Modeling the present, past and future of real terrains from in-situ geological annotations

(Masters-level internship, could be extended to a Ph.D.)

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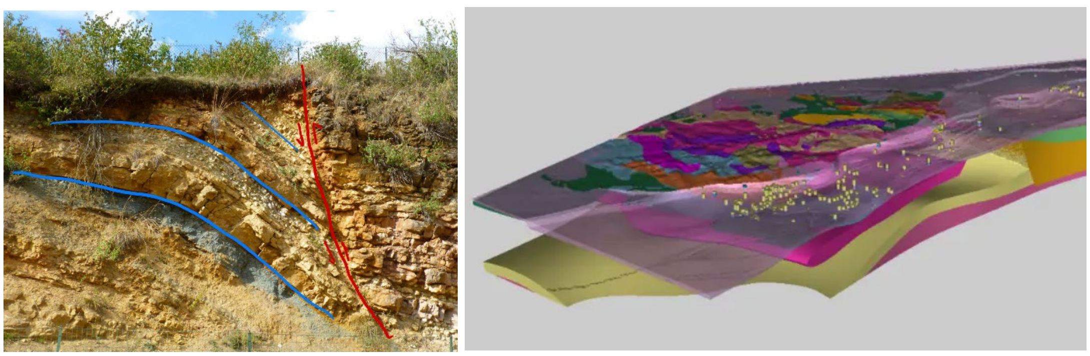

*Figure 1. Geologists sketch notes about subsoils onsite (left). These notes are subsequently used to model the subsoil in 3D (right, @BRGM). Our goal is to lift ambiguities in this process by **modeling the geological events that resulted in the observed structures**.*

Context and goal

One of the fundamental challenges of geology is to understand the soil, the subsoil and its history, which makes it of great importance to society. Mapping the different types of underground rocks is key to an optimal access to water and natural resources. Knowledge of soils and their chemical composition helps ensure the viability of certain plant species, and thus protect biodiversity. Finally, the study of the physics and history of landscapes improves understanding of risks, enabling to anticipate and prevent landslides, floods, coastal erosion.

Geologic knowledge is first acquired in the field. Geologists observe the geometry and composition of the subsoil where rock structures outcrop. They record their observations in field notebooks with sketches, annotations, various notes and measurements, as illustrated in Figure 1a. This information is subsequently analyzed and used to draw up geological maps, and to create 3D models of the subsoil structure (Figure 1b).

However, translating field observations into geologically-consistent 3D models is a tedious manual process. First, experts need to make numerous assumptions and hypotheses to deduce complete underground structures from sparse observations and measurements. Second, existing tools focus on specifying the static 3D geometry of the soil at the time of observation rather than reasoning about the sequence of past geological events (sedimentation, uplift, crustal folding and faulting, erosion) that resulted in this geometry [1].

Our goal is to inform the creation of geological maps by modeling the history of the soil. Accounting for the events that caused specific geological structures will help experts decide among concurrent interpretations of the field observations, will help deduce the geometry of these structures in-between observations, and will allow simulating the evolution of these structures through time, in the past and in the future [2].

Approach

Our long-term goal is to provide a modeling tool that infers past geological events from present observations of the soil structures. Achieving this goal entails several sub-goals, which we plan to explore as part of this internship:

1. Study the most common geological events and formulate constraints that each event implies on soil structures. For example, sedimentation comes from the deposition and solidification of particles transported by fluids (air, rivers, oceans), with the associated constraint that sedimentation only adds material with a flat surface. We will collaborate with the French institute on geology BRGM to perform this study, and build on existing literature on geologic modeling [3,4].
2. Define a spatio-temporal representation of the soil suitable for geometric modeling of the geologic structures and their evolution. Prior work proposed different representations of the static geometry of the soil, including implicit surfaces [5] and heightfields [6]. The key challenge will be to adapt these data structures to model *transformations* of the geometry through geological events.
3. Implement a 3D modeling tool [7] that allows users to create soil structures by sketching the same annotations as they do in field observations. The tool will translate these annotations into geologically-sound structures by enforcing the event-based constraints formulated in 1. on the spatio-temporal representation defined in 2.

In the context of a master-level internship, we will narrow the scope of this research to a small number of geological events (1.), and focus on the definition of the representation adapted to these events (2.). If successful, the internship could be pursued as a Ph.D. to explore all three sub-goals in depth.

Work environment and requirements

The internship will take place at Inria Sophia Antipolis, in the GraphDeco group (http://team.inria.fr/graphdeco). Inria will provide a monthly stipend of around 1400 euros for EU citizens in their final year of masters, and ~600 euros for other candidates.

Candidates should have strong programming and mathematical skills with knowledge in geometric modeling, computer graphics, and experience in Python data science libraries.

References

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