Conclusion

The results presented in this volume span almost fifteen years, inviting a retrospective look not only at the scientific developments themselves, but also at the conditions under which this work was carried out.

Over this period, the way research is funded has become the subject of increasing scrutiny within the scientific community. A growing body of literature has pointed to the limitations of project-based funding systems, which, while fostering competition and accountability, also tend to favor short-term, low-risk, and highly structured research. In such a framework, scientific agendas may become subtly shaped by external priorities, and the time required for deep, exploratory work is often constrained.

These trends raise fundamental questions about the conditions under which scientific knowledge can most effectively develop. Many of the processes explored in this volume, whether related to deformation, diffusion, or phase transformations, unfold over long timescales and involve mechanisms that are difficult to access experimentally or to model. Understanding them requires not only sophisticated tools, but also time: time to explore, to question assumptions, and to revisit interpretations.

In this context, funding schemes that prioritize scientific freedom and long-term vision play a crucial role. By supporting investigator-driven research and encouraging high-risk, high-gain approaches, they create the conditions for advances that cannot be planned in advance. The European Research Council has been instrumental in this respect, providing a framework in which curiosity-driven science can thrive.

This perspective echoes words written by Jean Perrin in 1937[1]:

"En sorte que, par un retour singulier, l'intérêt pratique le plus pressant du pays est de favoriser la recherche pure, poursuivie pour sa seule valeur intellectuelle ou artistique."

Nearly a century later, this statement remains remarkably relevant. It captures with striking clarity the idea that the most transformative scientific advances often emerge not from immediate objectives, but from the freedom to explore fundamental questions over time.

This is not merely a general statement. Over the course of this project, several themes that eventually proved to be central, such as pure climb creep or stress-induced amorphization, were not part of the initial proposal. Their emergence was the result of a progressive exploration, guided by observations and intermediate results rather than predefined objectives. Such developments would have been difficult, if not impossible, within a more constrained framework.

Beyond funding mechanisms alone, however, the structure of the scientific community itself also plays a critical role. Mineral physics remains a relatively small field within the geosciences, in terms of the number of researchers and the overall critical mass available to address its challenges. Yet the questions it seeks to answer are of comparable complexity to those tackled in much larger disciplines, such as materials science. This creates a

[1] "Thus, by a singular reversal, the country's most pressing practical interest is to support pure research, pursued for its own intellectual or artistic value."
Quoted in: Fernand Lot, "La Vie scientifique", Revue des Deux Mondes, article on the Palais de la découverte, p. 445. A note in the text indicates that this passage is from a text by Jean Perrin written in 1937 and later published in La Science et l'Espérance (Paris: Presses Universitaires de France).

structural asymmetry: while the scientific problems are equally demanding, involving, for instance, the coupling of processes across multiple scales, the collective resources available to address them are far more limited.

This contrast is further amplified by the broader ecosystem in which these disciplines evolve. Materials science benefits from substantial and sustained investment, often driven by strong industrial interests, which support the development of advanced methodologies, large collaborative efforts, and ambitious multiscale approaches. In mineral physics, by contrast, such resources are more limited, and comparable developments must often be carried out within smaller teams and with fewer dedicated infrastructures.

This is particularly evident in the development of multiscale modeling strategies. In fields with a large critical mass, the different scales, from atomistic simulations to macroscopic behavior, can be addressed by specialized communities working in concert. In smaller fields, these connections must often be built progressively, sometimes within a single research group, requiring continuity, persistence, and a long-term perspective.

In this context, the ability to pursue sustained, exploratory research becomes even more essential. It allows the gradual construction of coherent frameworks in which experimental observations, theoretical models, and numerical simulations can be integrated across scales. More broadly, it highlights the importance of maintaining research environments in which ambition is not constrained by immediate structural limitations, but supported by time, continuity, and intellectual freedom.

The work presented in this volume has benefited directly from such conditions. It illustrates how, even within a relatively small community, sustained effort and methodological diversity can converge to shed new light on the physics of minerals across scales. More generally, it serves as a reminder that scientific progress depends not only on ideas and techniques, but also on the conditions that allow them to emerge.

Among these conditions, the collective dimension of research is essential. The advances described here are the result of the combined efforts of many individuals, bringing together complementary skills, perspectives, and approaches. The diversity of backgrounds, expertise, and scientific cultures within the projects has been a constant source of enrichment, enabling questions to be addressed from multiple angles and fostering the emergence of new ideas. In this sense, this work is not only the outcome of a scientific approach, but also of a shared endeavor.

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