WHEN TERRESTRIAL AND MARINE ECOLOGISTS MEET:

Using complementary methods (X-ray tomography and luminophores) to study earthworms bioturbation in an organic matter compartmented soil

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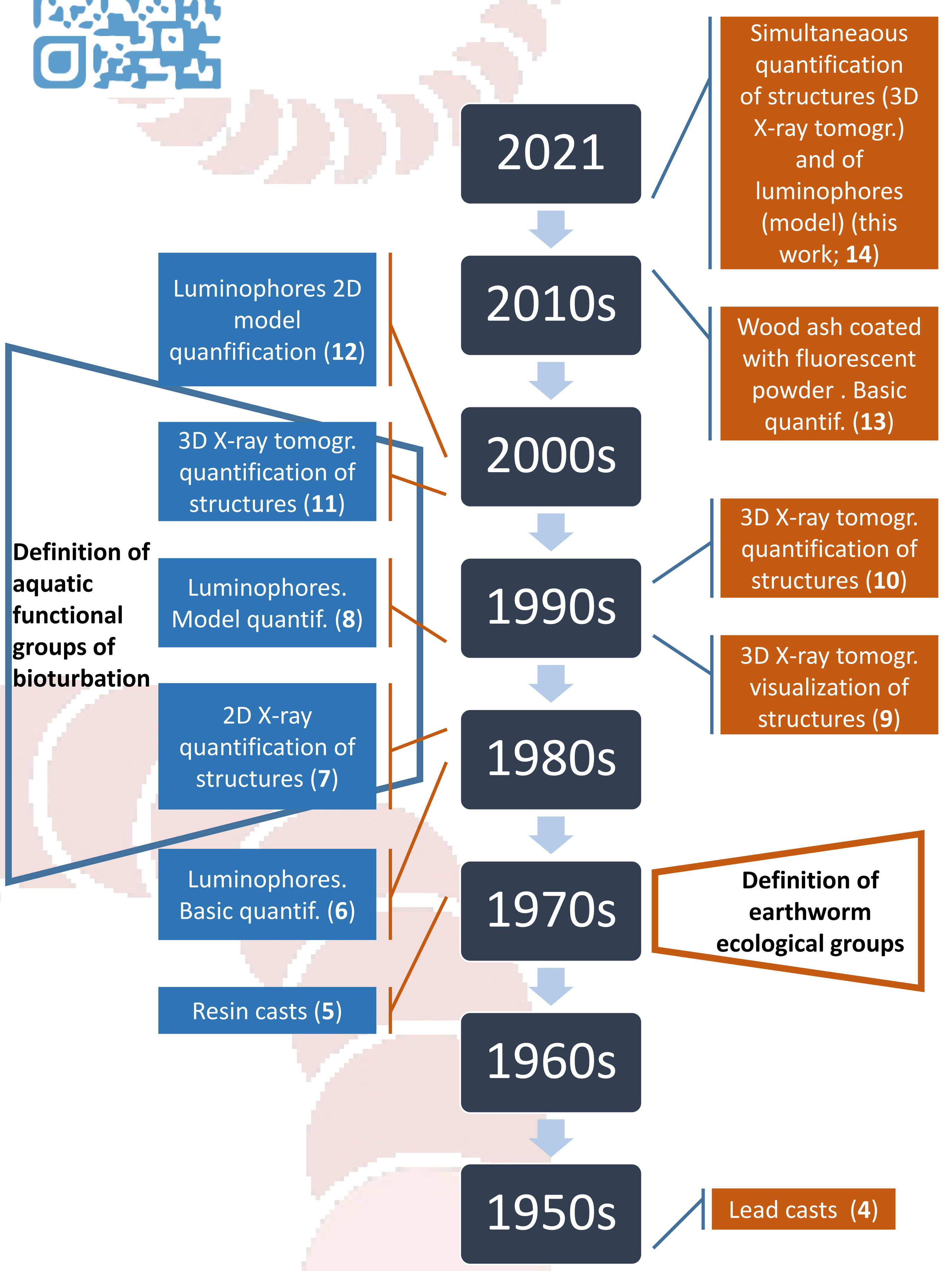

*Fig. 1. Timeline presenting initial published major methodological developments in the study and quantification of actual biogenic structures and particle mixing bioturbation (using fluorescent tracers) in terrestrial and aquatic ecosystems. Luminophores are fluorescent inert sand particles (**3**). Any error in the timeline would be fortuitous and beyond the control of the authors.*

Some historical background to begin (Fig. 1) : until very recently soil ecologists studying the effects of earthworms on soil were focussing on the earthworm biogenic structures aspect. Aquatic ecologists, and more especially in marine environments, have investigated biogenic structures too. However, in the same time, using different particulate tracers and developing numerical transport models, they also put a significant effort in the quantification of reworking (i.e. the movement of particles as defined within bioturbation). This allowed defining functional groups of bioturbation (see update of the classification, **1**) when earthworms are since 1971 so far only classified in ecological groups (**2**). Recently, we decided to test the complementarity of the luminophores and 3D X-ray tomography techniques to study earthworms bioturbation in an organic matter compartmented soil.

In order to do so, soil columns were built of two soil layers (0–15 and 15–30 cm at 4 and 2% organic matter content, respectively) and of three discrete layers (about 1 mm thick) of fluorescent inert tracers (luminophores; 10 g of 63–125 µm tracers) (Fig. 2). To mimic monospecific communities, about 6 g of each earthworm species (two endogeic and two anecic species; Fig. 3) were added at the surface of six soil cores. The following experimental steps are presented in Figure 2.

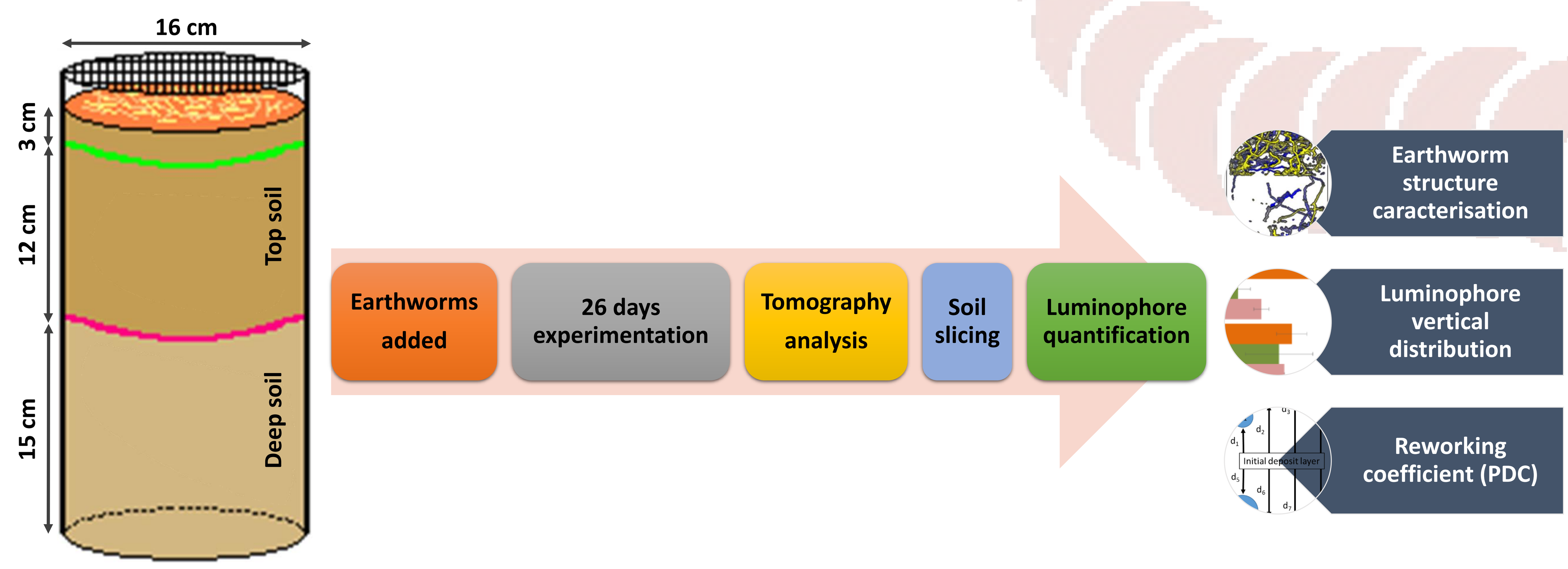

Fig. 2. Sequential steps of the experiment carried out at 16°C and 60% humidity in a controlled dark room, after the construction of soil columns including the luminophore deposition at three different depths.

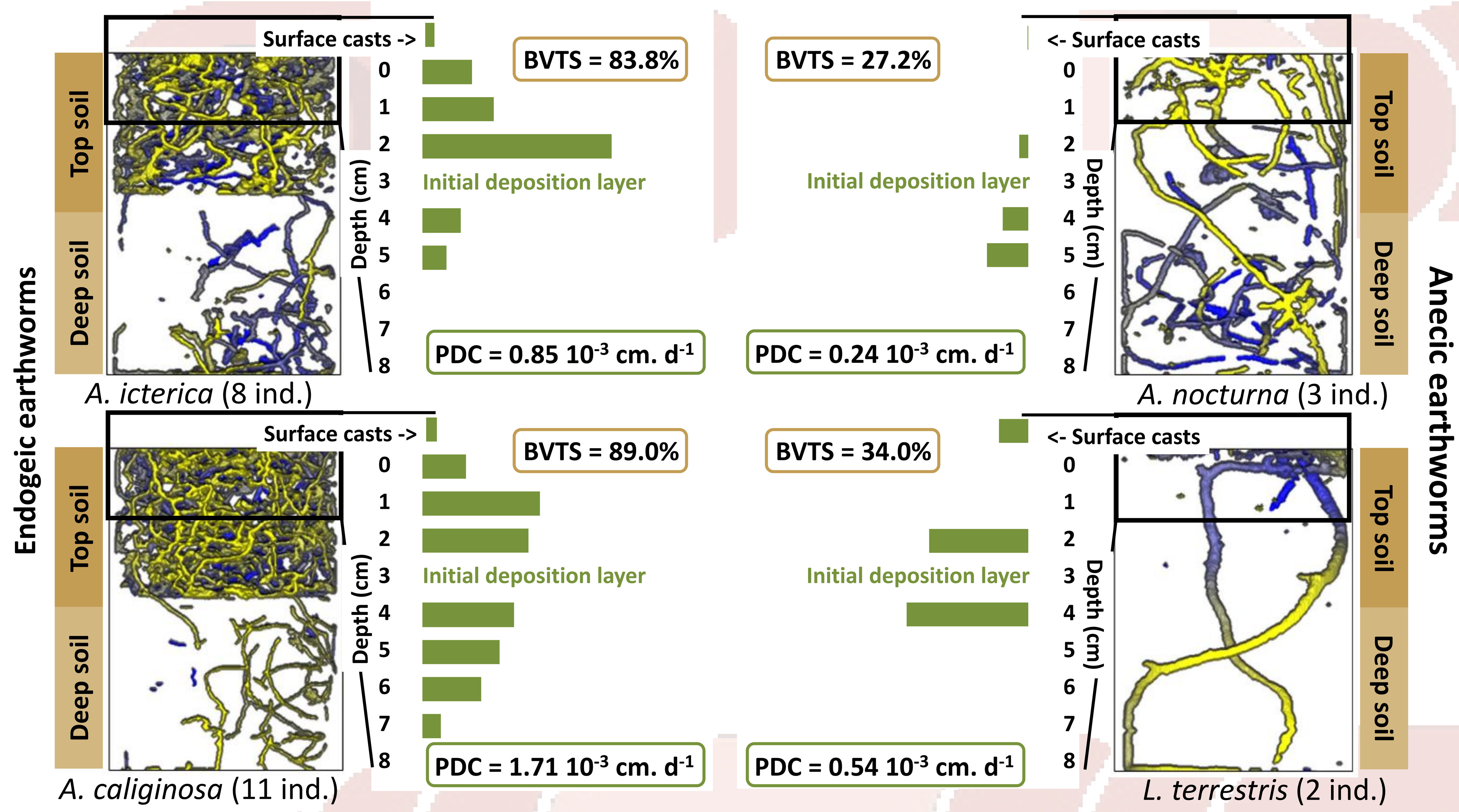

Fig. 3. Examples of burrow systems of the four species in the experimental soil cores. Colours are provided for 3D rendering (yellow and blue in the foreground and background, respectively). Mean burrow volume in the top soil (%; BVTS). Mean vertical distribution of luminophores in the casts and soils around the deposition layer after 26 days and corresponding computed particle displacement coefficient (PDC). For a better poster reading, only the results obtained with intermediate green tracers at maximum distributed down to 7 cm depth are presented here.

Endogeic earthworms burrowed more in zones with higher organic matter contents and this explains why they are mainly found close to the soil surface in non-tilled soils.

Luminophore displacements indicated that: (i) endogeic species and especially *Aporrectodea caliginosa* bioturbated the most soil close to the surface and (ii) the two anecic species influenced the luminophore distribution differentially with *Lumbricus terrestris* displacing significantly more luminophores (whatever their initial depth) than *Aporrectodea nocturna* due to its intense surface cast activity.

The luminophore technique can be a useful tool by itself but also a significant complement to X-ray tomography methods for understanding earthworm behavior since it provides information on soil layer mixing, bioturbation intensity, and the origin of surface casting.

Finally, as in aquatic ecology, the use of particle tracers in soil bioturbation studies appears to be a promising tool for the identification of soil bioturbation functional groups.

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