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► **To cite this version:**

Jérôme Denis, David Pontille. Material fragilities. Revue d'Anthropologie des Connaissances, 2023, 17 (4), <https://journals.openedition.org/rac/31276>. <10.4000/rac.31276>. <halshs-04319209>

**HAL Id: halshs-04319209**

**<https://shs.hal.science/halshs-04319209v1>**

Submitted on 22 Dec 2023

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# Material Fragilities

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*Revue d'Anthropologie des Connaissances*  
2023, vol. 17(4), <https://journals.openedition.org/rac/31276>

## **Abstract**

This introductory article shows how the prism of fragility can be used as a way to conceptually and empirically further the research work that has foregrounded the material part of human societies by focusing on the agency of artifacts and the strength of matter. It discusses the relevance and limits of fragility as a notion, starting with its conception in materials science which is notably based on the idea of external constraint. It then demonstrates, drawing on the articles of the special issue, that another conception of material fragility is possible, which opens up the way to an investigation of the sociomaterial interdependencies that contribute to holding things together. Because it does not pin down things to the sole concern for shock and loss, material fragilities can be conceived, and practiced, as generative.

## **Keywords**

agency • fragility • new materialism • materials • maintenance

The role of artifacts in organizing and developing human activities has been at the core of numerous studies in the social sciences and humanities. Alongside Leroi-Gourhan, who never ceased to make the study of technology and its evolution a human science in its own right (Schlanger, 2023), Marx and Foucault's thoughts were key in different streams of research in history, anthropology, geography or sociology prone to give a prominent analytical place to objects, from the most mundane to the most complex ones (Mukerji, 2015). In the late 1980s and through the 1990s, the interest in the material part of the world was renewed and crystallized in science studies, as a vigorous response to the "linguistic turn" which had ruled the domain for years (Pickering, 2010). Initially inspired by ethnographic work that highlighted the pivotal role of instruments in the production of scientific knowledge (Knorr-Cetina, 1981; Lynch, 1985; Latour & Woolgar, 1986), curiosity for artifacts has been amplified by the shift from the study of science to that of technology (Woolgar, 1991). The almost simultaneous rise of similar concerns in anthropology (Gell, 1996), urban studies (Cronon, 1991), philosophy (Verbeek & Kockelkoren, 1998) and organization studies (Orlikowski, 1992) has been described, beyond disciplinary specificities, as a "material turn".

More recently, the material part of the world has been examined afresh by a series of studies that have usually fallen under the umbrella of "new materialism". While the first "turn" focused on the involvement of objects in the lives of human beings, highlighting their political and moral significance (Winner, 1980; Akrich, 1987; Latour, 1996b; Gell, 1998; Pickering, 1995), this research stream seeks to move away from the tropism of human action. In line with Deleuze and Guattari (1980) and Whitehead (1978), they describe the unpredictability of self-organization processes and the inherent creativity of matter at work in both human and non-human life, far beyond the scope of technical objects (DeLanda, 2006; Barad, 2007; Bennett, 2010; Clark & Szerszynski, 2021).

Beyond their major differences, and the countless debates and criticisms to which they have been exposed, these two analytical movements, barely sketched out here, do share a common feature: they consider matter in a "positive" approach (Ingold, 2013), focusing almost exclusively on its solidity and strength. When breakdown or failure is mentioned, it is essentially from a Heideggerian perspective, so as to insist on the epistemic virtue of the provisional disruptions they provoke, but not to consider fragility as a form of presence of things in the world (Denis & Pontille, 2023).

This is as if the claimed openness of whole research areas in the humanities and social sciences to a physicality that goes beyond anthropocentrism and challenges the dualisms inherited from modern science could only be achieved provided that all signs of precariousness or degradation were left aside, excluded from theoretical demonstrations as well as empirical descriptions. Yet, aging, erosion, wear and tear and corrosion are ordinary, mundane phenomena, and we can assume that they form a common experience for human beings, although their consequences and understanding greatly differ from one situation to another. How to account for this absence? And, above all, what can we learn from exploring forms of material fragility? This thematic issue aims to provide some answers to this question.

## **Materialisms and agency**

The lack of an overt interest in fragility by studies on the political role of artifacts, as well as in those investigating matter's own organizing capacities, owes much to the fact that these

two movements share, beyond the diversity of perspectives and cases, one main issue: that of agency and its boundaries. This is the very explicit aim of the studies which, at the end of the 1980s and during the following decade, made a plea for the inclusion of objects of all kinds, from the most mundane to the most imposing, in the description of the “social” (Winner, 1980; Akrich, 1987; Latour, 1996b; Gell, 1998; Pickering, 1995). Far from merely arguing for the addition of a material background to the landscape of human relations, such material semiotics aimed to understand the participation of technical objects in human life by investigating “the ‘doing’ of things” (Hennion, 2015), by acknowledging the range of actions in which they play a part (Akrich & Latour, 1992). As a result of translation (Callon, 1986) and inscription (Akrich, 1987), artifacts acquire the ability to “make do”, that is to engage in a power relationship with certain individuals and collectives, and to impose specific reactions to their use (Latour, 1988). Objects are here considered as actors (or actants in the semiotics vocabulary) who do politics (Latour, 1996b), or even ethics (Verbeek, 2005), “by other means” than those usually recognized in the humanities and social sciences.

These studies were primarily directed against thought traditions that have promoted humanist exceptionalism at any cost, along the lines of Descartes and Bacon (Merchant, 1980). They also quickly moved away from the social constructivism inherited from Durkheim, which conceives the action of objects only as the result of interpretations and conventions that are, here again, exclusively social (Hennion, 2015). Not all material properties are equal, and not all objects can be political or social in the same way. That said, the materials’ ability to act is here essentially related to solidity. If objects contribute to the organization of human life, like the one of other living beings, it is essentially through the materials they are made of, which enable them to last (Goody, 1986; Winner, 1980). If one can translate moral requirements, principles, interests and produce inequalities into things themselves, it is insofar as they hold together and resist (Gell, 1998)<sup>1</sup>. Of course, such a quality is by no means intrinsic, and the stability of objects is generally the result of a complex sociomaterial process (Callon, 1986), a long-term collective effort fraught with pitfalls, sometimes doomed to failure (Latour, 1996a). Even so, when objects act here, it is because they have achieved a certain inertia, or even immutability. As Fernando Domínguez Rubio points out about art conservation practices, in this perspective material fragility is a blind spot: “Rarely, if ever, do these approaches take into account the fact that objects wear down and change, that they break, malfunction and have to be constantly mended, retrofitted and repurposed (...)” (Domínguez Rubio, 2016, p. 60).

At first sight, the studies assembled under the label of “new materialism” differ greatly from this perspective. They offer a twofold expansion. On the one hand, they open up the range of materials taken into consideration, going well beyond the technical objects usually associated with the STS approach. On the other hand, they shift the focus of analysis away from human forms of action: instead of describing how human beings extend their gestures by delegating them to artifacts, in line with Leroi-Gourhan’s (1945) thought, the aim is to explore the unpredictability of self-organization processes and the creativity of matter itself, or rather of the multitude of materials at play in both human and non-human life (DeLanda, 2006; Barad, 2007; Bennett, 2010; Clark & Szerszynski, 2021). What is described here is an

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<sup>1</sup> The article by de Laet and Mol (2000) on the trajectory of a water pump in Zimbabwe is a remarkable exception from this point of view. Although they do not directly question the idea of fragility, by showing the importance of the “fluidity” of the pump (its capacity to change radically as it is used), the authors explicitly criticize the perspective of the sociology of translation, which focuses on closure times and the role of material stability in the success of innovations.

ecology of multiple, changing interdependencies, highlighting spontaneous forms of action by matter itself, its propensity to manifest that does not derive directly from humans, whose activity is always embedded in a field of heterogeneous forces. In this perspective, explicitly inspired by vitalism, matter is not apprehended in terms of stability. On the contrary, far from figures of solidity and immutable forms of composition, its agency is understood through its tendency to constantly transform itself and to generate surprises in ever-dynamic, heterogeneous assemblages.

However, there is not much evidence of material fragility in these studies either. Focused on action, many insist on the strength of matter, its power of expression, in line with Jane Bennett's (2004) analyses. As Diana Coole and Samantha Frost state in the introduction to their book, "new materialists emphasize the productivity and resilience of matter" (Coole & Frost, 2010, p. 7). If there is any fragility here, it lies rather with humans and their institutions, who constantly neglect or at least underestimate the autonomy of matter and the unpredictability of its assemblages, to their own detriment (Connolly, 2013). This human fragility is particularly noticeable in the face of major disasters that, while highlighting the risks associated with certain material technological failures, place the autonomy of earth forces at the forefront, and mainly call into question the lens of human action exceptionalism, which is even reflected in the very idea of the Anthropocene (Clark, 2014; Haraway, 2016).

By taking the issue of material fragility head-on, this special issue aims to offer a conceptual and empirical extension of the rich and infinitely diverse work that has fuelled the two material turns (too) briefly outlined in the previous paragraphs. Such an extension can be understood as a follow-up to the symmetrical posture that has been adopted to address the question of agency. If shifting the focus on action away from human exclusivity has proved fertile, wouldn't it also be fruitful to broaden our understanding of fragility, the epistemic and political value of which has been highlighted by feminist theories of care (Molinier, Laugier & Paperman, 2009; Tronto, 1993)? What can we learn from an inquiry into fragile materials? Under what conditions can the term itself, which is morally charged in everyday language, help us to (re)think the sociomaterial condition of human beings, or even the earthly condition? But also, of course, what are its limits? What is its heuristic potential?

This special issue has been assembled around these questions, formulated as invitations. Including four research articles, a speculative essay on the behind-the-scenes aspects of a call for papers on fragility, and a review of Fernando Domínguez Rubio's book *Still Life*, this issue aims to open up new paths of inquiry and to identify lines of flight, rather than providing exhaustive, definitive answers. Before going into the articles in more detail, we suggest to highlight the relevance, but also the ambiguities, of fragility as a notion, based on its use in materials science.

## **What fragility makes visible**

In 2004, Jacques Roux and Thierry Magnin published a rather unusual book in the "Matières à penser" collection of the University of Saint-Étienne (Roux & Magnin, 2004). Including a foreword by Isabelle Stengers, the book is conceived as an encounter between Roux, a polytechnicien turned sociologist, and Magnin, a physicist, then director of the "Sciences des matériaux et des structures" laboratory at the École des Mines of Saint-Étienne. Its title leaves no doubt about its relevance to our concerns: *The condition of fragility. Between materials science and sociology*. The program is perfectly clear. While initiating this conversation, Roux aimed at starting an interdisciplinary dialogue, moving from materials

science to social sciences. It was not intended to blindly apply concepts from the former to the latter, obviously, but rather to lay the groundwork for a possible translation.

Let's clear up any misunderstandings immediately: the result, from this point of view, is not convincing. Essentially, because, quite surprisingly, Roux adopts in this book a very narrow definition of "the social", which does not consider any material property other than through metaphors (about bodies, materials, etc.). Nevertheless, the discussion with Magnin is highly valuable. With a generosity of detail, this conversation helps us to understand the place of fragility in materials science and, as Stengers wrote in her foreword, draws a fascinating portrait of these "impure" sciences, which hold a special place in the field of physics. This is with this in mind that we suggest rediscovering this discussion<sup>2</sup>: as a deep dive into the subtleties of material fragility, which can help us strengthen the questions that have fueled this special issue and better understand the scope of the analyses developed in its articles.

The main lesson to be learned from Roux and Magnin's discussion helps to to dispel what is undoubtedly one of the most important misunderstandings surrounding the notion of fragility. In materials science, fragility is not the opposite of hardness or solidity, but of ductility. Here, it is "the event of rupture" (Roux & Magnin, 2004, p. 33) that stands at the horizon of fragility. In this respect, hardness, which at first glance could be separated from fragility, is instead directly intertwined with it, since it relates to breakage in a way that contrasts with ductility. As Magnin explains, in materials science, a fragile material is one that has a tendency to break quickly, whereas a ductile material is one that can withstand significant physical transformations and return to its original shape after being stressed.

There is no need to go into technical detail to understand the significance of this first point for the exploration of material fragility in many of the situations studied in STS. Such exploration does not aim at highlighting a neglected part of sociomaterial reality that would evolve on the margins of solidity, a fragile world outside the mechanisms of power, or even weakened by them. Rather, it consists in investigating sturdiness, hardness, inertia — so many qualities that have been put forward as proper to the material part of social activities — insofar as they are consubstantially linked to forms of fragility. This first path invites us to reshuffle the cards of the materialist vocabulary. From its perspective, considering the material part of the world in social sciences is no longer reduced to highlighting the effects of consolidation or perpetuation as opposed to the instability of phenomena of lesser material consistency. This implies investigating a physical continuum where rigidity and fragility are no longer systematically opposed, and where the relationship to transformations prevails over claims to immutability.

From this starting point, the exchange with materials science opens up several promising lines of analysis. The first is rooted in the very name of the science: looking into the question of fragility means investigating *materials*. And they are multiple, changeable, their behavior is uncertain. Materials resist the tendency towards global apprehension that is at play in other specialities of physics.

In fact, the material – one could say the real matter, as opposed to the matter that is conceptualized in the science of structures – appears as a complex and random assemblage which recklessly blends pure and impure, regular and irregular, bits of structural theory and

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<sup>2</sup> We are most grateful to Michel Péroni for bringing this book to our attention during a stimulating discussion at the research seminar of the "Politics of knowledge" team at the Max Weber Centre in Lyon.

failures, established networks and parasites, expected bodies and stranger bodies, mixtures and overlays... (Roux & Magnin, 2004, p. 132).

Hence, taking materials and their behavior into account is a vehicle for diversifying and increasing the comprehensiveness of descriptions. From this point of view, this represents a form of resistance to the hegemony of theoretical physics and a Western science committed to a unified model of matter and time that ignores singularities. Exploring materials provides the means to respond to Bernadette Bensaude-Vincent's recent call to multiply "the tiny narratives, the local pictures, which break the continuity of the master narrative, driven by the time of classical mechanics, a vast abstract container indifferent to what happens within it" (Bensaude-Vincent, During & Hoquet, 2022, p. 701). Put differently, following this direction helps to multiply partial and situated views on heterogeneous material assemblages that would otherwise remain unnoticed.

This first line of inquiry into material fragility also resonates directly with the lively discussion that took place a few years ago in anthropology, when Tim Ingold (2007), reacting to the literature on "material cultures", advocated dropping the ubiquitous term "materiality" in favor of a concrete, precise analysis of materials at play in specific situations. He criticized the explanatory claim of a vague notion that hid the diversity of phenomena and processes at play in the objects studied by anthropology. In line with these debates, following the path of fragility obliges us to go beyond the vagueness of "materiality" to become sensitive, empirically and conceptually, to the undisciplined multiplicity of the elements that compose matter (Papadopoulos, Puig de la Bellacasa & Myers, 2021, p. 1-17).

However, investigating fragility, and with it the path of materials, does not just lead to a vast horizon of heterogeneous elements with unexpected behaviors. This also raises the question of the scale of what is being observed, and of the entities whose fragility is considered problematic. Even though materials science is decentered from the global view of structural science, its descriptions do not stand at the level of molecules either. As Stengers writes in the foreword to Roux and Magnin's book,

(...) the physics of materials is a science of the "mesoscopic", which inhabits the no man's land between the molecular scale and the macroscopic scale. Which means that it's an art of negotiation and relevance. It does not stage the explanatory power of notions ever articulated to the notion of ideal situation (...) but brings multiple "beings" into play. These beings do explain but also have to be explained. For instance, the micro-cracking that the material can tolerate poses the problem of its critical threshold, above which cracks that propagate must be described, and the propagation will reach a "pragmatic" limit at the break-up stage as well. (Stengers, in Roux & Magnin, 2004, p. 10).

An "art of negotiation and relevance", materials science can never escape the dizzying yet ever-present question: what counts? And more precisely, when it comes to fragility, what breaks? As Roux explains a little further on: "the material is not pure matter, isolated in its intrinsic definition; it is what runs through this or that form, this or that object, to give it consistency, a hold in the world" (Roux & Magnin, 2004, p. 41). Along the path of materials, what comes to the fore is thus the question of form and its dynamics, and the ability to retain or regain it after being stressed. Investigating fragility means describing what holds and what makes hold, as well as what no longer holds or does not hold enough, without ever leaving behind the particular situation in which these issues arise.

Finally, the encounter organized by Roux is an invitation to follow the path of what he calls the “operative ontology” of materials. Materials science deals with them not from an abstract, decontextualized point of view, but according to a series of operations they undergo. Fragility is therefore not an essence, a quality intrinsically inscribed in the nature of things, but a situated behavior. Above all, this behavior only occurs in the context of a local solicitation. It is “provoked” – to quote Fabian Muniesa (2014) – through scientists and engineers experimentations. This is the final lesson to be drawn from the conversation between Roux and Magnin. Material fragility must be approached not as the property of an assemblage of elements described in isolation, but as the condition of a temporary agencement, seized in what Roux proposes to call a “relational grammar”. Yet, as we previously saw, in materials science fragility is closely linked to breakage and deformation. The relational grammar that unfolds here is therefore very particular, since the solicitation to which things are subjected is entirely dedicated to the imposition of a constraint. This is such provoked constraint that makes it possible not only to reveal material fragility, but also to measure and know it, that is, to associate the performance of the material assemblage with a specific level of stress.

Solicitation through constraint is at the center of two articles in this special issue. In their article on “red mud”, Sylvain Le Berre, Valentin Goujon and Vincent Banos show that since the end of the 19<sup>th</sup> century, attempts to valorize these toxic residues that come from the transformation of bauxite ore have involved testing them out, in order to demonstrate their performance for a variety of uses. Whether experimented for underwater immersion, used to form road underlays, landfill covers, agronomic substrates or grouts for filling cavities, red mud is put to the test of numerous mechanical constraints, both in the laboratory and on natural sites. These solicitations are designed to check their composition, consistency, texture and resistance under defined and controlled conditions. As the authors show, while these experiments have led to the gradual production of knowledge about red mud, they have above all revealed the fragility of a material that is particularly recalcitrant to its commercial valorization.

The experience of fragility under constraint is also crucial in the various ways a huge LED floor is apprehended, which are analyzed by Dominique Vinck, Mylène Tanferri-Machado and Élodie Fischer in their article. Starting from the setting up of this technical device, unprecedented in its size (783 m<sup>2</sup>), during a centuries-old cultural event — the Fête des Vignerons in Vevey, Switzerland — the authors examine the multiple tests it undergoes throughout its involvement in the stage performance. Among them, the constraints caused during the numerous rehearsals for the show raise a number of concerns. The large number of performers parading with their equipment (shoes, bicycles or wheelchairs) and their animals (cows, goats, mules and horses) perform a sort of situated experiment during which the fragility of the floor is tested under extreme conditions, which have the advantage of being the same as those of the show itself. Similarly, weather events push the technical equipment to its limits. Summer heat, for instance, distorts floor and frame materials (expanding during the day and contracting at night), altering the thickness of joints and forming black lines on the TV image of the event. Moisture generated by heavy rain, or by water deliberately poured over the floor to lower its temperature, is another source of constraint for the electrical connection of LED panels. The authors’ descriptions offer an extensive overview of the successive stresses to which the LED floor is exposed, which in turn manifests a variety of material fragilities without ever reaching the point of break-up.

Having discovered Jacques Roux's fascinating conversation with the materials scientist Thierry Magnin, we now have a slightly clearer idea of what material fragility refers to and, above all, of the type of investigation it calls for. A behavioral quality, material fragility is not so much the opposite of rigidity as one of its facets. Always experienced in situation, it is revealed through solicitations which activate in a singular manner the materials flowing through things and their environments to ensure the hold of the former. That being said, this conceptual specification is also valuable in that it demonstrates the restricted nature of materials science's framework. Despite the immensity of its fields of application, this approach takes a narrow view of fragility: that of rupture and the events that lead to it. As Stengers points out in her foreword, this prism of the "undergone", of the power relationship that separates, on the one hand, a thing put to the test and, on the other, a disruptive agent, is very limited. By naturalising a shock from outside (as does the notion of resilience), this framing is politically and morally questionable, particularly if one tries to translate it into social sciences. The condition of fragility becomes highly asymmetrical if it is restricted to the contingency of a shock, if it is entirely encapsulated in the vocabulary of risk. How then can we think about fragility without being held back by the double focus of rupture and external constraint? How can we keep the benefits of the paths we have mapped out so far in order to investigate the material part of the world beyond the figures of solidity and strength, while broadening the register of fragility's "relational grammar"?

The articles in this issue, each in their own way, offer preliminary answers to these questions. They engage with material fragility as a descriptive and analytical operator that reshapes attention, not only of the people who care about it in situation, but also of the researchers who follow them and are willing to learn from their experience (Denis & Pontille, 2022). The articles draw complementary threads from their investigations, that go well beyond the frame of external constraint and rupture. Apprehended *in medias res*, fragility is here experienced through the sociomaterial interdependencies that hold things together.

## **Interdependencies**

The main limitation of a definition of fragility based on external stresses lies in its assumptions regarding entities and their boundaries. To understand the reaction of a thing, it has to be apprehended as autonomous in the first place. The scientific laboratory and its experimental instruments are essential to this end. They provide a framing through which a thing is clearly delineated from its environment, and thus make it possible to generate, and thus control, an event that enables the thing to manifest itself (Latour, 1999). In this sense, the material trial set up by the materials science experimentation is akin to a "provocative containment" (Lezaun, Muniesa & Vikkelsø, 2013).

As mentioned above, this particular form of controlled solicitation can be found in the articles of this special issue. But neither the idea of constraint nor even that of "solicitation" is sufficient to account for all the fragilities at play in each case. Things are constantly overflowing, and material fragility is less a matter of external provocation than of heterogeneous, uncertain processes where multiple entanglements are the norm. It is not problematized by the persons and institutions who are concerned with it as an isolated behavioral characteristic either. Rather, fragility is at the core of a widespread preoccupation that deals with numerous interdependencies, where the difference between what is fragile and what renders fragile is anything but self-evident.

Loup Cellard and Clement Marquet's article on submarine telecommunications cables — the essential conduits for the data flows that feed the global Internet —, highlights the ambivalent relationship between these cables and local ecosystems. The starting point for their investigation is quite simple. In the Marseilles bay, Posidonia meadows, a flowering plant endemic to the Mediterranean, are a species threatened by the many disturbances caused by port activities, especially trawling and boat anchoring. Cable laying, for which authorization requests have been multiplying for several years now, seems to be an obvious additional threat, and routing them through the seabed is proving to be a tricky business to avoid further damaging the Posidonia meadows. However, such danger is not that obvious when it comes to the actual interactions between cables and seagrass beds. Cellard and Marquet's in-depth study of the various actors involved — those who are concerned with undersea flora, those who take direct responsibility for it in their environmental preservation activities, others who reason about the route of future networks, still others who take care of their implementation in the undersea environment or monitor their evolution over time —, reveals forms of relationship that are far more complex than unambiguous threat. They show the various "frictions" at work between the cables and the Posidonia meadows, which gradually become visible as the two come into contact. Two of these frictions are particularly illustrative of the question of interdependence.

Once the route has been chosen, the authorizations approved and the cables have been laid with care for both the species they pass through and themselves, comes the time for operation. The time of the technical functionality of telecommunication networks and the speed of digital exchanges, but also the slower pace of ecological observation of cross-reactions between cables and Posidonia meadows. In the eyes of their various observers, these interactions are considered open and dynamic. While the initial fragility of the seagrass beds crossed by the cables is a concern, it is deemed transitory, to the extent that the relationship may even reverse over time, and eventually turn favorable. Although the cables are laid in the heart of the Posidonia meadows, the former are gradually integrated into the latter as they develop. The active role of seagrass beds can even extend beyond this space for cables, offering protection against external damage through an intertwining effect. Cellard and Marquet emphasize a form of relational agency that contributes to the mutual reinforcement of entities towards one another. They carry on their analysis by looking at the discussions surrounding the removal of some cables. With an average operating life of a few decades, the cables are not intended to remain in the seabed forever. However, the integration and wrapping of cables in Posidonia meadows is sometimes such that it is deemed better to leave certain sections in place rather than damaging the plants. Besides the ambivalence of fragility over time, the authors' analysis of interdependencies also highlights the cascading phenomenon that occurs when efforts are made to protect cables and seagrass beds with various types of technical equipment. Far from being binary, protective interactions are likely to generate new frictions and thus extend the list of beings made fragile, such as underwater substrates or yachtsmen, by the steel strands or specific anchors that hold the cables in place.

At the center of Dominique Vinck, Mylène Tanferri-Machado and Elodie Fischer's analysis, the succession of choreographies on the LED floor also reveals entangled fragilities. In the course of the tests we have already mentioned, rehearsals bring out various interdependencies that call for reciprocal adjustments. For example, on some days, the temperature accumulated by the anthracite surface of the stage slabs is such that actors have to adapt their costumes, using non-standard shoes to withstand the heat and avoid burns. By contrast, other feet that walk on the floor are a source of threat. This is the case

for animals such as cows and mules, whose hoof beats can cause damage to the LED panels. Their dejections add perils of their own. Their urine, especially, whose acidity can damage electronic components. Conversely, the shifting, moving nature of the digital ground can lead to troublesome reactions from animals, surprised and frightened by the graphic animation beneath their feet. While these various gestures, which deviate from the scenography, must be mastered to ensure the smooth running of the live show (e.g. appropriate footwear for humans, stable and familiar ground for animals), they are also a key concern for audiovisual stage technicians. The desire to provide beautiful images for live television broadcasts and heritage archiving comes with its share of interdependencies and fragilities. These include the brightness of the floor, which affects traditional lighting effects; faulty LED panels, which must remain invisible to camera lenses; and joint dilation, that creates black lines on the screen, all requiring the adaptation of video capture conditions and digital corrections to mask visual defects. Vinck, Tanferri-Machado and Fischer show how unsuspected entangled fragilities are gradually being explored by a variety of actors who, although busy around the same LED floor, have their own concerns and find themselves enmeshed in specific interdependencies juxtaposed with those of others.

Different forms of relationship are at play in Sylvain Le Berre, Valentin Goujon and Vincent Banos' analysis of tests on residues produced during the processing of bauxite ore and reconditioned into Bauxaline. Carried out on the ground, underground and on the seabed, the experiments initiated by the industry are organized into two main types of consistency test for Bauxaline. While geotechnical and geomechanical tests aim to reveal the dynamic properties of its composition, ecotoxicological, agronomic and geochemical tests are designed to detect its physico-chemical manifestation. Since these experiments concern the behavior of this composite material under a wide range of conditions, red muds face interdependencies as a problem from the very beginning. Two aspects are central in these tests: Bauxaline's resistance and its non-toxicity, namely its propensity to avoid causing fragility in other living beings, whether in an underwater environment, in the vicinity of roads when Bauxaline is used as a possible underlay, or in an agronomic context as a cultivation substrate. And, as the authors show, each of these tests gives rise to strong and troublesome interactions with the environment in which the residues are immersed. This is the case, for instance, with the turbulence of underwater waters dedicated to test the mechanical strength of red muds, or with the "circulation of surface and ground water" which accentuates the risk of landslides in backfill grouting experiments.

While highlighting the knowledge produced by these experiments, the authors show that revealed interdependencies are actually twofold. Both material and commercial, the tests aim to "align the material and the product, the product and the market". In other words, despite their variety, the experiments initiated by industry share a common goal: to find a commercial opportunity for Bauxaline. But the highly heterogeneous and toxic composition of the residues, as well as their geochemical instability, compromise the success of each experiment. The problem lies in the difficulty of reducing the variability of matter, and making its internal heterogeneity a relevant attribute for its market value. The very power of the material, which is celebrated by the proponents of a vitalist conception in line with Bennett (2010), turns out to be problematized as fragility by those who seek to add value to Bauxaline. No economically valid stabilization has emerged from "the intertwining of mineral and residual agency and techno-market assemblages". The material entanglement at play here is stretched between the expected overall performance and the fragility of composition and texture revealed throughout testing.

A quite different kind of performance is at stake in the legal preservation of sealed biological samples used to solve criminal cases, which Vololona Rabeharisoa and Florence Paterson have investigated. Objects collected from the crime scene and made up of a wide variety of materials that are packaged in a “plastic, kraft paper or cardboard” container, sealed biological samples are virtually powerful: subjected to the technics of genetic analysis and turned into evidence, they can lead to the solving of a legal case and thus contribute to the force of law. However, once stored for forty years, sealed biological samples are exposed to the ravages of time and run the risk of inexorable transformations. The authors focus on two processes underlying these potential changes, which highlight specific entanglements of fragilities. The first is contamination, whose legal definition is primarily positive. This is because the crime scene has been contaminated by the criminal that it is possible to collect the traces they left behind and sealed them. The downside of this strength, however, lies in the very making of sealed biological samples, which involves successive manipulations along the forensic chain, from the first samples taken at the crime scene to their reconditioning for storage, after the elements required for their genetic analysis have been extracted. Despite the preventive procedures guiding each stage, new traces may be added as the sealed biological samples transit to their place of storage. Such contamination hinders the identification of the criminal’s traces, and points toward a concern that multiplies interdependencies: the list of people potentially involved is extended to all those who have been in contact with the crime scene.

The second process relates to degradation. Even though this may be the result of the individual who committed the crime covering their own traces, or of negligence on the part of those involved in the forensic chain, it is mainly due to entropic processes. Interactions between the materials making up a single sealed biological sample, or even between different sealed samples stored in close proximity to one another, are likely to generate long-term transformations that jeopardize both their material integrity and their legal value. These interdependencies of fragility between materials, whose agency can lead to excessive overflow, bring to the fore the “intra-actions” (Barad, 2007) of the sealed biological samples themselves, and remind us that “biological and ecological concepts of decay are full of activity, exchange, acquisition and redistribution” (Jacobs & Cairns, 2014, p. 69). Given the interweaving of materials and traces, the care for material fragility takes the form of a separation work. Rather than an external solicitation that takes for granted the autonomy of the entity whose reactions are put to the test, the challenge here is to “differentiate between contamination that is useful to the investigation and that which pollutes it, and the degradation that comes from the materials’ own life from that caused by human manipulation, some of which may be malicious”. As shown by Rabeharisoa and Paterson, such differentiation is considered a delicate and constant process which, alongside the legal procedures in place, calls for knowledge of forensic practices as close as possible to the trajectory of sealed biological samples.

### **Fragile becomings**

Just as Bennett (2005) argues for understanding material agency in terms of the “agency of assemblages”, the authors of this special issue invite us to consider fragility from the point of view of the material interdependencies it renders manifest. As fragility becomes a preoccupation in a range of very different situations, it reveals agencements full of heterogeneous materials whose behavior is uncertain, and which are perceived through a range of inquiries, which forms and instruments are themselves diverse. While they all deal

with these multiple interdependencies, each article focuses on a specific institutional configuration, though, within which relationships and interactions are neither of the same order nor of the same intensity. Material fragility itself is addressed by a range of actors, whose number, qualities, and level of involvement are different. Ultimately, the various beings at play are engaged in practices oriented toward very specific concerns.

Whether dealing with residues reconditioned into Bauxaline or with sealed biological samples, the consideration given to the material fragilities that emerge from the activities may vary from person to person. Yet, in both cases, it is directed towards the singularization of the involved entities. Whilst the aim of the manufacturers is to find a market for these toxic residues, that of the professionals in the forensic chain is to ensure that sealed biological samples keep their full potential as evidence. The value of the market on the one hand, the force of law on the other. In both cases, the inquiry into fragilities aims to cut the links of dependence, to untangle the threads that contribute to the evolving ontology (a stabilized good that can be sold here, an unaltered object that can be used as legal evidence there) of those that, by attaching the thing to other beings, modify its ability to act and its expressive power. The horizon of concerns is quite different in the exploration of the cross-reactions of the LED floor and of the beings working on it, just as in the underwater interactions caused by the presence of telecommunication cables. As the authors of the two articles suggest, activities dedicated to stage performances and the functionality of the global internet rarely give rise, in the situations under study, to disentangling and empowering initiatives that would be inclined to favor ontological singularity. Instead, they are animated by another watchword: make the most of the interdependencies between entities whose relative fragilities manifest gradually as the actions unfold.

Each configuration thus highlights in its own way fragilities that go far beyond the single instance of external constraint. Beyond the particularities of their research questions and the processes they describe, the four articles share a common view on the material forms with which the people compose. Far from describing stabilized arrangements subjected to shocks or crises that punctually put them to the test, they put to the fore, through the prism of fragility, the becoming of material assemblages. In this respect, they are in line with a pragmatist approach that combines the theoretical contributions of new materialism with an interest in the continuous processes through which material assemblages take on consistency, and last, while at the same time transforming themselves (Denis & Pontille, 2022). As Antoine Hennion has shown, fragility obliges us to take part in the “continuous processes that make beings and things last, while transforming them and the environment in which they make themselves last” (Hennion, 2019, p. 488).

Finally, each article of this special issue underlines in its own way a crucial point, both theoretical and ethical: material fragilities are not just the manifestation of a possible disappearance. Comprehended in a wide variety of ways by those concerned about the state of things for and to which they have to respond, material fragilities extend not only beyond the restricted framework of rupture, but more generally beyond that of loss. Of course, the avoidance or minimization of breakdown, degradation and aging are at the core of the actions undertaken to document, understand and compose with fragilities. But the latter are not only, and not always, treated as signs of a vanished past or a dying present to be preserved. They also act as calls to unfold a possible future for things, whose existence stems from their being “still in process of making” (James, 1909, p. 226). “Fragile” here no longer simply refers to a behavior prone to breakage or extinction in certain operative situations, but to the condition of material beings entangled in extended relational forms and

committed to uncertain common becomings. Fragility unfolds the time of matter, engaging those who care about it in long-term inquiries, which can vary greatly according to configuration, from the implementation of highly controlled maintenance techniques to the subtle stewardship of degradation processes deemed irreversible (Denis & Pontille, 2022). Moreover, by not being confined to the anxiety of shock and loss, material fragility can be thought of, and practiced, as generative. They do not just turn back to the past, but nurture a form of “ordinary hope” (Jackson, 2023). They oblige us to invent and cultivate conditions of existence that persist as “an incentive or the sprout of something else, the fragment of a new future reality” (Lapoujade, 2017, p. 33). Lives to come, to make happen, to take care of.

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