismicity; should be comparable with Temelín site
- Ahaus (North Rhine-Westphalia; spent fuel intermediate storage facility) – low seismicity, but higher than Konrad site
- Biblis (Hesse; nuclear power plant) – high seismicity

The spectra for Konrad and Biblis could be obtained from the recent scientific literature. The Ahaus spectrum dates back about 25 years.

The limitations of the information acquired for this report correspond to its rather limited scope. In the **ANNEX D** (Comparison of Temelín Ground Response Spectra to Spectra for German Sites – Appendix III mentioned in Annex D) background information are provided concerning seismic hazard in Europe and illustrates that Konrad and Temelín are both located in regions of very low seismicity.

The table below summarizes the different characteristic values of the response spectra for Temelín and the three German sites considered here.

The spectra for Temelín display generally higher values than the spectra for Konrad and Ahaus, two sites with low seismicity (Figure 2.11.2). Peak horizontal acceleration assumed for Temelín is even considerably higher than the corresponding value for Biblis. The high peak value of the horizontal acceleration in the Temelín spectrum, as well as the unusually rapid decrease towards higher frequencies, clearly requires clarification.

			Temelín		Konrad	Ahaus	Biblis
Horizontal. acc. (m/s^2)	Peak		4.25		~2.1	3	3.6
	High fr.		1.25		1.12	1	2
Vertical acc. (m/s^2)	Peak		1.8				1.8
	High fr.		0.6		0.56		1.1

Figure 2.11.2: Horizontal accelerations and vertical acceleration of Temelín in Comparison with Konrad, Ahaus and Biblis (ANNEX D).

3.11.3 Seismic Design Categorization for Structures, Systems and Equipment Components

Regarding to the IAEA Safety Guide 50-SG-D15, only seismic category 1 of structures, systems and equipment components was established for the Temelín NPP.
The seismic category 1 includes firstly:

- Items whose failure could directly or indirectly cause accidental conditions (seismic adequacy required up to SL2 as minimum),
- Items required for safe shutting down the reactor, monitoring its critical parameters, maintaining the reactor in a shutdown condition and removing residual heat over a long period (minimum three days) (seismic adequacy required up to SL2 as minimum),
- Items that are required to prevent radioactive releases or to maintain releases below limits established for design accidental conditions (seismic adequacy required up to SL2 as minimum).

Conservatively, the seismic category 1 also includes those items that are designed to mitigate consequences of LOCA and HELB accidents despite the fact that the primary pressure boundary and also all high-energy pipelines are designed to withstand SL-2 earthquake loads.

For equipment the seismic category 1 is then divided into the following three subcategories:

(1a) when the full functionality is required

(1b) when only mechanical integrity is required

(1c) when only stability is required to avoid seismic interaction

The electrical, I&C and active mechanical equipment (valves, pumps, fans etc.) components that are necessary to fulfill safety functions during and after an earthquake are typically included into the seismic subcategory (1a).

The distribution systems (pipes and ventilation ducts) and passive mechanical equipment components (tanks, heat exchangers, filters etc.) are typically included into the seismic subcategory (1b).

Structures, systems and equipment items, not included into subcategories (1a) and (1b) and that may impact the adjacent equipment important to safety due to their relative motion or falling down or that may fail and cause flooding are typically included into the seismic subcategory (1c).

3.11.4 Methods Used to Demonstrate Adequacy of the Seismic Category 1 Structures, Systems and Equipment Components

The following methods were used to demonstrate adequacy of the seismic category 1 structures, systems and equipment components:

- seismic analysis (for building structures, main pipelines, main mechanical equipment components and also for anchorage of equipment),
- seismic tests (for active mechanical, electrical and I&C equipment components),
- earthquake experience and indirect procedures (for small bore pipes, HVAC ducts, and also as an additional approach to verify seismic adequacy of equipment as mounted).

The relevant acceptance criteria are summarized in the POSAR – Chapters 3.7 and 3.10.

3.11.5 Used Seismic Codes, Standards and Guidelines

The main codes, standards and guidelines primarily used for evaluation of seismic hazard and for seismic design and qualification of the Temelín NPP are:

- IAEA 50-SG-S1 (revision 1), 50-SG-D15, TECDOC-343 and TECDOC-724
- ASCE 4-86
- ASME BPVC Section III, Division 1 (1992 edition) and QME-1-1994
- Russian PNAE G-7-002-86 (or equivalent IAE standards), OAG 130-003, OTT-87,
- IEC 980-89 (or CSN IEC 980)
- KTA 2201.4
- IEEE Std 344-87, Std 382-85
- US NRC RG 1.12, RG 1.70, RG 1.100, RG 1.166, Standard Review Plan – NUREG 0800
- Czech NTD A.S.I. Section III, and selected CSN norms.

The applicability and compatibility of these documents were deeply investigated to assure approximately the same level of safety.

4 CONCLUSIONS FROM THE MONITORING PROCESS

There is a clear consensus amongst the Austrian Expert Team that the information and materials received from the Czech Experts during the Experts' Workshop at SÚJB Praha (March 27 and 28, 2003) was very informative. The Czech experts made significant efforts to clarify open questions related to seismic safety issues. In some topics, however, the Austrian assessment still differs from the Czech Expert's opinion.

4.1 Geological and Tectonic Background Data

The main criticism refers to the fact that the performed geological and tectonic analyses are not appropriate for determining the seismic potential of faults in the near-region of the power plant and for ruling out that (part of) these faults have been active during the youngest geological times.

Only three out of twelve important faults near Temelín were studied in some detail. The performed examinations are not appropriate for dating the youngest fault activities as requested by IAEA and for ruling out active (Pliocene to Quaternary) faulting. The applied high-resolution geophysical methods applied for locating and mapping near-surface faults are regarded to be insufficient. In particular, the existing data for the Hluboka fault, which is aligned with a most prominent morphological scarp, are insufficient to date the youngest fault activity and to exclude a tectonic origin of the morphological feature. This has been also criticized by IAEA-mission in 2003.

The urgent need for an updated dataset for this fault is stressed by various features indicating Quaternary deformation along the fault. Such features are well illustrated in the official Czech reports. Features include the apparent deformation of Quaternary terraces of the Vltava River showing upward convex topography close to the Hluboka fault and an increase of the number of terraces north from the point where the Vltava crosses the fault. These geomorphologic features are not discussed in the report by Simunek (1995). Also, the presence of segmented fans adjacent to the scarp of the Hluboka fault may be indicative for active vertical movements along the fault. The latter is corroborated by published geodetic data indicating continued subsidence of the Budejovice Basin (Vyskocil, 1975). Both geomorphologic features and geodetic data have not been addressed in the available seismic hazard assessments.

The summarized assessments and scientific details are included in the Paragraphs 2.7 and 2.10 of the preliminary report.

4.2 Seismicity and Seismic Hazard Assessment

The deterministic method for seismic hazard assessment presented by Czech experts is based on an expert system, which is not internationally verified. The calculation of the near site hazard is based on insufficient data and uncertainties related to data ambiguities are not given. For some seismic source zones the maximum credible earthquake (MCE) and also the SL2 level earthquake is based on the relation $I_{mc} = I_0 + 0.5°$ (I_0= observed intensity of the largest known earthquake within a region and I_{mc} = maximum credible earthquake of the region). However, appropriate standard safety margins would be 1° intensity instead of 0.5° whereas some authors add 1.5°. This approach has also been critically evaluated by the IAEA Mission in Feb. 2003.

According to the Austrian point of view, the applied method underestimates the seismic hazard for the Temelín site by at least 0.5°. From historical reports an observed intensity of I = 5.5° – 6.0° is derived for the area of Temelín. Based on the derivation of the MCE from data of the strongest historical earthquake of the whole region (Neulengbach, 1590) we conclude a conservative value of 7° - 7.5°MSK for the SSE. Especially in areas of assumed low seismicity longer return periods of strong earthquakes should be considered and the geological record should be investigated in order to extend the temporal catalogue coverage. Despite recommendations by IAEA (Safety Guide 1992; Site Safety Review Mission, 1990) to determine a MCE by dating youngest movements of faults (paleoseismological method) this method was not performed.

The probabilistic method for seismic hazard assessment presented by Czech experts uses an inappropriate attenuation function derived from an U.S site. Attenuation functions describe the decrease of the seismic energy with increasing distance from the earthquake epicentre. The used function does not account for the strong directional variation of the attenuation of earthquakes felt in Southern Bohemia. The study presented by SÚJB (2003) assumes attenuation for earthquakes from the Mur-Mürz-Leitha Fault that is nearly one degree higher than that found by a more profound investigation by Simunek et al. (1995). In addition the probabilistic calculation does not use the correct spread of the data. For that reason this approach is not a stochastic one and does not follow IAEA recommendations. We expect that a recalculation will give an SL2-level earthquake of at least 7° MSK.

The correlation between intensity I = 7° MSK and a MHPGA (maximum horizontal peak ground acceleration) of 0.1g reflects only a global mean value. French, German and Russian standards correlate intensity levels with higher g values and therefore follow a more conservative approach. The value of 0.1g accepted in Temelín for the SSE is equal only to the minimum requirements of the IAEA and does not contain any safety margin! The Czech hazard assessment therefore cannot be addressed as conservative.

Detailed discussions of the Austrian critical remarks are included in the Paragraphs 2.5 und 2.10 of the preliminary report.

5 RECOMMENDED ADDITIONAL INVESTIGATIONS

It is recommended to the Austrian Government to offer the suggestion to the Czech decision makers to carry out further, specific investigations to enable a final and conclusive assessment. The following investigations and activities will improve knowledge and judgement considerably and are therefore advisable.

5.1 Build-up of a GIS-based Geological Database

It is strongly recommended to merge *all* available data from the near region of the site into a simple GIS-based project (e.g., in ArcView) in order to clarify the interpretations made. This has been suggested in similar words by IAEA. The database should contain the following data:

- Geological maps
- Tectonic maps
- Digital Terrane model
- Remote sensing data: Landsat and Radar data
- Historical and instrumental seismicity
- Micro-seismicity (including the data by Kutina, 1974)
- Geodetic data (e.g., Vyskocil, 1975)
- Interpreted seismogenic structures
- Used seismic source zone models

5.2 Assessment of the Near-Regional Faults

The Austrian Expert Team agrees that the efforts, which were undertaken to constrain the youngest ages of faulting along the fault in the near region, are not sufficient to exclude active tectonics. There is, however, clear evidence of possible Quaternary and active faulting at Hluboká and Tyn nad Vltavou (Hluboká Fault). In a radius of 25 km all such faults and lineaments should be investigated more thoroughly. In a wider area around the NPP (e.g. 50km) possible identified active faults that have at least a length of 5 km should be considered as potential sources of events that have to be modeled in order to assess the level of ground motion that could be produced at the NPP.

The main concerns of the Austrian Expert Team refer to the still unresolved seismotectonic significance of the Hluboká Fault. The undoubted geomorphological significance of the fault marked by a morphological scarp; active subsidence of the Budweis Basin indicated by geodetic data and the morphology of the basin; geometries of river terraces; segmented fans along the scarp; and published maps showing micro-seismicity in the region strongly contrast from the low efforts, which have been made to characterize the fault so far.

State of the art assessment of the age of the youngest faulting events along the Hluboká fault is recommended to include the following additional geological and geophysical investigations:

Step 1. Mapping of the suspected fault scarp, adopting recent techniques of tectonic geomorphology. Assessment of tectonically induced landforms such as fault scarps, hanging valleys, river platform patterns, river terraces, tilted and segmented fans etc. Mapping should result in a selection of sites for geophysical data acquisition.

Step 2. Assessment of the possible tectonic displacement of Vlatva river terraces. Investigations need to include reviews of existing data, field mapping and absolute age dating of selected terraces by any of the listed methods: radiocarbon dating (14C), 26Al/10Be, thermoluminescence (TDL), optically stimulated luminescence (OSL), U-series dating, electron-spin resonance, DNA/amino acid dating, paleomagnetic investigation, soil micromorphology, biostratigraphy (pollen, terrestrial gastropods, mammals).

Step 3: High-resolution geophysical fault mapping using 2D seismic, ground penetrating radar, gravimetry, geoelectrics. The sections should form the basis for the selection of proper sites for additional investigations by trenching.

Step 4: Trenching across several properly mapped and constrained sectors of the Hluboká Fault in order to prove or disprove the offset of young Quaternary sediments.

5.3 Integration of Geodetic and DEM Data

Examination of drainage patterns in South Bohemia and the Quaternary river terraces along the Moldau/Vlatva River suggests that the Hluboká Fault controls long-term uplift of the Temelín area (north of the Hluboká Fault) relative to the Budweis Basin. If this is the case, it may be that uplift is partly a seismic and is continuous, or related to seismic deformation along the fault. Geomorphology of the region should be assessed quantitatively with standard approaches utilizing digital elevation (DEM) models.

Possible uplift of the area north of the Budweis Basin is also indicated by published precise leveling data indicating annual vertical movements at rates of several tenths of a millimeter per year (some 0,1 mm/yr; Vyskocil, 1975). Due to the time elapsed since the published levelling campaigns, renewed conventional high-precision levelling is expected to provide an excellent database to verify or correct theses data (low-cost option). The approach may be supported by using space-based observation and the PSInSAR technique in retrospect. PSInSAR is a form of satellite radar interferometry using so-called permanent scatters (PS). A PS is any large unmoving angular object - typically a large building, but a large rock may also suffice. The movement of such PS can be computed to accuracy of about 1 mm in the line-of-sight of the observing satellite. Existing satellite image archives are sufficient to provide data for the last ten years.

In the proposed investigation data would be collected for an area 50 x 50 km centered on the Hluboká Fault. If there is a consistent difference in displacement rates between PS north and south of the fault, this indicates that uplift is continuing at measurable rates.

5.4 Seismology

The probabilistic hazard analysis undertaken by the Czech side does not follow state-of-the-art procedures. The main study presented uses a unique method, the basis of which is unclear. Further Information regarding the benefit of this unique method and the reason for applying it would be highly welcomed.

In any case, it would be useful, as a benchmark, to have a PSHA study in hand using the most up-to-date methods. Czech studies cite other work such as GSHAP for comparison, and show that results are similar - but only for short return periods. Long return periods remain to be analyzed.

Specific issues would be the following (of the three issues listed below, probably the upgrade of the earthquake catalogue is the area where the most benefit would be obtained from the effort expended):

Zonation: Low cost option: Use existing Czech model or GSHAP model with minor refinements. Probably the zone configuration is not really a major issue for Temelín. High cost option: One or more teams of experts construct new zone model(s).

Catalogue: So far as can be gauged, the earthquake catalogue used in the Czech studies is not very good. It may possibly be based on excellent historical data (one cannot tell from the documents seen), but the interpretation of these data clearly does not discriminate between small shallow (< 5 km) events and larger, deeper (c. 15 km) events, both of which may have the same epicentral intensity but should have different magnitudes. Low cost option: Use the GSHAP catalogue, or similar available regional data set. High cost option: Engage historians/seismologists to compile new catalogue for relevant area. How large a task this would be depends on how much historical data turn to be already accessible (probably a lot).

Ground motion and attenuation: The expected ground motion as a function of magnitude and distance is a key component of PSHA. Ideally, a suitable equation should be derived from local data, but for this region, local strong ground motion data to use as a basis are non-existent. Other approaches need to be used.

Low cost option: Use a standard published equation from the literature that ought to be regionally appropriate. High cost option: Estimate acceleration, velocity and displacements likely to occur for possible events (scenarios) on identified seismogenic faults at distances of at least 50 km from the NPP by a modeling approach involving at least two modeling groups to produce five-ten scenarios for each seismic source. Construct new attenuation equation either from specially selected imported empirical data or through synthetic modeling.

5.5 Seismicity Monitoring

The installation of a few (three to four) more seismic stations at distances of about 30-50 km from the NPP should be considered to better localize the microseismicity occurring near the NPP. Station locations should take into account the microseismicity pattern. The measure supports defining the possible activity of lineaments, blind faults etc., and obtaining more records of stronger remote events in order to better define attenuations.

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6.3 Abbreviations

ACORN	Alpine Carpathian on-line Research Network
ASCE	U.S. Normative Standard
ATPP	Austrian Technical Position Paper
CAV	Cumulative Absolute Velocity
CEZ ETE	Tschechische Elektrizitätsgesellschaft, Kraftwerk Temelín
ĈSN	Czech Normative Standard
D-A-CH	Deutschland-Österreich-Schweiz Germany-Austria-Switzerland
ECOS	Swiss earthquake catalogue
GIS	Geographical Information System
GSHAP	Global Seismic Hazard Assessment Program
I	Local (earthquake) intensity at a given distance from the epicenter
I_0	Epicentral Intensity
IAEA	International Atomic Energy Agency
KTA	Kerntechnischer Ausschuss German Normative Standards
Mmax	Maximum Earthquake Magnitude
MCE	Maximum Credible Earthquake
MHPGA	Maximum Horizontal Peak Ground Accelertion
MSK	Macroseismic Intensity Scale according to Medvedev Sponheuer Karnik
NPP	Nuclear Power Plant
PGA	Peak Ground Acceleration
PGAH	Peak Ground Acceleration Horizontal
PGAV	Peak Ground Acceleration Vertical
PNAE	Russian Normative Standard
PSHA	Probabilistic Seismic Hazard Assessment
RFS	Régle Fondamentale de Suréte
S&A-CZ	S&A-CZ Stevenson and Associates, Energoprùzkum
SIR	Specific Information Request
SL1	Safety Level 1 corresponding to the Operation Base Earthquake (OBE)
SL2	Safety Level 2 corresponding to the Save Shutdown Earthquake (SSE)
SSE	Save Shutdown Earthquake
SSSC	Selected Structures, Systems and Compnents
SÚJB	Státní úrad pro jadernou bezpecnost (State Office for Nuclear Safety)
TEC-DOC	IAEA's Technical Document Series
UBA	Österreichisches Umweltbundesamt Federal Environment Agency
UVE	Umweltverträglichkeitserklärung Environmental impact declaration
UVP	Umweltverträglichkeitsprüfung Environmental impact assessment
VLI	Verifiable Line Item
ZAMG	Zentralanstalt für Meteorologie und Geodynmik

ANNEX A

EVALUATION OF THE SPECIALISTS’ WORKSHOP PRESENTATIONS ON SEISMIC HAZARD ASSESSMENT OF THE TEMELÍN NPP SITE

Workshop at SÚJB Praha, March 27-28, 2003

EVALUATION OF THE SPECIALISTS' WORKSHOP PRESENTATIONS ON SEISMIC HAZARD ASSESSMENT OF THE TEMELÍN NPP SITE

The initiator of the project (BMLFUW - Lebensministerium) asked the Austrian Expert Team in the VLI-Document to evaluate the information presented by the Czech side during the SÚJB Workshop in Prague 2003. This chapter only deals with the information gained through the SÚJB Workshop.

Overall Evaluation of the Information Received

There is a clear consensus amongst the Austrian Expert Team that the information and materials received from the Czech partners during the Experts Workshop at SÚJB Praha (March 27 and 28, 2003) was very informative. The workshop allowed for detailed questioning on the data backup, methods and results of seismic hazard assessment for the site of the Temelín NPP. It was held in a very open, constructive and friendly atmosphere, which allowed for both public discussion and personal talks to the individual Czech experts.

All presentations during the workshop were very clear and supported by print handouts. Additionally, a digital version of all presented slides, and prints of several scientific / technical documents were handed over to the Austrian delegation.

This positive atmosphere, the friendly openness, and the high technical standard of the workshop are very much appreciated.

The presentations at the Experts Workshop at SÚJB Praha (March 27 and 28, 2003) addressed all specific topics raised by the Austrian side, which are summarized in the VLI list of PN6 (refer to **ANNEX E**). Comments to the data and solutions for each specified topic are listed in the subsequent chapters.

Detailed discussions of the adequacy of data, methods, and solutions, assessments of the Czech conclusions in terms of the seismic hazard estimated for the design basis of the Temelín NPP as well as suggestions for further action are included in the main part of the report.

The Austrian Expert Team attended the workshop at SÚJB in Prague and had numerous discussions with the Czech experts as well as internal discussions during this workshop and afterwards. Many questions were left open because either they could not be answered by solely studying documents or statements or assumptions by the Czech side could not be verified on the spot. Therefore it was decided to organize an internal workshop connected with a field visit to the area. Discussions during the internal workshop and field trip raised the standard of knowledge of the Austrian international team of experts. Therefore its Specific Technical Evaluations based alone on the content of the workshop are outdated by further information gained from field experience, further literature and internal discussions. Specific technical evaluations are presented within main part of the report and additional information in the annexes.

THURSDAY, March 27, 2003			
	Workshop Opening	SÚJB	11.30 - 11.40
1	**Site Seismic Licensing Requirements**	SÚJB	11.40 - 12.00
2	**Introductory Remarks of NPP Temelín**	Holan (ÈEZ ETE)	12.00 - 12.15
3	**Summary of International Seismic Missions and Audits**	Masopust (S&A-CZ) Prášil (ÈEZ ETE)	12.15 - 12.45
	- history of construction of the Temelín NPP		
	- summary of international seismic missions and audits		
4	**Geological Investigations**	Prachar (EPP)	12.45 - 13.45
	- regional and near-regional geological data		
	- site vicinity investigation		
	- site area investigation		
5	**Seismological Data – Earthquake Hazard Assessment**	Rudajev (ÚSMH AV ÈR)	13.45 - 14.30
	- historical earthquake data and catalogues		
	- region seismogenic zones		
	- isoseismal maps and macroseismic observations		
	- intensity attenuation relations		
	- probabilistic hazard assessment		
	Coffee Break		14.30 - 15.00
6	**Microearthquake Monitoring**	Nehybka/Hanžlová (ÚFZ MU Brno)	15.00 - 15.45
	- local seismic network		
	- recorded seismic events and interpratation of results		
	- seismological information display		
7	**Seismotectonic Investigations**	Šimùnek (EPP)	15.45 - 16.30
	- regional seismotectonic model, description and criteria		
	- deterministic hazard assessment		
	Discussion		16.30 - 17.00

FRIDAY, March 28, 2003			
8	**Temelín Seismic Monitoring System (SMS)**	Brom (ÈEZ ETE)	09.00 - 09.30
9	**Supplementary Earthquake Hazard Assessment**	Buben (ÚSMH AV ÈR)	09.30 - 10.20
10	**Earthquake Hazard Assessment – Summary**	Rudajev (ÚSMH AV ÈR)	10.20 - 10.40
11	**Seismic Design Basis**	Masopust (S&A-CZ)	10.40 - 11.00
	- SL1 and SL2 determination		
	- response spectra and accelerograms		
	Coffee Break		11.00 - 11.30
12	**Conclusion of Temelín NPP**	Holan (ÈEZ ETE)	11.30 - 11.45
13	**SÚJB Concluding Position**	SÚJB	11.45 - 12.00
	Discussion		12.00 - 12.30
	Workshop Closing	SÚJB	12.30 - 12.45

1) Time periods shown for lectures will consist about ten minutes for questions and answers.
2) SÚJB = State Office for Nuclear Safety
3) ÈEZ ETE = Temelín NPP
4) S&A-CZ = Stevenson and Associates, Office in Czech Republic
5) EPP = Enegroprùzkum
6) ÚSMH VA AR = Ústav struktury a mechaniky hornin AV ÈR (Institute of Rock Structure and Mechanics, Academy of Science, Czech Republic)
7) ÚFZ MU = Institute of Physics of the Earth, Masaryk University Brno
8) EGP = Energoprojekt

Table (above): Program of the Experts Workshop at SÚJB Praha, March 27 and 28, 2003. Topics closely follow the VLI's defined for PN6, Site Seismicity.

ANNEX B

LIST OF IAEA REPORTS ON EXPERT MISSIONS TO THE TEMELÍN NPP

LIST OF IAEA REPORTS ON EXPERT MISSIONS TO THE TEMELÍN NPP

List of IAEA Reports
• Site Safety Review Mission for Work Plans and Schedules, 1992
• Follow-up Review Mission on Progress on CEZ OA Documents, Tectonics, Microearthquake Monitoring and Hydrogeology, 1993
• Progress Review Meeting on Progress in Tectonics, Microearthquake Monitoring and Hydrogeology, 1994
• Review of WWER-1000 Safety Issues Resolution at Temelín NPP, 1996
• Expert Mission to Assess Resolution of IAEA Safety Issues at Temelín NPP, 2001
• Expert Mission to Assist the Czech Republic in Seismic Hazard Assessment of Temelín NPP, 2003

ANNEX C

GIS BASED TECTONIC INVESTIGATIONS OF SATELLITE - DATA FROM SOUTHWEST CZECH REPUBLIC

- Contribution to the Detection of Local Site Conditions
Influencing Earthquake Damage Intensity and Earthquake induced Secondary Effects
in the Area of the Nuclear Power Plant of Temelín (Seismic Microzonation)

-

VCE Holding GmbH

and

Dr.habil.Barbara Theilen-Willige / Technical University of Berlin, Institute of Applied Geosciences, Department of Hydrology,

and

Bureau of Applied Geoscientific Remote Sensing (BAGF)

Not appended to this Preliminary Monitoring Report.
Please refer to Annex C as separately published document.

ANNEX D

SEISMIC HAZARD ASSESSMENT AT THE NUCLEAR PLANT SITES: CURRENT PRACTICE AND STATE OF THE ART IN GERMANY AND FRANCE

Dr. Helmut Hirsch, University of Hannover et al.

Not appended to this Preliminary Monitoring Report.
Please refer to Annex D as separately published document.

ANNEX E

THE MONITORING SCOPE OF THE PROJECT PN6

Verifiable Line Items
Defined and accepted by the Austrian Expert Team
Revision 3, issued March 2002

Verifiable Line Items (VLI)

0. Introductory Remark

Verifiable line items prepared for the peer review of available literature on the seismicity of the site of Temelín NPP and the results of remote sensing, also taking account of information expected to be made available at the topical workshop on March 27 and 28, 2003.

It is intended to monitor the following items – updates might become necessary in the course of the project. The following sections correspond to the Preliminary Czech Agenda:

1. Site Seismic Licensing Requirements

- Review of documents on which the decision on site selection was based.
- Comparison of Czechoslovakian standards for seismic site evaluation valid at the time of site selection and the new Czech standards valid now, as well as review of comments on the changes and their background

2. NPP Temelín seismic site re-evaluation

- Seismic site re-evaluation procedure following current practices (methods, discrepancies, etc).
- In case of still ongoing re-evaluation, its status and schedule.
- Internal instruction defining this procedure
- Certification procedure available
- Key players involved in the process
- Risk management procedure

3. International Seismic Missions, Audits and Standards

- Investigation of equivalences and differences to international standards and recommendations (in particular IAEA, EU, Russian and US)
- Status of implementation of IAEA recommendations, in particular of site safety review missions and audits.

4. Geological Investigations

- Review of regional and near-regional geologic data – application of remote sensing techniques
- Discussion on location of “tectonic lineaments”, which correspond to tectonic structures, and geomorphologic features (note: this method alone does not allow one to distinguish between active and non-active faults)
- Use of raw data (satellite images and digital terrain models) as prime data for an independent control of tectonic maps handed over by the Czech experts, and for the evaluation of tectonic geomorphology, which could be the basis for specific questioning of the trenching results of the Energoprůzkum 1995 report
- Review of geological and hydrogeological investigations in the site vicinity and site area of Temelín NPP and the surrounding region
- Review of Engineering Geological and Geotechnical Background Documents (documentation including large scale maps of the excavation area for the power station and representative cross sections)
- Among others focus on depicted problems with faults and their activities which are mentioned in hydrogeological background studies

5. Seismological data

- Review of historical earthquake data and catalogues
- Focus on relevant historical earthquakes, their intensities; assessment of the maximum credible earthquake (MCE) and review level earthquake (RLE)
- Review of seismogenic zones
- Discussion of seismogenic models as key input for probabilistic hazard assessment
- Derivation of magnitudes and intensity attenuation relations
- Review of calculations regarding ground accelerations from intensities
- General focus on uncertainties in all calculations

6. Microearthquake Monitoring

- Seismic events recorded by local monitoring stations and interpretation of results
- Relevant results from field tests in the region
- Review of micro-seismic events recorded for site evaluation
- Correlation between microearthquakes and faults
- Review of local amplification factors from the engineering seismological model of the site

7. Seismotectonic Investigations

- Determination of seismotectonic zones and discussion of a regional seismotectonic model
- Investigation of the main fault systems
- Comparison of contradictory results in the Czech literature
- Determination of recent tectonic activity of the main faults (dating of fault movements)
- Investigation of tertiary sedimentation and quaternary influence of the relief
- Discussion on application of integrated techniques as recommended by IAEA (neotectonics, paleoseismology, geomorphology, sedimentology)
- Review of deterministic hazard assessment (worst possible case, events in aseismic areas, uncertainties in parameters, maximum earthquake capacity)

8. Temelín Seismic Monitoring System

- Discussion on technical aspects of the on-site monitoring system complementing the - scientific background (see 6. Microearthquake Monitoring)
- Methods to collect data
- Monitoring systems available
- Organisation and collection of technical data used for assessment
- External access to data

9. Supplementary Earthquake Hazard Assessment

- Complementation of probabilistic (see 5. Seismological Data) and deterministic hazard assessment aspects (see 7. Seismotectonic Investigations) with results of the Experts' Workshop in Prague.

10. Earthquake Hazard Assessment Summary

- Comparison with procedure of hazard assessments in other countries such as Germany and Switzerland (different expert teams elaborating studies).
- Consideration of unexpected large earthquakes which occurred in aseismic areas

11. Seismic Design Base

- Review of SL 1 and SL2 determination
- Determination of response spectra and accelerograms

The following engineering issues of design specifications would be of interest (but these belong to separate projects (PN 4, PN 5) and may not suite PN 6):

- Procedure for a possible upgrade of the plant design specifications and the related measures
- Building assessment
- Components and structures - assessment and ranking
- Walk down and potential retrofit
- Structural assessment and operation
- Post earthquake procedure and emergency plan

12. Conclusion of Temelín NPP

Evaluation of the conclusions of the operator presented at the Experts' Workshop in Prague

13. SÚJB Concluding Position

Evaluation of the conclusions of SÚJB's concluding position presented at the Experts' Workshop in Prague

14. Discussion

Evaluation of the results of the concluding discussion of the Experts' Workshop in Prague

ANNEX F

AUSTRIAN PROJECTS IDENTIFICATION

AUSTRIAN PROJECTS IDENTIFICATION

PN 1	Severe Accidents Related Issues – [Item No. 7a] *
PN 2	High Energy Pipe Lines at the 28.8 m Level (AQG/WPNS country specific recommendation) [Item No.1] *
PN 3	Qualification of Valves (AQG/WPNS country specific recommendation) [Item No.2] *
PN 4	Qualification of Safety Classified Components [Item No. 5] *
PN 5	Regular bilateral Meeting 2002
PN 6	Site Seismicity [Item No. 6] *
PN 7	Severe Accidents Related Issues – [Item No. 7b] *
PN 8	Seismic Design
PN 9	Reactor Pressure Vessel Integrity and Pressurised Thermal Shock [Item No. 3] *
PN 10	Integrity of Primary Loop Components – Non Destructive Testing (NDT) [Item No. 4] *
PN 11	Regular bilateral Meeting 2004

* The Items are related to Annex I of the “Conclusions of the Melk Process and Follow-up”

ANNEX G

MONITORING MISSION STATEMENT

MONITORING MISSION STATEMENT

The independent Austrian Expert Team agreed on a “Mission Statement” to define the monitoring process coordinated by VCE and IRF.

“Monitoring” is a process performed in a predefined frame addressing selected issues defined in the “Conclusions of the Melk Process” as well as in the “Roadmap” and the solutions to these issues adopted by the Czech side.

Issues and their solutions are monitored on the basis of the reference safety criteria and requirements coherent with Safety Approaches accepted in Western Europe. The requirements are checked against the generally applied Defence in Depth Concept.

The monitoring has the objective to obtain evidence that adequate solutions have been submitted by the licensee to the licensing authority and that these solutions have appropriately evaluated and approved by the regulator. Monitoring aims at performing an evaluation of the quality and the adequacy of an overall process and the implementation results.

The Czech side has offered documentation and discussion opportunities.

The monitor, in order to form a consistent opinion should be provided with the opportunity to ask for additional information and evidence or request supporting assessments to understand the evidence presented.

Reports of the Experts’ Team therefore include monitoring results of

- What has been done
- How the applicable requirements have been addressed
- How the safety objectives and requirements compliance was analysed and justified for the proposed solutions
- How the solutions in the frame of the licensing process and considered in the related regulatory process were evaluated.

The monitors were not tasked with performing a licensing review of the Temelín NPP, and nothing in their reports may be construed to present any such review. The responsibility for the safety and licensing of Temelín remains with CEZ a.s. as the owner of the facility, and with the SÚJB, as the designated nuclear licensing and regulatory authority under Czech law.