Scientific Report 2025 of TOPO-EUROPE as ILP Coordinating Committee

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1. Rationale for TOPO-EUROPE as ILP Research Coordinating Committee

Since its foundation, **TOPO-EUROPE** has developed into one of the flagships of the **International Lithosphere Program (ILP)**, catalyzing pan-European cooperation in solid and surface Earth sciences and fostering cross-disciplinary research on the coupling between deep Earth, surface processes, climate, and life. The program has successfully built an integrated scientific community that bridges geodynamics, tectonics, geomorphology, sedimentology, and georesources, while pioneering research at the interface between solid Earth evolution and the Earth's surface and biosphere (Balázs et al. 2025; Haq & Cloetingh, 2025; Ostorero et al. 2025, Sternai et al. 2025).

TOPO-EUROPE serves as a **pan-European hub of excellence**, aligning national and regional programs under a shared scientific vision. It has provided intellectual leadership for major international consortia such as **AlpArray, AdriaArray**, and **TOPO-TRANSYLVANIA**, and has inspired the establishment of **TOPO-Asia** and **TOPO-Arabia** - demonstrating its global relevance and exportability as a model for integrated lithosphere–surface process research.

The structural backbone of TOPO-EUROPE lies in its strong and enduring **institutional anchoring**: the **Institute of Earth Physics and Space Science (EPSS)** in Sopron, Hungary, serves as the operational headquarters under the coordination of István Kovács and Szilvia Kövér. This structure has ensured continuity, financial stability, and the ability to organize and host annual TOPO-EUROPE meetings, short courses, and the **Scientific Leadership Training Program**, collectively shaping a generation of early-career Earth scientists.

A defining feature of TOPO-EUROPE has been its **multiplier effect**. Initial ILP seed funding has generated more than **€30 million** in external resources through competitive European funding streams – including **ESF EUROCORES (€14.5 M)**, several **Marie Skłodowska-Curie ITN networks (€9 M)**, a **COST Action (€0.5 M)**, and thematic EU programs in **geothermal energy (≈€5 M)**. Furthermore, members of the TOPO-EUROPE community have been awarded numerous **ERC grants** and **national research prizes**, underlining the program's catalytic role in scientific career development and innovation capacity.

Equally important, TOPO-EUROPE has been formally adopted by the **Academia Europaea** as a core activity of its **Earth and Cosmic Sciences Section**, and has recently secured the support of the **Topical Events Committee of the European Geosciences Union (EGU)** for the forthcoming years. This strategic endorsement consolidates TOPO-EUROPE's visibility across the European scientific landscape and ensures its integration into the EGU's broader framework addressing solid Earth, surface processes, and climate–tectonics–life interactions.

TOPO-EUROPE as an **ILP Coordinating Committee (CC)** continue to maintain the momentum of this dynamic community, to ensure continuity in training and outreach, and to preserve a unique European platform that integrates deep Earth research, surface dynamics, and societal relevance in areas such as geo-resources, geohazards, and renewable energy.

2. Main foci of TOPO-EUROPE's science for 2026

In the next phase, TOPO-EUROPE will reinforce its interdisciplinary research on **Earth Dynamics, Earth Environment,** and **Healthy Living**, emphasizing the integration of geodynamic and surface process models, biogeodynamics, and sustainable georesources. These activities will directly contribute to ILP's overarching objectives of understanding the evolution of the lithosphere and its interactions with other Earth system components over geological and human timescales.

Key scientific directions include:

• Advancing **coupled models** of mantle–lithosphere–surface evolution, integrating petrological, biogeochemical, biological and thermomechanical models and data.

• Expanding the field of **biogeodynamics**, quantifying feedbacks between orogenesis, magmatic activity, erosion, climate, and the geological carbon cycle.

• Exploring the emerging field of **Future Biogeodynamics**, quantifying feedbacks between plate tectonics, climate, and life, and improving predictive capabilities with the goal of ensuring the long-term survival of humanity and the ecosystems on which it depends.

• Investigating the **geodynamics of natural hydrogen systems, geothermal energy**, and **carbon storage** as part of the transition toward sustainable energy.

•Reinforcing **data-driven approaches** combining seismology, geodynamics, thermochronology, geomorphology to better constrain lithospheric structures and their surface expression.

• **Training the next generation** of scientists through short courses, summer schools, and leadership training programs, fostering gender balance and pan-European inclusion.

2.1 Working Group 1 (Surface-Deep Earth Coupling and Biogeodynamics)

Leads: Pietro Sternai (University of Milano-Bicocca), Taras Gerya (ETH-Zürich)

WG1 will focus on integrating geodynamic, petrological, and biogeochemical processes controlling lithosphere–asthenosphere evolution and their implications for surface processes, climate and life. Building on recent conceptual advances in coupled deep-Earth and surface dynamics (Békési et al. 2025, Haq & Cloetingh, 2025; Ali et al., 2025; Lavecchia et al. 2025; Oravetz et al. 2025, Ostorero et al., 2025; Porkoláb et al. 2025a,b), WG1 will promote a new research agenda under the theme '**Biogeodynamics: linking the living and solid Earths**'.

Specific objectives include:

- Developing a **Doctoral Network (DN)** proposal on *Biogeodynamics and carbon fluxes in orogenic systems*, with focus on the effect of extreme outgassing events on climate and life.
- Assessing feedbacks between tectonics, surface processes, magmatic activity and climate across the Cenozoic integrating current research on paleotectonic reconstructions, direct observational/analytical constraints from the geological record, geophysical data, and numerical climate and geodynamic modeling
- Integrating petrological and geochemical datasets into geodynamic modeling to constrain mantle wedge processes, volatile cycling, and crustal recycling.
- Combining geodynamic, climate and biological models to quantitatively assess **Future Biogeodynamics**, thereby improving our ability to safeguard our societies and sustain their healthy connection with long term Earth and environmental cycles.
- Collaborating with **TOPO-Asia** and **TOPO-Arabia** to build a global framework for comparative orogenic system analysis and assess their impact on the evolution of climate and life.

2.2 Working Group 2 (Geo-resources, Renewable Energy and Applied Geosciences)

Leads: Gábor Tari (OMV Vienna), Eszter Békési (HUN-REN EPSS), Kristóf Porkoláb (HUN-REN EPSS), Jan-Diederik van Wees (TNO, Utrecht University)

Renewable energy and climate mitigation are inherently linked to deep and surface Earth interactions, which are central to the TOPO-EUROPE initiative. Coupled Earth processes are essential for assessing natural resources: e.g., geothermal, critical elements, hydrogen (Békési et al. 2025; Schöpfer et al. 2025, Tari et al. 2025) and ensuring the sustainable and safe operation of critical infrastructure (e.g., geothermal or nuclear plants). The aim of WG2 in the coming years is to integrate state-of-the-art geophysical, geological, engineering, economic, and societal aspects to advance opportunities for renewable energy and

geohazard mitigation. WG2 continues to serve as a key platform for knowledge exchange and coordination within these research fields for the TOPO-EUROPE community.

Specific results and objectives include:

- The TOPO-EUROPE events generated very highly rated proposals for natural hydrogen exploration: a **COST action proposa**l with a 92% rating (not funded), a **2025 Horizon proposal** with a 100% rating (pending), and a **Spanish National Research Fund proposal** (funded in 2025 with Hungarian and Austrian collaborators from the TOPO-EUROPE community).
- Besides natural hydrogen, **geothermal research** was a focal point of the 2025 Workshop, with targets for 2025 and 2026 funding opportunities (Horizon,) and key research directions outlined. A **Clean Energy Transition Partnership (CETP)** proposal under the the Horizon program was submitted right after the workshop, and new research topics on deep geothermal energy were initiated in preparation for future EU calls.
- A new wave of momentum in geothermal research was created by the opening of the **HUN-REN TKI Rybach Research Centre** during the workshop. This initiative consolidates renewable energy research competencies within Hungary, enabling collaboration among researchers from various institutions in this high-potential region and facilitating participation in larger geothermal projects alongside other TOPO-EUROPE members.

3. Activities planned for 2026

TOPO-EUROPE will consolidate in 2026 its position as the **leading ILP Regional Coordinating Committee** through a structured and diverse activity plan:

- **Annual TOPO-EUROPE Conference** in Sopron (EPSS), featuring topical sessions, EGU/ILP joint keynotes and training modules.
- **Interdisciplinary workshop** on *Earth Dynamics, Earth Environment, and Healthy Living*, in collaboration with Academia Europaea and EGU Topical Events Committee.
- **Short Course and Summer School**:
    - *Leadership in Geoscience* (October, Sopron) for early- and mid-career researchers;
    - *Coupled Deep Earth and Surface Processes* (Vienna, Tartu, Sopron rotation);
    - *Biogeodynamics and Geo-Energy Systems* (Milan and Zurich).
- **Exchange and mentoring programs** for young scientists from EU13 countries.
- **Joint workshop** with ILP Task Forces, notably the Sedimentary Basins Task Force (Krzywiec et al., in press).
- **Collaborations** with TOPO-Asia and TOPO-Arabia, supporting the global ILP RCC network.

- **Preparation of thematic journal volumes** (Global and Planetary Change, Tectonophysics).
- **Outreach and public engagement** on geohazards, climate–tectonic interactions, and energy transition.

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