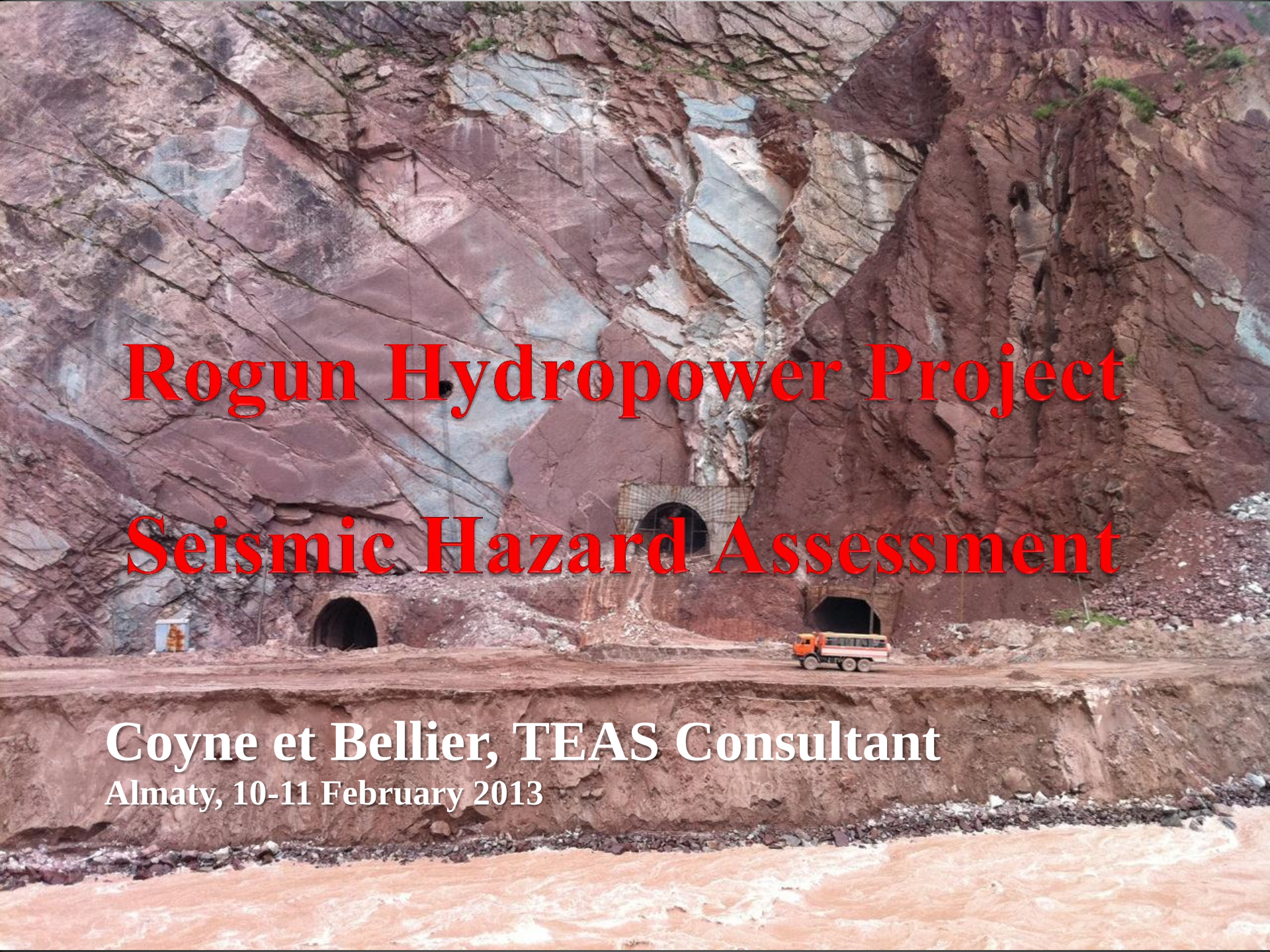


Rogun Hydropower Project

Seismic Hazard Assessment

Coyne et Bellier, TEAS Consultant

Almaty, 10-11 February 2013

Objectives of the presentation

As the seismic safety of Rogun dam is of the highest importance, with this presentation we would like to:

1) Inform riparians on previous seismic studies undertaken for Rogun;
2) Inform on the process agreed for the seismic hazard assessment under TEAS;
3) Inform on what has been done so far under TEAS.

1. Previous Seismic Hazard studies undertaken for Rogun dam site

- Lahmeyer's 2006 report:
  Peak Ground Accelerations were calculated by a site specific probabilistic seismic hazard assessment undertaken by Geodynamic Research Centre (part of HydroProject Institute (HPI)), Moscow;

- BRGM's (Bureau de Recherches Géologiques et Minières, France) review of Lahmeyer's 2006 report;

- HPI's recommendations in 2009 design report.

2. Process agreed for the site specific Seismic Hazard Assessment under TEAS

Design Criteria Document (disclosed for the consultations in November 2012) set out levels of earthquakes for the design, i.e. OBE and MCE earthquakes in line with requirements of ICOLD (International Commission on Large dams) bulletin 72 (Selecting Seismic Parameters for Large Dams), as follows:

- *Operating Basis Earthquake (OBE) represents the level of ground motion at the dam site at which only minor damage is acceptable. The OBE is best determined by using **PSHA** (probabilistic seismic hazard analysis). It typically has a 50% probability of not being exceeded in 100 years;*
- *Maximum Credible Earthquake (MCE) will produce the maximum level of ground motion for which the dam should be designed and analysed. There should be "no failure" during this earthquake and the impounding capacity of the dam should be maintained. Could be determined by **PSHA or DSHA** (deterministic seismic hazard analysis)*

2. Process agreed for the site specific Seismic Hazard Assessment under TEAS, cont'd

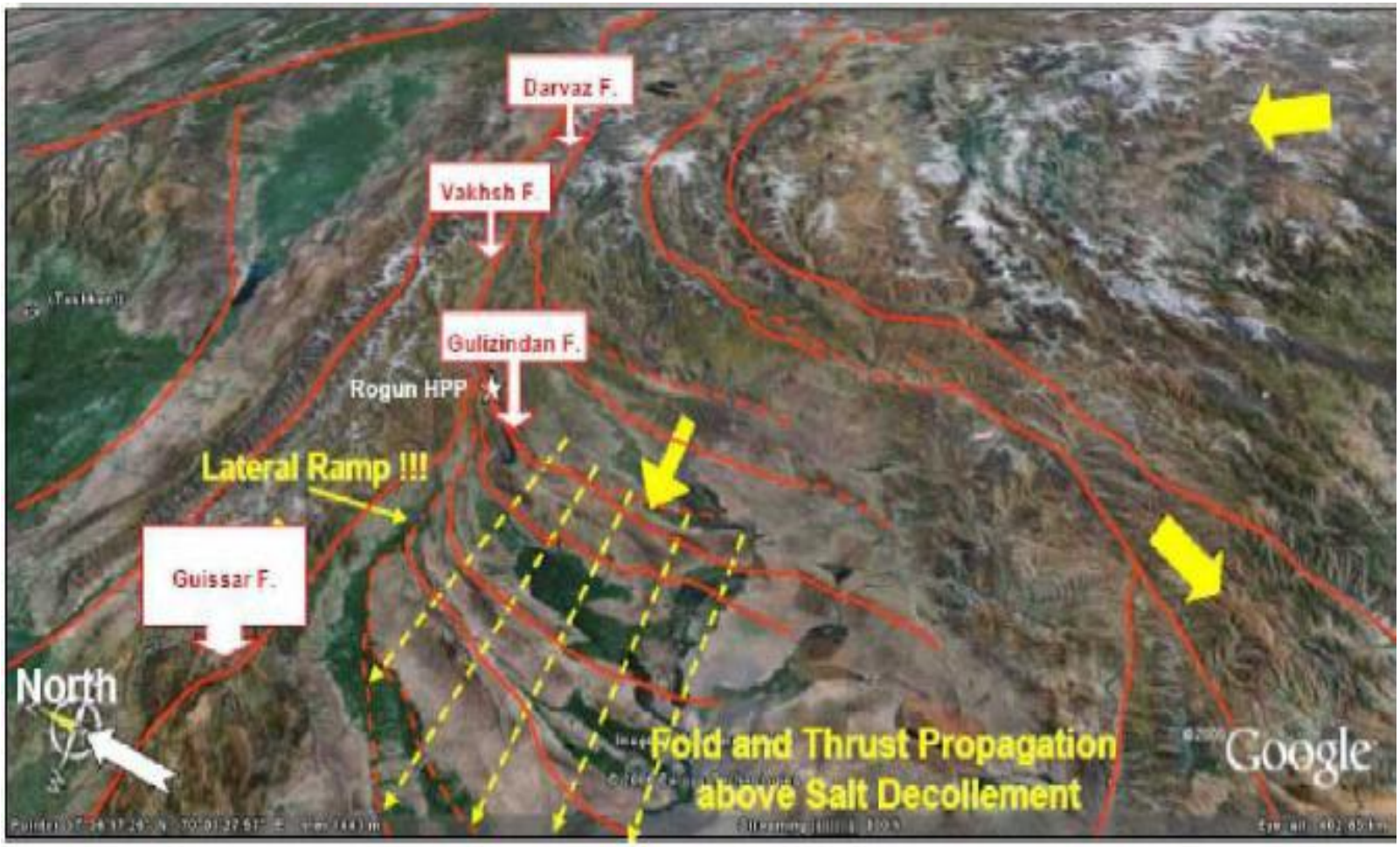
- Seismic design parameters of interest: Peak Ground Accelerations (PGA), design response spectra, seismic displacements along faults;
- Phase 2 TEAS studies: Undertake a DHSA to derive seismic design parameters for the **MCE**;
- Prior to Phase 3 studies: Undertake a PHSA to derive seismic design parameters for the **OBE and verify the design parameters for MCE estimated from DSHA.**

2. Process agreed for the site specific Seismic Hazard Assessment under TEAS, cont'd

- The DSHA was undertaken by BRGM, a sub-consultant to the TEAS Consultant. BRGM are a renown international company with a long expertise in seismic hazard assessments;

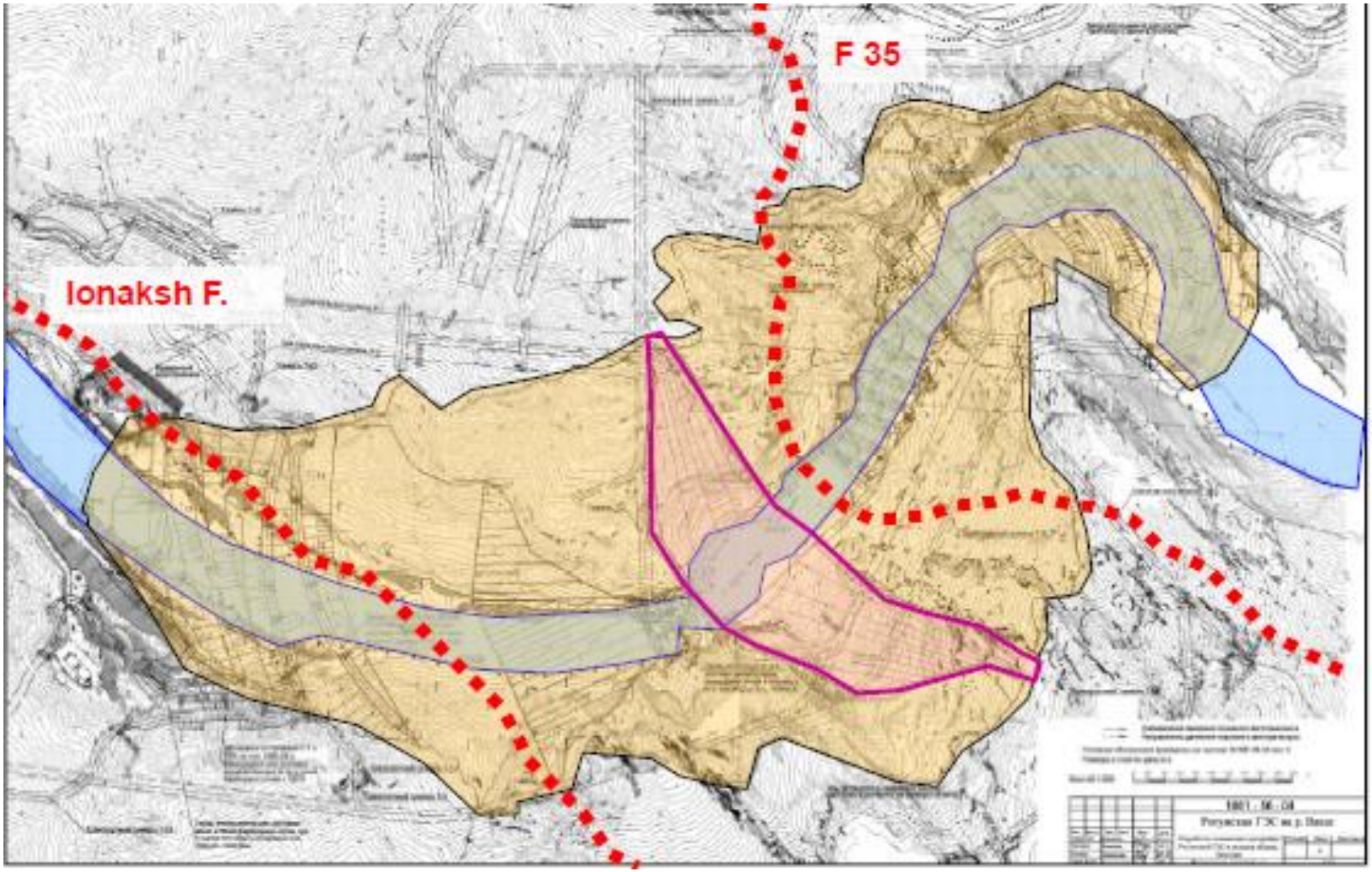
- A draft report on DSHA was submitted by the TEAS Consultant on 15th January 2013 and reviewed by the WB, PoE and the Government of Tajikistan;

3. DSHA undertaken by BRGM under TEAS - Regional Geotectonical Framework



3. DSHA undertaken by BRGM under TEAS, cont'd

Faults that cross the footprint of the dam



3. DSHA undertaken by BRGM under TEAS, cont'd

Summary on the geotectonic setting in the Rogun dam region:

1. Gissar – Kokshal fault;

2. Illiak – Vakhsh fault;

3. Ionakhsh and Gulizindan faults.

The Rogun dam is located between Ionakhsh and Gulizidan faults

3. DSHA undertaken by BRGM under TEAS, cont'd

Methodology adopted in DSHA:

- **Moment Magnitudes and Fault displacements** associated with MCE have been calculated for each fault based on empirical method developed by Wells & Coppersmith (1994) which correlates:
  - moment magnitudes, (M)
  - Fault surface rupture length (SRL),
  - Maximum (surface) displacements (MD), and
  - Average (surface) displacements (AD)
- Relationships (illustrated on slides 12-14) are based on the following formula:

  $M=a+b*\log(SRL)$; $\log(MD)=a+b*\log(SRL)$;
  $\log(AD)= a+b*\log(SRL)$
- The coefficient a & b were developed using a worldwide database for 421 historical earthquakes associated with shallow (<40km deep) earthquakes of M>4.5

3. DSHA undertaken by BRGM under TEAS, cont'd

Methodology adopted in DSHA, cont'd

- **Peak Ground Accelerations (PGA)** associated with MCE have been calculated for each fault based on empirical method developed by Ambraseys et al (2005), Berge-Thierry et al (2003) which correlates:
  - moment magnitudes, (M)
  - Epicentral distance, d, and
  - Focal distance, h

3. DSHA undertaken by BRGM under TEAS, cont'd

- Draft report on DSHA analysis submitted by TEAS consultant on 15th January 2013 provides the following seismic parameters for each fault:
  - Maximum Magnitude (M);
  - PGA
  - MD (maximum surface displacement)

- Tajik Government, the WB and the TEAS PoE reviewed the report and made several comments;

- BRGM will revise the report;

- PSHA will be undertaken to refine the seismic design parameters