Terra Forma Speculative Mapping: Paris Watershed and Underground Environment

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Abstract
This visual essay discusses an object-map of Paris basin soil and subsoil, commissioned for the *Element Terre* exhibition within the Architecture and Landscape Biennial 2022 (Versailles, France). To create this map, we contacted actors and researchers whose work is related to soil: earth scientists, materials specialists, and human habitat specialists. Using a model from the publication *Terra Forma: A Book of Speculative Maps*, we designed a specific reference system, the 'soil' model, to map entities, movements and conflicts in the underground environment(s). The resulting map aims to reveal what is going on beneath our feet, what is hidden from view, to go beyond representations that are limited to the surface.

Keywords
speculative mapping, Critical Zone, soil, subsoil, Paris

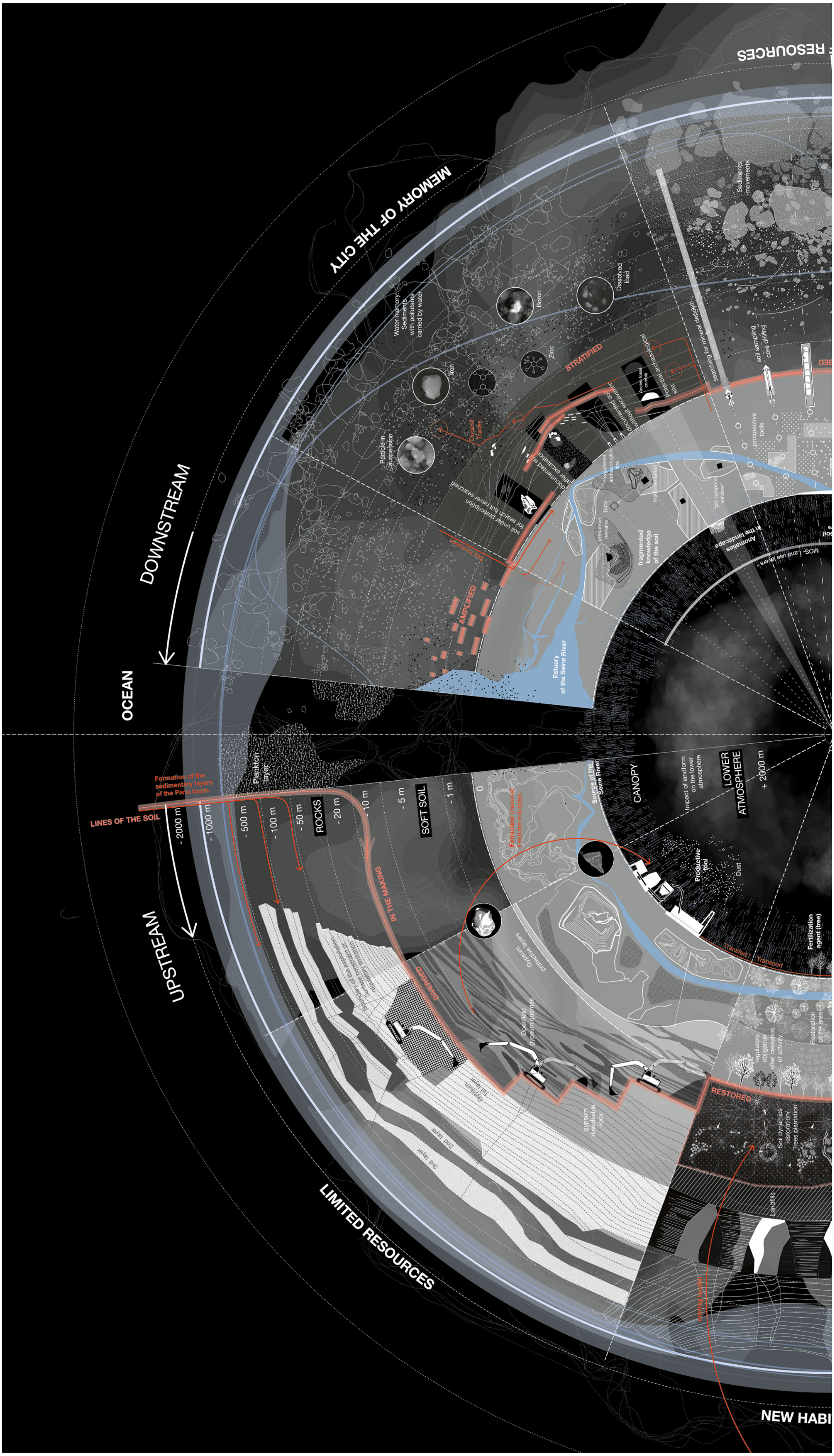
For the Architecture and Landscape Biennial 2022 (Versailles, France), we were commissioned by the Institut Paris Région (the institution in charge of the observatory and development of urban dynamics of Paris metropolis) to produce an object-map of Paris basin soil and subsoil within the *Element Terre* exhibition. To create this map, we contacted actors and researchers whose work is related to soil: earth scientists (geochemists, geophysicists, geologists), materials specialists (quarries, materials companies), and human habitat specialists (planners, archaeologists). The resulting map uses a model from the book *Terra Forma: A Book of Speculative Maps*, which suggests alternative ways of visualising the earth and its (living) elements.[1] We asked: is the territory in which we live sufficiently described, known and represented to meet the challenges of the environmental crisis? We think that current maps don't help us to understand and respond to this crisis, for a variety of reasons linked to the way and the historical context in which they were created.

We designed a specific reference system, the 'soil' model, to map entities, movements and conflicts in the underground environment(s). It aims to reveal what is going on beneath our feet, what is hidden from view, to go beyond representations that are limited to the surface. This projection moves away from the traditional planisphere to reveal the complexity of the critical zone (thickness, interactions with the surface, diversity of inhabiting entities). The globe is turned inside out to place the atmosphere at the centre of the map. The atmosphere is surrounded by concentric layers of soil. These are themselves surrounded and limited by the deeper rocks that form the peripheral edge of the map. In this way, there is no longer any outside; the earth is limited both above and below: we must live, build and feed ourselves within this thickness of a few metres.

Close-up of the soil map

The ground, and its depths, are often under-represented in the collective imagination, but also in that of the construction industry. Considered as a 'stable' surface on which to build, its components are neglected. Yet the ground is alive, and it is also the scene of transformations that will have an impact on life above ground. Soil and its resources are also the subject of speculation and disputes. The soil is an area to be defended, not just horizontally, but – and this is what we propose to explore here – vertically. In order to map the Anthropocene, we need to acknowledge the heterogeneous composition of these soils: inhabiting organisms, hosted objects. The understanding of the urban soil varies according to the actors: ground is either a hazard when cavities threaten to collapse, or a place where geochemical cycles are disturbed, or a cement layer (stopping the circulation of water), or a repository of ancient buried civilizations, or an abandoned entity to be exploited, a source of raw materials, a source of heat, and so on.

Fig. 1: Close-up of the soil map. Map: authors.


RESOURCES
MEMORY OF THE CITY
DOWNSTREAM
OCEAN
UPSTREAM
LIMITED RESOURCES
NEW HABI
LINES OF THE SOIL
Formation of the sedimentary layers of the Paris basin
- 2000 m
- 1000 m
- 500 m
- 100 m
- 50 m
ROCKS
- 20 m
- 10 m
- 5 m
SOFT SOIL
- 1 m
0
Source of the Seine River
CANOPY
Impact of landform on the lower atmosphere
LOWER ATMOSPHERE
+ 2000 m
Plankton layer
IN THE MAKING
STRATIFIED
AMPLIFIED
RESTORED
Estuary of the Seine River
fragmented knowledge of the soil
Water memory: Sediments with pollutants carried by water
Particle in suspension
Iron
Zinc
Boron
Dissolved load
Sediments movements
soil sampling core drilling
prospective tools
Anomalies in the landscape
MOS - Land use layers
Productive soil
Dust
Fertilization agent (tree)
Transfert / Transport
Restoration of the area
regulatory obligation after cessation of activity
Soil dynamics restoration: trees plantation
2nd layer
3rd layer

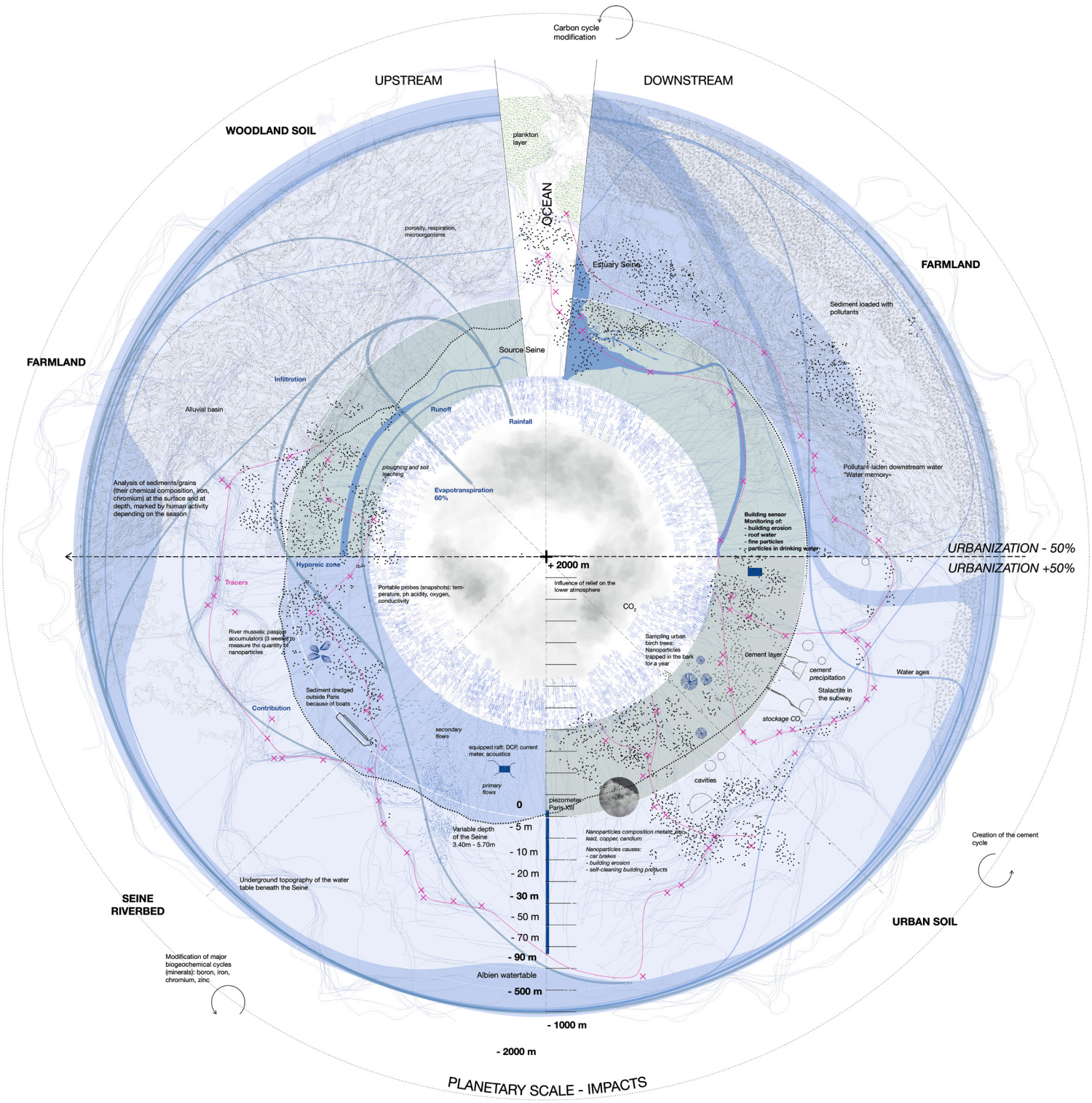
Water map: geoscientists' view of the Paris watershed
We had first a workshop with the geoscientists, which led to a 'watery' view of the soil, as the grains of the soil bond with water. However, the dragging of sediments outside the city disturbs the morphology and chemical composition of the riverbed. As a geochemist told us during the workshop, the relationship between soil and water is complex and requires further research:

> The Seine doesn't just collect surface water; there is also water that reaches the Seine from below, which can take a very long time. We need to sample the water table at its deepest levels. These waters are of different ages. The Seine is really a collection of something that has been everywhere. A real exploration.[2]

Water transports potential pollutants. It ages and has memory, it takes the chemical composition of the upstream city, the nanoparticles, pollutants, materials and so on, downstream. Water at the surface and at greater depth is studied, but we don't know its paths very well, especially at depth and in the city, where the connection between surface and depth is cut off. Then, in the city, another cycle is created with the reaction of water, carbon dioxide and concrete, which doesn't exist in the natural world: the cycle of cement.

As a result, the workshop and the map concluded that much more research is needed to monitor cities to understand the urban environment. The geoscientists we worked with during the workshop raised the idea of constructing a 'long term sensor building' to monitor the chemical fluxes, the reactions between water, air, heat, and the chemical residue of building materials.

Fig. 2: Water map: geoscientists' view of the Paris watershed. Map: authors.

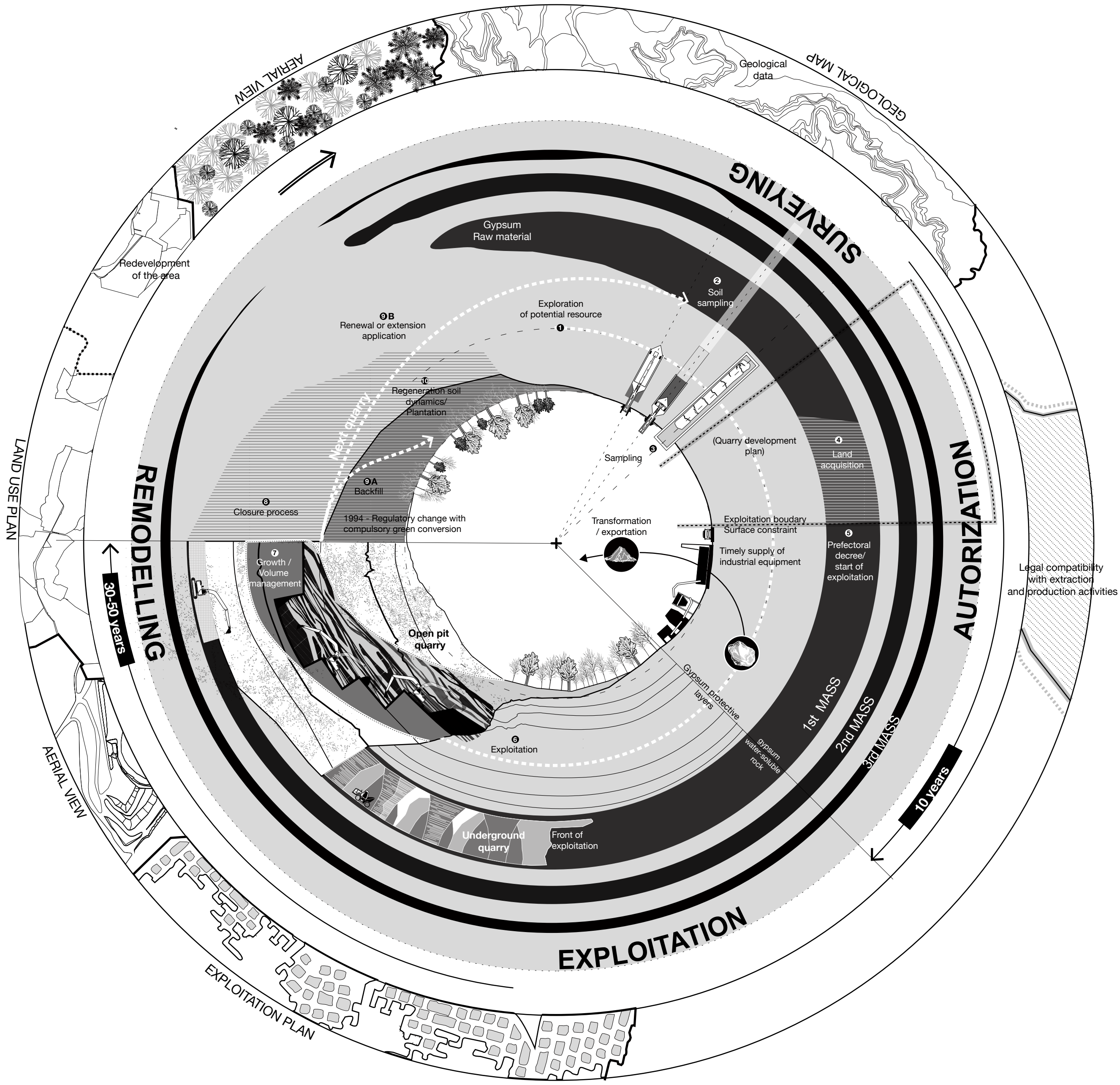

Carbon cycle modification
UPSTREAM
DOWNSTREAM
WOODLAND SOIL
plankton layer
OCEAN
porosity, respiration, microorganisms
Estuary Seine
FARMLAND
Sediment loaded with pollutants
FARMLAND
Source Seine
Infiltration
Alluvial basin
Runoff
Rainfall
ploughing and soil leaching
Evapotranspiration 60%
Analysis of sediments/grains (their chemical composition, iron, chromium) at the surface and at depth, marked by human activity depending on the season
Pollutant-laden downstream water "Water memory"
Building sensor Monitoring of:
- building erosion
- roof water
- fine particles
particles in drinking water
URBANIZATION - 50%
URBANIZATION +50%
+ 2000 m
Hyporeic zone
Tracers
Portable probes (snapshots): temperature, ph acidity, oxygen, conductivity
Influence of relief on the lower atmosphere
CO_2
River mussels: passive accumulators (3 weeks) to measure the quantity of nanoparticles
Sampling urban birch trees: Nanoparticles trapped in the bark for a year
cement layer
cement precipitation
Water ages
Stalactite in the subway
Sediment dredged outside Paris because of boats
Contribution
stockage CO_2
secondary flows
equipped raft: DCP, current meter, acoustics
primary flows
cavities
0
piezometer Paris-XIII
Variable depth of the Seine 3.40m - 5.70m
- 5 m
- 10 m
- 20 m
- 30 m
- 50 m
- 70 m
- 90 m
Albien watertable
- 500 m
Nanoparticles composition metals: zinc, lead, copper, candium
Nanoparticles causes:
- car brakes
- building erosion
- self-cleaning building products
Creation of the cement cycle
Underground topography of the water table beneath the Seine
SEINE RIVERBED
URBAN SOIL
Modification of major biogeochemical cycles (minerals): boron, iron, chromium, zinc
- 1000 m
- 2000 m
PLANETARY SCALE - IMPACTS

The quarry life cycle

This map integrates the interviews we conducted with planning actors such as managers of quarries (of gypsum, alluvial deposits). It raises issues related to exploitation and risk such as holes in the ground, displacement of land, and the controversial shortage of materials, as construction is expanding rapidly while quarries have a lifespan that will come to an end in the coming decades. Indeed, as an interviewee from the Paris-region quarry association reminds us, 'aggregates are the second-most used resource after water'.[3]

We map gypsum quarries, digging deep down, opencast or underground, and alluvial deposit quarries in the riverbed, the different layers of rock left bare, the holes left and the filling in of quarries (becoming feral infrastructures), but also what is considered new resources, new frontiers at depth: geothermal energy or CO_2 storage, which could lead to even deeper exploitation of soil. The materiality of this same soil – of the Paris basin – changes drastically compared to the one described by the geosciences: it is a more solid material into which we can dig to extract matter because this soil is already full of holes and poses the risk of collapsing. Controversially, the quarries exploit the river sediments that the scientists are concerned with.

Fig. 3: The quarry life cycle. Illustration: authors.

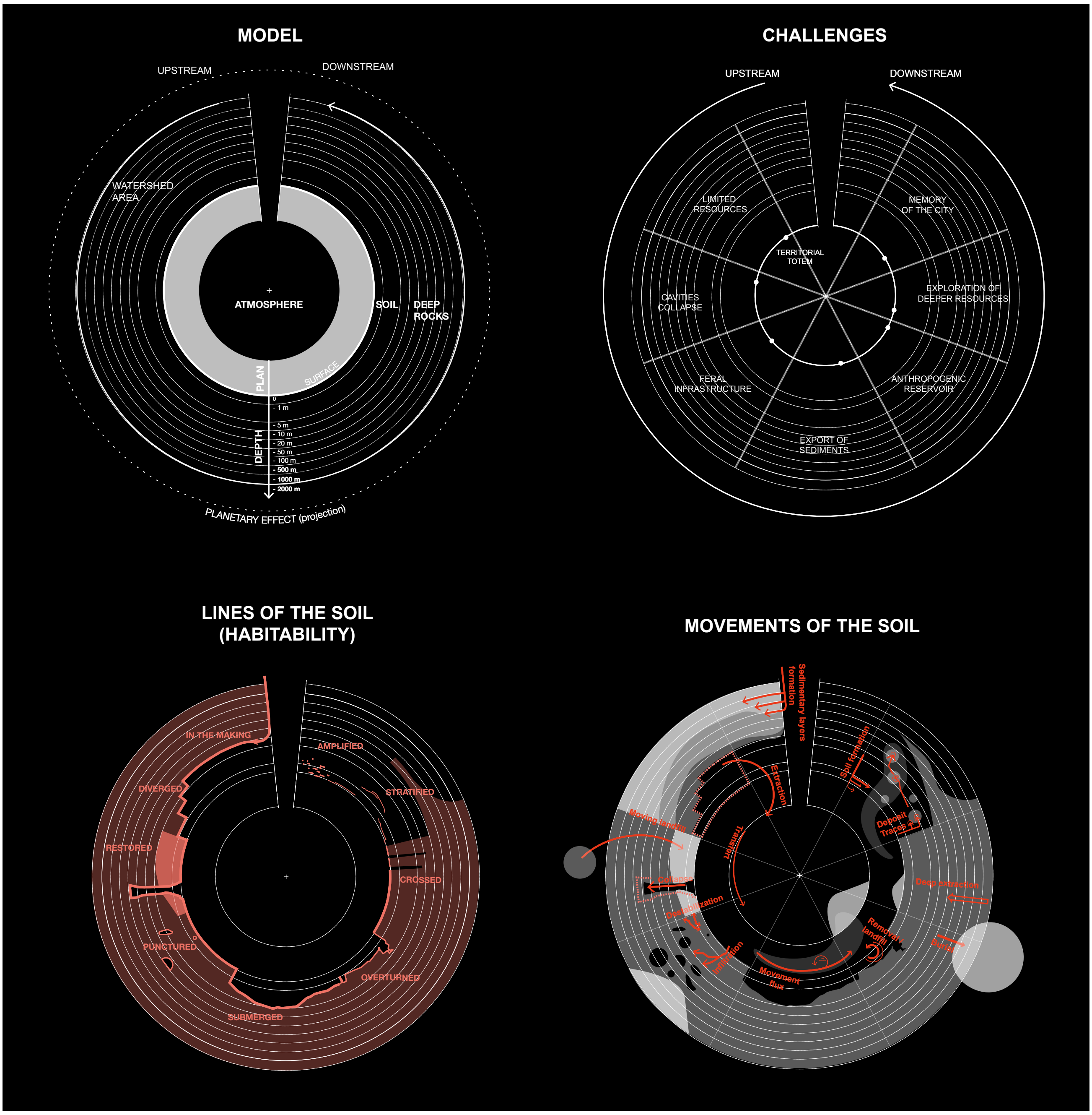

AERIAL VIEW
GEOLOGICAL MAP
Geological data
SURVEYING
Gypsum Raw material
Redevelopment of the area
Soil sampling
Exploration of potential resource
Renewal or extension application
Regeneration soil dynamics/ Plantation
Next quarry
(Quarry development plan)
Land acquisition
Sampling
Backfill
Closure process
1994 - Regulatory change with compulsory green conversion
Transformation / exportation
Exploitation boudary Surface constraint
Timely supply of industrial equipment
Prefectoral decree/ start of exploitation
AUTORIZATION
Legal compatibility with extraction and production activities
LAND USE PLAN
REMODELLING
30-50 years
Growth / Volume management
Open pit quarry
Gypsum protective layers
gypsum water-soluble rock
1st. MASS
2nd MASS
3rd MASS
10 years
Exploitation
Underground quarry
Front of exploitation
AERIAL VIEW
EXPLOITATION
EXPLOITATION PLAN

Schemes of the construction of the map

This map explores the different depths at which soils are inhabited to identify where and to what extent the imprint of human activities is located. What we are particularly interested in, shown in red on the map and the diagrams, is the movement of the soil. Which soils are being moved? Which layers? How does this impact on soil composition? What is the impact on local and remote areas? This line shows the type of movement generated.

The ground line, which we are used to seeing as a flat horizon, is in fact a moving line, diverged, punctured, stratified, or submerged, and so on. It is a multi-layered line, with many variations, evolving over time as many events occur.

Fig. 4: Schemes of the construction of the map. Schemes: authors.


MODEL
UPSTREAM
DOWNSTREAM
WATERSHED AREA
ATMOSPHERE
SOIL
DEEP ROCKS
PLAN
SURFACE
DEPTH
0
- 1 m
- 5 m
- 10 m
- 20 m
- 50 m
- 100 m
- 500 m
- 1000 m
- 2000 m
PLANETARY EFFECT (projection)
CHALLENGES
UPSTREAM
DOWNSTREAM
LIMITED RESOURCES
MEMORY OF THE CITY
TERRITORIAL TOTEM
CAVITIES COLLAPSE
EXPLORATION OF DEEPER RESOURCES
FERAL INFRASTRUCTURE
ANTHROPOGENIC RESERVOIR
EXPORT OF SEDIMENTS
LINES OF THE SOIL (HABITABILITY)
IN THE MAKING
AMPLIFIED
DIVERGED
STRATIFIED
RESTORED
CROSSED
PUNCTURED
OVERTURNED
SUBMERGED
MOVEMENTS OF THE SOIL
Sedimentary layers formation
Soil formation
Extraction
Moving landfill
Transfert
Deposit Traces
Collapse
Deep extraction
Destabilization
Removal / landfill
Burial
Infiltration
Movement flux

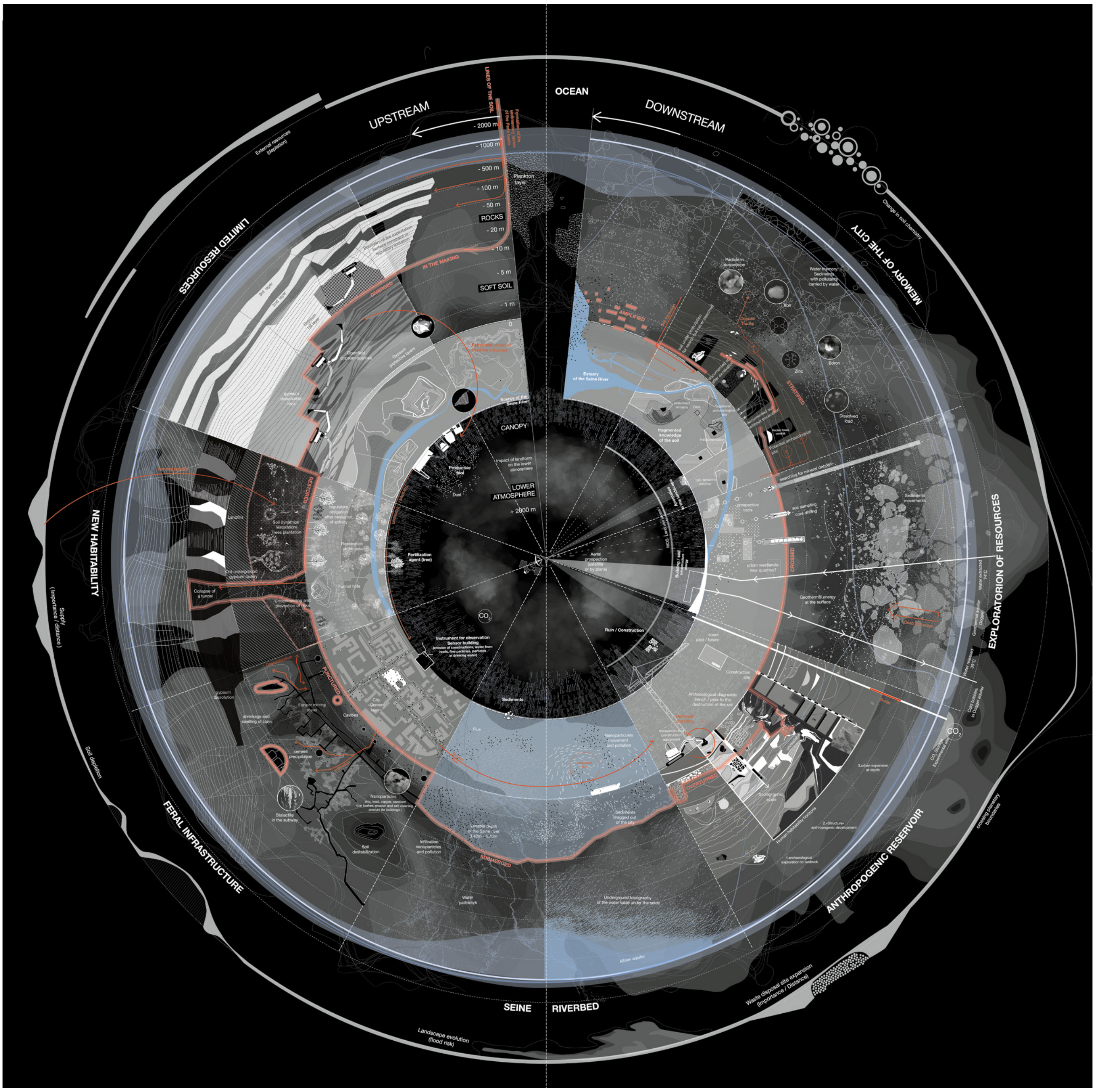
Soil map

This experience led to a broader reflection on how to reposition the city in its watershed, and in its underground environment, and thus to include in the understanding of the city previously excluded elements such as mines, quarries, underground water, what could be called environmental logistics. The map also highlights the impact of these elements at depth, which in fact establishes a connection between upstream and downstream. Because there is connectivity at depth, everything is linked, even if this is not obvious on the surface.

Thanks to the map's specific metric and frame of reference, it is possible to visualise these elements with the granularity needed to understand them. In other words, the map shows what the city depends on (which is too far away to be seen on maps using conventional metrics). In this case, the distances are compressed because we are using a different reference system aiming to look at the soil at depth over the entire perimeter of the watershed – the unit that enables the city to subsist. This would not have been possible without this interdisciplinary approach.

Our ambition was also to contribute to or co-construct, through collective design, a definition or understanding of the critical zone (a term that is relatively new): what is the critical zone? Is there a shared understanding of the critical zone? What are the common elements? Or those that are irremediably different and sometimes conflicting?

Fig. 5: Soil map. Map: authors.


OCEAN
UPSTREAM
DOWNSTREAM
LIMITED RESOURCES
MEMORY OF THE CITY
NEW HABITABILITY
EXPLORATORION OF RESOURCES
FERAL INFRASTRUCTURE
ANTHROPOGENIC RESERVOIR
SEINE
RIVERBED
- 2000 m
- 1000 m
- 500 m
- 100 m
- 50 m
ROCKS
- 20 m
- 10 m
- 5 m
SOFT SOIL
- 1 m
CANOPY
LOWER
ATMOSPHERE
+ 2000 m
Landscape evolution
(flood risk)
Soil depletion

Workshop at the biennial

This map shows the methods of tracing, observing or learning about or exploring the ground used by the various actors. The map shows the technical and scientific instruments that are used to explore this invisible underground world.

A workshop organised during the biennial gathered actors who are not used to collaborating or exchanging views, because of professional or institutional boundaries.[4] We built an assembly concerned with sharing the problems, which obliged all participants to go beyond normative or institutional statements. The map acts as a 'boundary object', questioning the habitability of the territory in a situated and pragmatic way: what can prevent or favour habitability, and thus detecting the contradictions inherent in the planning processes. Our map makes entities (inhabiting organisms and objects housed in the soil, rock or atmosphere) and processes (cycles, water and sediment paths, land movements) visible that are missing from conventional maps, but also from our traditional thought patterns. Thanks to the multiplication of frames of reference, issues and entities raised by each actor a cosmopolitical space for the Paris watershed is gradually composed.

Fig. 6: Workshop at the biennial. Photos: authors.


RÉSERVOIR ANTHROPIQUE
RESSOURCES EXPLORATOIRES

Notes

1. The soil map of the Paris watershed is the result of a study supported by the IdEx Université de Paris (ANR-18-IDEX-000), Centre des Politiques de la Terre and Paris Region Institute for Architecture Biennial. The workshop with the geoscientists of the Institute of Physics of the Globe was conducted in June 2021, with Jérôme Gaillardet (geochemist), Julien Bouchez (geochemist), Pascale Louvet (geochemist), Eric Gayer (geochemist), Marc Benedetti (geochemist) and François Métivier (geophysicist). Interviews with the quarries companies were conducted in February 2022. Participants: Eric Gomez (Director BRGM), Gilles Bouchet (Syndicat National des Industries du Plâtre), Etienne Fromentin (Unicem). Frédérique Aït-Touati, Alexandra Arènes, Axelle Grégoire, *Terra Forma: A Book of Speculative Maps* (MIT Press, 2022).
2. Julien Bouchez (geochemist at the Institut of Physics of the Globe), comment in a workshop hosted by SOC, IPGP Paris, 18 June 2021.
3. Eric Gomez (Regional Director Ile de France at BRGM), interviewed by the authors, 4 February 2022.
4. Workshop hosted during the Biennale in the exhibition space and conducted by SOC participants : Emmanuelle Blondeau (landscape studio TER), Virginie Crenn (GSM granulats), Ludovic Faytre (Institut Paris Région), Jérôme Gaillardet (IPGP), Laurie Gobled (Institut Paris Région), Eric Gomez (BRGM), JM Guihaume (Syndicat National des Industries du Plâtre), Thierry Hauchard (GSM Granulats and UNICEM) and Sophie Mambrini (Placoplatre Firm).

Biography

SOC (Société d'Objets Cartographiques) was co-founded by Alexandra Arènes, Axelle Grégoire and Soheil Hajmirbaba. The studio conducts research involving a network of actors from various disciplines with the aim of encouraging exchanges between the arts, sciences and architecture. Alexandra and Axelle wrote *Terra Forma: A Book of Speculative Maps* (MIT Press, 2022). Alexandra is Doctor in Architecture (University of Manchester, 2022). In collaboration with scientists from the Critical Zone, she develops maps of the earth's cycles: Gaïa-graphy. Axelle is an architect and doctoral student at the Muséum National d'Histoire Naturelle. She develops projects that contribute to renewing the representation of territories.