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Crustal formation on low-Mg exoplanets

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The chemical composition of a planet can influence its internal structure, mineralogy, volcanic behaviour and ultimately its habitability. Current geological models are only calibrated on Earth derived data and few data from our Solar System. Therefore, the effects of an exotic chemical composition on a rocky exoplanet (planet outside of the Solar System) are widely unknown. This research has performed 1 and 2 GPa experiments using a Piston-cylinder to investigate the melting behaviour of low Mg/Si compositions. Two starting compositions were used with varying Ca/Al concentrations. The mineralogy of both compositions is dominated by enstatite, with some quartz. The high Ca/Al experiments included clinopyroxene as well. Additionally, the melts produced were highly Si-enriched (dacitic to rhyolitic), but the melt fraction of the high Ca/Al experiments was slightly lower, causing the melt composition to be the most felsic. On Earth, these melt compositions are correlated with viscous melts. Therefore, the viscosity was calculated with the help of the calculations of Giordano et al. (2008), and results showed indeed a viscosity 80 to 5000 times higher than an average mid-ocean ridge basalt. This causes the melt extraction velocity to decrease significantly as calculated by equation 1 of Katz et al. (2022). The melts generated by the experiments of this research are thus hard to extract and would take billions of years to reach the surface. Consequently, the possibility of these melts to ever reach the surface is minimal, decreasing the likelihood of volcanism occurring on the planet. However, volcanism is the main process to generate a crust and a secondary atmosphere. Increasing the potential of melts to reach the surface include (1) an increased mantle potential temperature generating more melt, (2) the planet's radius (increases the surface gravity, and so the melt extraction velocity) and (3) the presence of H_2O in the melt, which lowers the solidus temperature. The latter has the most prominent effect. Other possible factors were not considered in this research but could be investigated.

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The characterization of the felsic magmatism in the Central African Karagwe-Ankole Belt

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The Central-African basement is characterized by a complex geological history and is composed of a number of cratons and younger fold-and-thrust belts. Among these, the Mesoproterozoic Karagwe–Ankole Belt extends from the southern margin at Lake Tanganyika to northern Uganda along an NNE orientation. The belt has been subdivided into two domains, namely the Western Domain and Eastern Domain, based on different arguments (Tack et al., 1994). Between these two domains an alignment of mafic-ultramafic massifs is found. This distinct alignment is known as the Kabanga-Musongati mafic-ultramafic complex. The most striking difference between the two domains is the occurrence of granitoids (Tack et al., 2010). While the Eastern Domain is devoid of S-type granitoids, these intrusives are found in large numbers and different generations in the Western Domain. Most interesting, however, is the youngest generation of granitoids in the Western Domain, as these have been linked with high-grade granite-related mineralisation (Dewaele et al., 2011). The geodynamic origin of the magmatism has been reinterpreted multiple times, the result being that there are numerous geotectonic models regarding the tectonic origin and evolution of the Karagwe-Ankole Belt (e.g. Fernandez-Alonso et al., 2012; Debruyne et al., 2015; Koegelenberg et al., 2015). The endmembers of these models revolve from purely intraplate tectonics to full-scale continental collisions.

This study presents a new interpretation of the felsic magmatism in the Western Domain. The aim is to identify variability within granitoid samples from different regions and with different petrographic compositions and ages. In addition, the geodynamic fingerprint of the samples was evaluated. For this study, samples were collected in eastern Rwanda, western Rwanda and the Akanyaru border region between Rwanda and northern Burundi. These samples were petrographically

examined using reflected light microscopy, and based on their major and trace geochemistry. An age estimation was obtained for some samples with zircon U-Pb dating, by using ICP-MS. Samples were then assigned to petrologic and geochronologic groups on the basis of petrographic and geochemical arguments.

Although limited sample representation constrained statistical robustness, variability was observed both regionally and temporally, based on petrographic and geochemical data. Geochemical discrimination diagrams did not yield conclusive evidence supporting either intraplate, volcanic-arc, or syn-collisional tectonic settings. The absence of a clear geodynamic signal may reflect the complex (re)melting and crystallization histories of the granitoids, as well as possible post-magmatic fluid–rock interactions. These processes likely played a significant role in modifying or obscuring the original tectonomagmatic signature of the Western Domain granitoids within the Karagwe–Ankole Belt.

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Transtensional fault system of the Gulf of Patras revealed by reflection seismic profiles: geometry, displacements, and seismic hazard

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The Patras Gulf, located in western Greece, occupies a complex tectonic domain where major fault systems interact and where regional seismicity is high. However, its tectonic dynamics remain poorly constrained. This study aims to produce a detailed mapping of the active faults in the gulf and to evaluate their seismic hazard potential. Faults were identified through the combined analysis of high-resolution seismic reflection profiles and bathymetric data. Deformation patterns were further assessed by computing surface vertical offsets for each fault. Seismic hazard was estimated from empirical relationships based on fault geometric parameters. The results highlight two distinct tectonic systems related to the regional tectonic framework: (1) a graben structure in the western gulf, forming a horsetail geometry linked to the Katouna-Stamna strike-slip Fault; and (2) a strike-slip system in the eastern gulf, including flower structures, which represents the offshore continuation of onshore fault systems and forms part of a dextral transtensive zone at the western termination of the Corinth Rift. The central gulf acts as a transitional zone where mixed kinematics accommodate the stress interaction between both systems. Stratigraphic relationships indicate that these systems have been connected since at least ~20 kyr, as similar MIS 2 lacustrine/alluvial sedimentary facies occupy the depocenters of the graben and transitional zone. Seismic hazard assessment emphasizes the potential risk for the city of Patras, with maximum expected magnitudes exceeding M_w 6 for the largest fault structures in the gulf, but this evaluation remains preliminary and should be refined, as creep is documented onland (Fig. 1).

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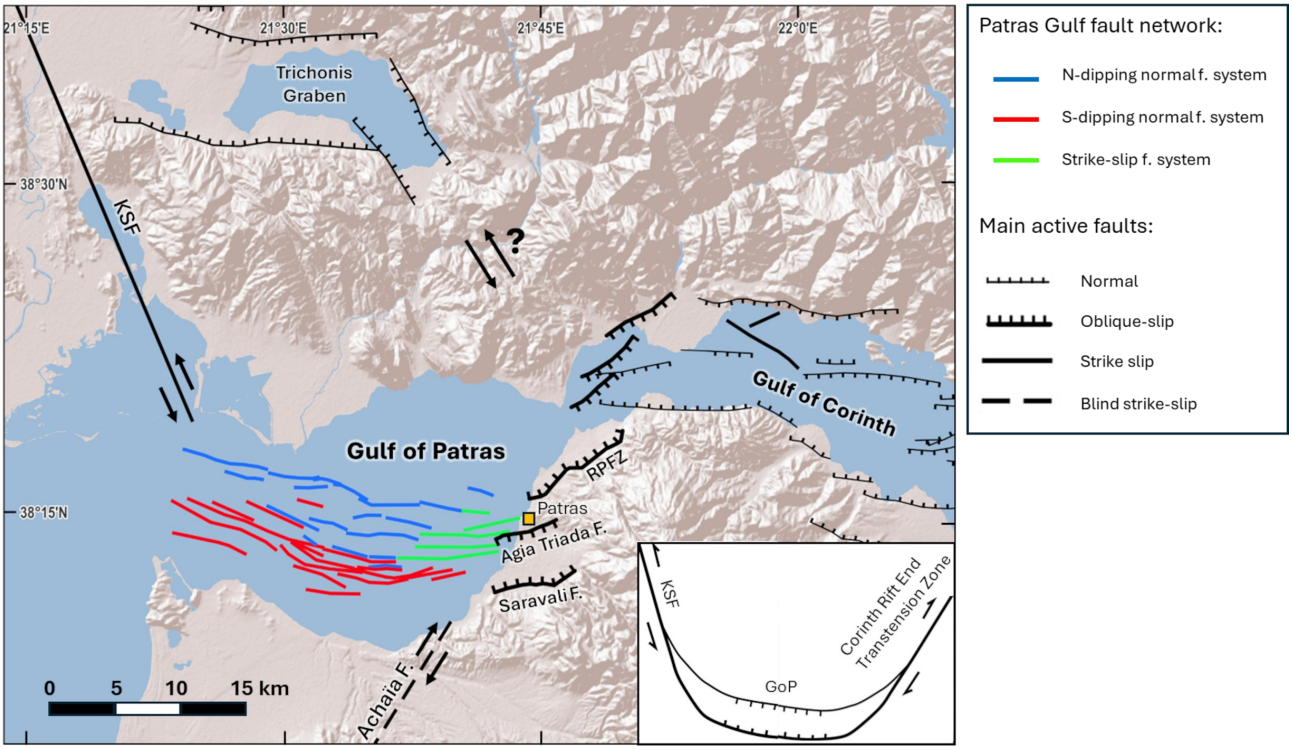

Figure 1. Insertion of the newly mapped fault network of the Gulf of Patras into regional tectonics and synthesis scheme of the interaction between the fault network and the neighbouring major tectonic faults. Regional main faults from Kiratzi et al. (2008); Margaris et al. (2010); Elias (2013); Pérouse (2013); Beckers et al. (2015); Elias & Briole (2018); Christodoulou et al. (2023). Abbreviations: F. = fault; KSF = Katouna-Stamna Fault; GoP = Gulf of Patras; RPFZ = Rion-Patras Fault Zone.

Mineralogical and petrological study of the alkaline granitic complex of Évisa (Corsica, France)

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The alkaline granitic complex of Évisa, Corsica, hosts NYF-type pegmatites (Bonin et al., 1978). The main pegmatite is characterized by the occurrence of fayalite, a rare mineral in this type of rock, together with sodic amphiboles such as riebeckite and arfvedsonite (Bonin et al., 1978; Bernard, 2020). Recent pegmatite classification schemes (Wise et al., 2022) suggest that the Évisa body occupies an intermediate position between two NYF subgroups: fayalite-bearing pegmatites and sodic-amphibole-bearing pegmatites. This pegmatite is compared with those described in other similar complexes (Amis, Cape Ann, and Quirra). Mineralogical analyses, including X-ray diffraction, X-ray fluorescence spectroscopy, and scanning electron microscopy, reveal a pronounced zoning pattern: progressive cooling from the margins towards the centre of the pegmatite, leading to an enrichment in silica, rubidium, and potassium in its core. These results are compared with those obtained from a neighbouring alkaline intrusion, the Bonifato complex. Although both complexes display strong similarities, the Évisa body is distinguished by a trace-element enrichment resulting from successive hydrothermal episodes. In addition, hydrothermal syntheses were carried out to test the hypothetical occurrence of zircon exsolution within fayalite from the Évisa complex (Calberg, 2022). Experimental conditions, set at 400, 500, 600, and 700 °C under 1 kbar, did not produce evidence of such an exsolution from the starting compositions. A phase diagram of the zircon–fayalite system is presented, and the possibility of syn-crystallization between the two phases is discussed.

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Potential geochemical reactions induced by hydrogen during UHS in carbonate reservoirs: an exploratory study using equilibrium geochemical modelling

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Underground hydrogen storage (UHS) in geological reservoirs is a promising method to store large amounts of clean energy over seasonal time scales. This could play an important role to

balance supply and demand in renewable energy systems, as electricity could be used to produce and then store green hydrogen at moments when supply exceeds demand. However, the introduction of hydrogen in geological reservoirs during storage may trigger fluid–rock interactions that could compromise reservoir integrity or gas quality over time. This is particularly the case for carbonate reservoirs, such as the Loenhout natural gas storage reservoir in Belgium. In this study, we evaluate whether equilibrium geochemical modelling in PHREEQC can be used to obtain base-level (theoretical) insights into reactions that hydrogen could trigger when brought into contact with saline groundwater and minerals such as calcite, quartz, hydroxyapatite, and pyrite. These minerals were selected based on rock characterization (XRF, XRD, SEM-EDS) performed on rock samples from Loenhout. The samples were also subjected to wettability tests.

Results for monomineral systems indicate minimal hydrogen effects on quartz stability and minor interactions with hydroxyapatite. However, they suggest that pyrite dissolution and reduction may occur, forming pyrrhotite, which could potentially affect reservoir geochemistry through reaction cascades that facilitate sulphide speciation shifts toward HS^- and S^{2-}. These processes appear to be enhanced by elevated hydrogen partial pressures and temperature. For calcite, results obtained with the standard database in PHREEQC suggest that hydrogen addition promotes methane formation and calcite dissolution, generating elevated pH conditions exceeding 13. However, the thermodynamic feasibility of these reactions, particularly carbonate reduction pathways, depends on the presence of catalysts or microbial activity. Furthermore, a decline in hydrogen solubility in calcite-bearing systems is attributed to competing gas-phase occupancy by methane, although this remains speculative given the modelling uncertainties. Polymineral modelling confirms trends observed in monomineral calcite systems but suggests complex mineralogical interactions, where pyrite redox reactions are buffered by calcite dissolution, promoting the precipitation of iron sulphides (pyrrhotite). In conclusion, our work provides an evaluation of the use of equilibrium geochemical modelling to understand geochemical reactions in UHS and their dependence on reservoir conditions. The results indicate the need for further experimental validation to reduce modelling uncertainties.

Sedimentological, palaeoenvironmental and palaeoecological reconstruction of the upper Tielt Formation (Ypresian, Belgium): unexpected resilience of benthic foraminiferal communities in the face of hyperthermal P.

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Among of the many hyperthermals during the ice-free hothouse of the Early Eocene Climatic Optimum (EECO), hyperthermal P (ca 50.8 Myr ago) is one of the more pronounced rapid global climate warmings in the Cenozoic. The effect of this warming event on shallow marine ecosystems has however not yet been identified, nor characterised. Doing so could lead to an improved understanding of global effects of the extreme climate warming which is currently taking place on Earth, something which cannot be simulated in straightforward scientific experiments. Hyperthermal P is practically unstudied in the shallow marine North Sea Basin. In the Ampe quarry (Egemkapel, Belgium), the Tielt Formation (Ypresian, early Eocene) has recently been exposed up to a greater depth, so that it now contains both the Egemkapel clay Member, thought to have been deposited during hyperthermal P, and the upper part of the Kortemark silt Member, representing the pre-hyperthermal conditions. This is a rare opportunity to study large outcrops within this interval and leading to an improved interpretation of its stratigraphy, depositional environment and ecological changes related to the climate perturbation encompassed within. Therefore, here the sedimentological, palaeoclimatological and palaeoecological aspects of the onset and peak of this extreme hyperthermal in the North Sea Basin have been studied.

Sedimentological and foraminiferal data indicate that the Tielt Formation was deposited in a tidally influenced, shallow marine and well-oxygenated palaeoenvironment. Bulk organic stable isotopes and benthic foraminiferal carbonate stable isotopes (from benthic foraminifer *Cibicidoides proprius*) were analysed in high resolution for this study, confirming the position of the hyperthermal. A negative oxygen isotope excursion close to the base of the Egemkapel clay Member suggests a temperature increase of at least 2.5 °C during this event. Nevertheless, analysed communities of benthic foraminifera changed notably little over hyperthermal P, indicating a resilience of the local ecosystem during intense climate change. Minor changes in the foraminifera assemblages seemingly represent local sedimentary facies shifts.

Combining EMP analysis and XRF scanning to fingerprint tephra layers in Chilean lake sediments

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Palaeoseismology aims at reconstructing the history of past earthquakes by analysing the geological record, providing estimates of their magnitude, recurrence intervals, and spatial distribution. Such reconstructions are essential for understanding seismic hazard and improving preparedness for future events. Southern Chile represents an ideal location for palaeoseismological research, as the subduction of the Nazca Plate beneath the South American Plate generates frequent earthquakes alongside intense volcanic activity. This study focused on sediments from Lake Rupanco (40°85'S, 72°27'W), one of seventeen glacially formed lakes in the Chilean Lake District, shaped by piedmont glaciers during the last glacial period. The lake is surrounded by prominent volcanoes, and its sediments record both seismic and volcanic events. Sediment cores taken from Lake Rupanco as well as other lakes in this area contain turbidite layers created by earthquake-related remobilization of sediment, interspersed with tephra layers composed of ash and glass shards created by volcanic eruptions. These tephra layers can serve as chronostratigraphic markers, making it possible to correlate them between lakes and therefore also allow more accurate correlation of earthquake deposits recorded between these layers in the sedimentary infill of

different lakes.

The objective of this research was to investigate the major-element chemical composition, or "fingerprint," of Holocene tephra layers within the Lake Rupanco using electron microprobe analysis (EMPA) on a 12 m long sediment core. Additionally, a comparison between the destructive EMPA methodology and X-ray fluorescence (XRF) core scanning was made with the aim to investigate the potential of non-destructive analyses for future tephrochronology purposes. The conventional EMPA approach was applied to 55 tephra layers from the sediment core, involving subsampling and laboratory analysis. In parallel, XRF core scanning was employed on the entire core as a non-destructive method for measuring chemical composition, providing a faster analysis of the tephra layers with minimal sample preparation while preserving sediment integrity.

Comparison of the EMPA data with published geochemical data from Holocene eruptions of various volcanic centres in southern Chile enabled confident identification of a limited number of tephra layers. The age estimations for these deposits contributed to the refinement of the pre-existing radiocarbon-based Lake Rupanco sediment core age-depth model. The direct comparison between the EMPA and XRF results revealed a weak correlation, suggesting that XRF scanning, with the current applicated methodology and statistics, does unfortunately not yet provide a reliable substitute for EMPA in tephra characterization. This could be explained by the fact that the XRF scanner measures the bulk sediment (including water, carbonates, biogenic silica, and glass shards), resulting in mixed signals compared to the analysis of individual hand-picked glass shards in the EMPA method. However, when the comparison was done using only data derived from well-identified tephra layers, the correlation values were clearly better. These findings indicate that replacing EMPA analysis with XRF has potential, though further investigation is required to establish whether XRF can be effectively applied for high-resolution tephrochronology.

Diagenetic study of the Aubel ETB-14 borehole of the EU-region Meuse-Rhine Einstein telescope

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This Master thesis presents a diagenetic study of the Aubel ETB-14 borehole, located in the Booze-Le Val-Dieu ridge in eastern Belgium, as part of the geological reconnaissance study for the Einstein Telescope project in the EU region Meuse-Rhine. The core penetrates a stratigraphic sequence comprising unconsolidated Cretaceous sediments, Namurian shales, Dinantian carbonates, and Famennian siliciclastics. The research aimed to reconstruct the paragenetic evolution of the Dinantian and Famennian lithologies, inferring the evolution of diagenetic fluids involved, and contextualize the results within the broader geological framework of the region.

Through a combination of petrography, cathodoluminescence, fluid inclusion microthermometry, stable isotope geochemistry, and trace element analysis, a paragenetic sequence was established. A regionally consistent quartz–dolomite–calcite vein assemblage was observed in both the Famennian and Dinantian lithologies, indicating shared diagenetic histories and fluid flow systems, likely linked to the Variscan orogeny. Fluid inclusion data revealed diagenetic phases originated from an evolving brine system with salinities ranging from 18 to 25 wt% $CaCl_2$.NaCl and homogenization temperatures between ~60 °C and 140 °C, consistent with conditions reported in the study region.

This study also suggests early diagenetic deformation in the Famennian lithologies, highlighting mechanical heterogeneity in supposedly homogeneous formations, relevant for the Einstein Telescope project. Overall, the findings provide new insights into the fluid-rock interaction history and structural evolution of the Booze-Le Val-Dieu ridge, reinforcing its status as a geologically coherent and technically promising candidate site for one of the Einstein Telescope's underground nodes within the search region.

Using flow direction indicators in lake sediments to reconstruct lahar channel activation at Villarrica Volcano, Chile

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Lahars are among the most destructive volcanic geohazards, yet their long-term behaviour in response to climatic and volcanic factors remain poorly understood. This study investigates sedimentary deposits from Lake Villarrica and Calafquén, located near Villarrica Volcano, Chile, for detailed reconstructions of channel activation during lahar events. For this, sedimentary flow indicators such as asymmetrical convolutions, cross laminations and erosional marks are evaluated and utilised. Onshore lahar records in the study area became more detailed after 1900 CE. Deposits younger than this can therefore be compared with historical records to interpret the formation of flow structures. Older events are reconstructed through a reversed workflow.

Sediment cores were analysed using medical and micro X-ray computed tomography (CT) to identify flow structures and their vergence in 3D. Detrital remanent magnetisation (DRM) measurements were then used to orient these structures within a geographic reference frame, and additional grain-size analyses were conducted to complement and validate the structural interpretations.

As a result of previous analyses of the cores, two different instruments were used for DRM measurements in for this study: a SQUID type and a USM type magnetometer. The readings revealed up to 71° mismatch between the two magnetometer datasets. These are hypothesised to be caused by signal deflections, sampling deformation, grain reorientation after coring, but most importantly a chemical remanent magnetisation (CRM) overwrite. CT imaging also exposed several interpretive challenges, including indistinct foreset and backset geometries in climbing ripples, conflicting structures within one deposit, and underflow reflections on slopes. Besides the DRM mismatch, these uncertainties further reduce the reliability of palaeoflow indicators in the study area. In contrast, grain-size data showed strong and consistent trends, with coarser grains occurring closer to the onshore lahar source and at greater depths, aligning well with theoretical expectations, onshore lahar records, and prior research in the lakes.

As a result, reconstructions of channel activations prior to 1900 CE are largely based on grain-size evidence. This was conducted for six events ranging from 1575 to 1837 CE. Additionally, a correction was made for the 1920 CE event,

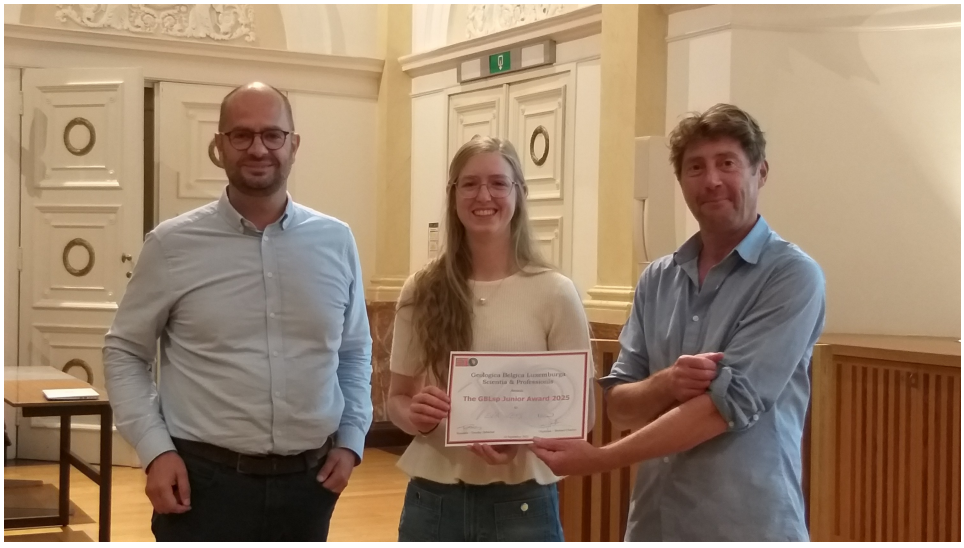
where no lahars were observed onshore, but clear underflow layers are present in the cores of Lake Villarrica.

In order to objectively understand the value of different flow indicators in future studies, an additional quantitative analysis was performed on their plausibility. This shows that cross laminations are the most reliable structure, while around half of the observed asymmetrical convolutions contradict the onshore records.

Overall, the findings in this thesis provide an initial insight into the potential of using flow structures for studying lahar dynamics and channel reconstructions. However, a deeper understanding of the encountered challenges is necessary to reliably apply this approach in future case studies.

The **Geologica Belgica 'Master Day'** is an annual event organised by the scientific association *Geologica Belgica Luxemburga Scientia & Professionis* to give recently graduated students in Geosciences the opportunity to present their Master's thesis research in a competitive inter-university context. The 2025 edition of the 'Master Day' took place on 10 September at the University of Liège, Belgium.

The ten graduates who presented the results of their Master's thesis during the 'Master Day' organized this year at the University of Liège. They came from KULeuven, UGent, and ULiège.



The Master Day award winner, Eva Vets, receiving her diploma from Tim Debacker, president of *Geologica Belgica Luxemburga Scientia & Professionis*, and Bernard Charlier (ULiège).