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Confronting the Uncertainties Associated with Long-Time Scales: Analysis of the Modes of Preservation of Memory of Radioactive Waste Burial Sites

RESEARCH

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ABSTRACT

The burial of radioactive waste in deep geological repositories has gradually imposed itself since the 1980s in various countries. Considered more stable, safe, and responsible than storage above ground, this solution is seen as a way of keeping the waste out of human reach, and of freeing oneself of the obligation to monitor repositories. However, it soon became clear that the idea of relying on the relative stability of deep geological repositories for the safe disposal of nuclear waste to remove it from the 'all too human' risks associated with history's turbulences, has produced new uncertainties, and raised new questions, given the multi-millennial time scales involved.

This article presents a study of the strategies adopted by the actors in charge of radioactive waste management in the face of the temporal constraints imposed by the length of their radioactive life. More specifically, it is intended to question the representations of temporality that allow the designers of these projects to assume their responsibilities by transmitting information and warnings towards to an extremely distant future, to recipients who are not easily representable and for whom they already have a responsibility even though they do not yet exist.

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INTRODUCTION

The burial of radioactive waste in deep geological repositories—and thus the use of a geological barrier to contain radioactivity throughout the period of radioactive decay—has gradually imposed itself since the 1980s in various countries.[1] Considered more stable, safe, and responsible than storage above ground, this solution is seen as a way of keeping the waste out of human reach, and of freeing oneself of the obligation to monitor repositories (Barthe 2006). However, it soon became clear that the idea of relying on the relative stability of deep geological repositories for the safe disposal of nuclear waste to remove it from the 'all too human' risks associated with history's turbulences, has produced new uncertainties, and raised new questions, given the multi-millennial time scales involved (Ogorzelec-Guinchard 2019; Ogorzelec-Guinchard & Calla 2020).

This article presents a study of the strategies adopted by the actors in charge of radioactive waste management in the face of the temporal constraints imposed by the length of their radioactive life. More specifically, it is intended to question the representations of temporality that allow the designers of these projects to assume their responsibilities by transmitting information and warnings towards an extremely distant future, to recipients who are not easily representable and for whom they already have a responsibility, even though they do not yet exist. Although part of our reflection, the question of the characteristics of radioactive waste and of the socio-technical controversies regarding its burial will not be addressed here. Indeed, these topics have already been developed in reference research works on which we have based our arguments (Barthe 2006; Buser 2015; Hecht 2004; Hecht 2006; Hecht 2007; Hecht 2010).

In order to render intelligible the collective experiences of time, that our societies have had since events such as the Chernobyl accident or the fall of the Berlin Wall, historian François Hartog attempts to reflect in terms of a 'regime of historicity' the relations between the past, the present and the future of an era (2003). According to him, facing a profound crisis of the future, we have engaged in a regime characterized by a tyranny of the instant and an ever-expanding perpetual present. Building upon his work we consider the practices of those in charge of waste burial projects (when faced with the millennia-long radioactivity of the waste they have to manage) as indications of a new 'regime of historicity' that is still difficult to discern. In other words, we choose to take seriously their attempts to publicly assume the unprecedented temporal dimensions of their responsibilities. Indeed, whether they are hypocritical or sincere, even if they only seek to make burial projects socially acceptable, their discourses are necessarily situated within the perspective of The Ethics of Discussion and must respect its norms (Habermas 1991). This is how the question of temporality imposes itself on them.

In this perspective, choosing the burial option requires the transmission of the memory of radioactive waste storage sites. This problem lies at the interface of two levels:

1. On the one hand, reflection on the consequences of these temporal dimensions began when the U.S. Department of Energy brought together experts from different disciplines (Sandia Reports 1991; Sandia Reports 1993) and continued in the form of international mechanisms—backed by the Nuclear Energy Agency (NEA)—such as the RK&M program (Preservation of Records, Knowledge and Memory, 2011–2019) and, currently, IDKM (Information, Data and Knowledge Management). A structuring framework, consisting of information shared between the agencies concerned as well as a common 'toolbox', have thus been progressively developed.
2. On the other hand, as techniques have evolved and issues concerning nuclear waste have been integrated into policies (Barthe 2006), agencies in various countries have undertaken more concrete work for setting up techno-administrative mechanisms as well as focus groups made up of technicians from the sector, elected officials, and citizens of local sites earmarked for radioactive waste storage projects.

In this paper, we propose to analyze how the temporal dimensions are taken into account at each of these levels. We will first examine how and why, in order to fulfill their responsibilities in a new temporal framework, the managers of radioactive waste disposal facilities must keep alive the memory of these disposal sites. In this context, we will see that they must deal with a tension between maintaining constant perseverance concerning the conservation and transmission of information and the ever-uncertain framing of an interpellation preceding, in extremis, a fatal encounter with the contents of the repository. We will then attempt to show how, from now on, perseverance must be passed on from generation to generation, in an ever-renewed effort, and to what extent the framing of the decisive moment is uncertain.

RESEARCH CONTEXT AND METHODOLOGY

This article is part of a research project on the transmission of memory of radioactive waste disposal sites (TMS) that was conducted between 2019 and 2022 and brought together researchers in socio-anthropology, archaeology, geography, and communication sciences.

Our study was conducted by associating two distinct approaches to confront recommendations constructed by experts at an international level with the effort to take memory into account in the context of a concrete radioactive waste burial project:

- One is based on the analysis of a set of recommendations formulated in the framework of an international program of research on the preservation of information, knowledge, and memory of these sites (RK&M).
- The other is based on observations and interviews conducted during an ethnographic visit to Bure, France, where a nuclear waste burial project is being developed (Cigeo: the project for an industrial geological storage center).

The objective was then to compare the results, obtained through these two approaches, concerning concrete memory aids such as markers intended to warn of the proximity of the waste for several centuries after the repository was sealed.

Using the first approach, we conducted a content analysis of the fact sheets presenting 35 'mechanisms' of transmission of information, knowledge, and memory identified within the framework of the RK&M program and grouped together under the title of 'toolbox' (see Table 1 in the Appendix section), by taking into consideration two levels of communication:

1. The first objective was to better understand the interactions in which the authors of RK&M reports engaged when elaborating this toolbox, which is addressed to the different actors in the world of science and technology as well as to the different components of the public sphere (political groups, associations, local and national elected officials, etc.). In a pragmatist perspective, we have chosen to consider the toolbox as a 'gesture' or an invitation awaiting a response from those who agree to take it up and use it.
2. The second objective was to describe the forms of communication that govern—mostly implicitly—the interactions between the different actors brought together by the 'mechanisms' that the authors of the RK&M reports recommend.

The methodology for these content analyses combined pragmatist attention to the description of the concrete behaviors of the participants in an interaction and the techniques for reconstructing the patterns of analysis of narratives as they have been mobilized since the publication of Greimas' work and taken up in the sociology of translation. Although distinct, the two levels of communication have been studied in parallel insofar as the action addressed by the designers to our contemporaries, or possible future receivers, is translated into the content of the fact sheets presenting the 'mechanisms' (see Table 2 in the Appendix section).

The fieldwork was conducted in the form of an ethnographic visit, conducted in October 2019 at the Meuse/Haute-Marne Center of the National Agency for Radioactive Waste Management (Andra). The site is located in the town of Bure (Figure 1) and houses an underground laboratory whose mission is to prepare the future industrial geological storage center (Cigeo).

Figure 1 Location of Bure (site of the industrial geological storage center project—Cigeo—and of our field trip). Source: Géoportail.gouv.fr.

During this ethnographic visit, in parallel with photographic surveys as well as spatial and landscape observations, that will not be presented specifically in this article, we conducted semi-structured interviews with six people: the head of the 'Memory' program, the head of the 'Permanent Environment Observatory,' an archivist at the Meuse/Haute-Marne center, a person from the agency's communications department (who is leading a group of local residents to whom Andra is proposing to reflect on the memory of the site), a writer and a visual artist (who were winners of a competition organized by Andra on the question of long-term memory), and a researcher in the field of geo-prospective studies, financed by the agency to test the use of markers on the site expected to house Cigeo. These meetings gave us the opportunity to ask those different actors a series of questions about their activities in connection with the issue of memory transmission (see the Table 3 in the Appendix section). We were also able to talk to the head of security at the Meuse/Haute-Marne center and an agent at the site who introduced himself to us as a 'territorial mediator.'

ANALYTICAL READING AND RESULTS

TWO MODES OF INFORMATION, KNOWLEDGE, AND MEMORY TRANSMISSION

Beginning in 2011 and continuing through 2019, as several national agencies affiliated with the Nuclear Energy Agency engaged in the development of projects of geological disposal of radioactive waste, the RK&M initiative attempted to answer the question, 'How can we continue to remember and understand, across generations, where, why, and how radioactive waste was buried?' (RK&M report 2019: 16). The ambition of this program was to propose 'a toolbox consisting of concrete methods for preserving archives, knowledge, and memory' (RK&M report 2019), categorized into 35 'mechanisms.' The latter are heterogeneous and have different geographical 'scopes;' they do not operate at the same 'time scales,' do not concern the same 'actors'. However, despite the variety of 'mechanisms' that it groups together, it can be noted that the 'toolbox' of the RK&M initiative essentially mobilizes two modes of transmission.

- Based on 'mechanisms' such as culture, education, knowledge management, but also on regulation and surveillance, etc. the first mode of transmission aims to reinforce the permanence of an 'indirect,' 'mediated' link between generations, in cultural, economic, and political contexts likely to change over time. It seeks to lengthen time over the centuries.
- The second mode of transmission, on the other hand, seeks to create a 'direct,' 'unmediated' link with future generations, through more 'technical' mechanisms that are in theory, as independent as possible of changes in social environments. The goal, here, is to 'frame' the event of an 'encounter' by means of information and warnings about waste—whenever that encounter takes place.

According to the authors of the RK&M reports, each of these two modes of transmission has 'strengths' and 'weaknesses' that must be taken into account. It is important to note that information, when left unaltered for a very long period of time, without being adjusted to contextual changes, can turn into puzzles and opportunities for error, and even jeopardize security in the event of an inadvertent intrusion into the repository. Conversely, successive adjustments to changing contexts can gradually—sometimes imperceptibly—cause a deviation from the intended meaning of the original message. For this reason, the actors who have identified the 'mechanisms' recommend adopting a 'dual-track strategy' that takes into account both continuity and discontinuity.

> There is no single approach or mechanism that would achieve, on its own, the preservation of RK&M over centuries and millennia. To state it bluntly, simply putting up a marker or dumping records in an archive will not do much. Rather, a systemic RK&M preservation strategy is needed. This strategy must include a variety of RK&M transmission approaches with multiple mechanisms and different key characteristics, that are integrated with one another or that are complementary, act as indexes to each other, and provide for diversity and redundancy, and with a view to maximizing information accessibility, understandability, and survivability over the various timescales considered (RK&M final report 2019: 47).

ENSURING THE PERMANENCE OF INFORMATION

In order to transmit information for a period of several thousand years, those in charge of radioactive waste disposal projects seek to ensure the preservation of memory by means of media that are as immutable as possible, and ideally protected from wear and tear as well as from accidents of fate. Thus, the 'mechanisms' included in the 'toolbox' must be, as it were, able to persevere in their being. In this regard, the fact that a robust memory preservation medium does not require maintenance for several millennia is not only interesting from an economic point of view, but it is also and above all a component of its reliability. This reflection approach invites to think about materials that are as unalterable as possible, such as permanent paper or other inscription materials such as sapphire. However, the fragility of these materials soon becomes evident. Protected from

light and humidity, the detailed archives are consulted only on rare occasions, and when they are, they are handled wearing gloves … In a space open to the public, such as the Meuse/Haute-Marne center of Andra, visitors are no longer allowed to handle the sapphire disks—even though they are considered particularly durable—because some of them were broken as a result of being dropped (interview with archivist).

The designers of the RK&M 'mechanisms' often emphasize that the production of permanence, for example that of the relevance of a piece of information, requires continuous reactivation. The logic underlying visible time capsules designed to be opened on a regular basis ('mechanism' in the RK&M 'toolbox') is exemplary in this respect. The opening of the capsules at pre-defined times, can also be combined with their physical maintenance. It also makes it possible to monitor the state of their content and to update it to reduce the risks of desynchronization between the latter and the cognitive capacities of the recipients who will open it.

Moreover, instead of creating single information materials, which prove to be fragile, would it not be judicious, in order to ensure a degree of permanence, to ask ourselves to what extent their multiplicity could constitute an asset, and to bet on the fact that while one medium is fragile, two media—or better, **n** media integrated in different environments—will be less so? We note, for example, that for the designers of the RK&M 'mechanisms,' the preservation of information does not rely solely on the authenticity of original documents gathered in a single site, similarly to how archives are usually conceived, but multiple geographically dispersed copies. Posted in town halls, distributed in schools, deposited in time capsules, and in museums, The 'Key Information File' (which are short documents providing a summary of the location, content, and purpose of the facility) should, according to the authors of this 'mechanism,' 'be as widely distributed and accessible as possible.'

MARKERS FOR TRANSMITTING MEMORY

This logic of multiplicity also underlies many of the 'mechanisms' contained in the 'toolbox.' Among these, those that are part of the 'Markers' approach caught our attention because of the diversity of meanings they take on according to their location with respect to radioactive waste. Markers must indicate the proximity of the radioactive waste storage sites. The RK&M program distinguishes five types of markers, differentiated according to the depth at which they are positioned (surface, subsurface and deep), keeping in mind that the deeper a marker is buried, the closer it is to the radioactive waste.

Concerning surface markers, the RK&M initiative recommends the construction of monuments that can withstand erosion for several millennia without requiring maintenance. Because of their size, they can easily be associated with various forms of media insofar as they can house a time capsule, be included in cultural heritage inventories and catalogues, or serve as media for various collective commemoration events. While they do not provide an absolute guarantee against the risk of dilution of the meaning that underlay the design of the monuments, these potential 'references' to other memory preservation mechanisms are thought to ensure a degree of continuity.

On the surface still, some anthropogenic traces of past construction activities or activities of the storage facility may be deliberately left visible, maintained, and even highlighted in order to 'stimulate interest' and encourage people to look for other clues or additional information about the site. It should be noted that for the authors of the RK&M reports, from the perspective of industrial efficiency and economy, this 'mechanism' is based on the enhancement and utilization of the traces inevitably left by the construction site and that, unlike monumental constructions, the production of artefacts has no direct cost and the expenses related to their maintenance remain relatively low.

At this level, surface markers are strategically placed 'at or near the site' for 'immediate visual recognition' to attract attention. To this end, they must be explicitly differentiated from 'natural' shapes and colors. Consistency in their size and in the materials they are composed of must be a clear indication that they are artifacts. Thus, their shape makes them noticeable, and their function is to arouse the curiosity of those who will discover them. Vulnerable to theft or vandalism, and to erosion that may disperse them in the landscape, but built to last, these objects are seen by RK&M participants as capable of surviving without requiring any particular maintenance. Consequently, even if other memory preservation mechanisms 'are lost,' these markers should theoretically still be able to 'preserve or regenerate awareness' of the storage site's existence.

At another level, the RK&M reports advocate burying identical artifacts in the subsurface directly below ground level. Despite their similarity in shape and material to surface markers, they have a different role. The aim is no longer to target the curiosity of those who find them. The fact sheet describing this 'mechanism' mentions that when they are discovered, these markers must 'create awareness of the presence of hazardous waste material at the site' and serve as an explicit warning likely to 'deter intrusions.' In addition to the message that each of these objects is intended to convey, their number and spatial distribution are 'indicators' that clarify the nature of the human activity that gave rise to the creation of the site on which they are discovered. Sheltered from climate variations as well as from the jolts of history, the temporal stability of those buried artifacts is reinforced and more likely to resist over time than surface markers.

Finally, regarding the deeper levels, the RK&M report identifies 'deeply buried markers' that are meant to 'intercept' and 'dissuade' accidental intruders before they draw too close to the nuclear waste repository.

AN EXPERIMENT WITH MARKERS

Among the three local mechanisms studied during our ethnographic visit to Bure—development of the site's archives, creation of an Ecotheque, and a study on markers—the latter particularly caught our attention.

As part of a research project on the spatial distribution of these objects, a researcher in geoprospective studies and a geomorphologist scattered ceramic artifacts on plots of land owned by Andra in Bure. The experiment is based on the observation that, because of its extremely resistant nature, ceramics is one of the materials that archaeologists most commonly find in the field, including on the surface. In this context, the idea was first to produce specific artifacts in an innovative and resistant material. As in the RK&M recommendations, the geometric shapes and bright colors of the polymers selected for the experiment should immediately indicate that they are artifacts, and thus draw the attention of the 'archaeologists of the future' who will find them.

Considering several scenarios relating to climate and geomorphological changes, the two researchers' project proposes to drill holes of about twenty centimeters in diameter, positioned in proximity to the access roads to the storage facility, and intended to house artefacts: 'so that with the progressive erosion of the landforms, the small colored objects would be progressively exposed and scattered, just like smarties tumbling out of a box' (Geo-prospector interview; Figure 2). It should be noted, furthermore, that this type of experiment has already been conducted in archaeology, on the basis of surface prospecting and excavation data to estimate the discrepancies between the organization and positions of the buried structures and their image on the surface, considering the decomposition and displacement effects related to anthropic and natural activities (Raynaud 1998).

However, as the researcher in geo-prospective explained to us during a visit to the sites on which artifacts were dispersed and where he was taking measurements,

> The idea, for the moment, is to position the artifacts in a line on different sloping surfaces on Cigeo's land parcel and see what happens… this may seem trivial and basic, but, at least, it already gives us an idea of how the small objects move, how they are carried away by the rains, how they react to meteorological variations, to agricultural practices… (Geo-prospector interview).

Upon arrival at one of the three areas selected for the experiment, the researcher finds that the artifacts have moved 2m50 to about 4m50 from the original spot where they had been positioned seven months previously. However, as can be seen on the images below (Figures 3–5), these objects designed to last thousands of years, are totally discolored, often broken, and can easily be confused with the limestone fragments that litter the gravely soil of the fields on which they were dispersed.

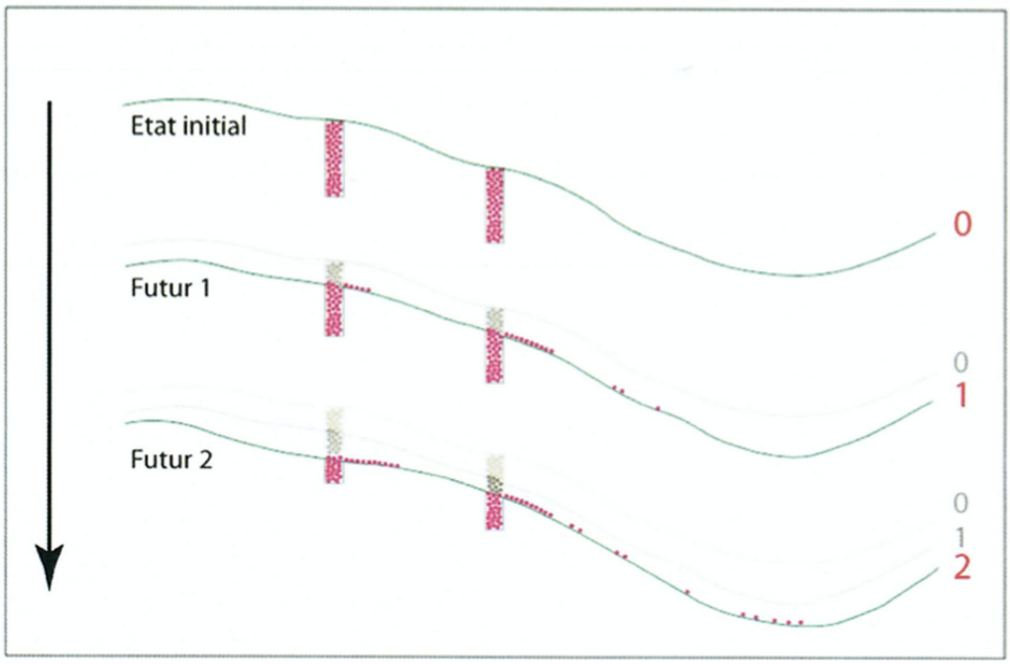

Figure 2 Concept of marking, using small objects placed in holes drilled in the ground and gradually dispersing with erosion of the ground surface (diagram: Geoprospective researcher).

Figure 3 Credit: C. Guinchard.

Figure 4 Credit: C. Guinchard.

Figure 5 Credit: C. Guinchard.

On the last dispersal area where we accompany him, despite having a record of the exact coordinates of the location where they were originally positioned, the artifacts are nowhere to be found and seem to have completely disappeared, which seems very surprising since in the same field, another area is perfectly identifiable. With her experience in archaeological surveys and landscape analysis one of the authors was able to realize, and pointed out to the researcher, that the municipal road was much closer to this test area than to those observed previously. Thus, it is quite possible that someone saw the two colleagues depositing the artifacts and returned to steal them after their departure. We agree with the interviewee that in recent years, the Cigeo project seems to have given rise, among Bure's residents and activists in the region and beyond, to an anti-nuclear sentiment. In this respect, the frequent occupation by protesters, of Lejuc Wood, now owned by Andra, is only one of the most publicized examples. Our guide confides to us: 'The tensions are such that at the time when we deposited the artifacts, two Andra cars were accompanying us! Not very discreet indeed…' (Geo-prospector interview).

Beyond the human disturbances affecting this experiment, if the 'dual-track strategy' recommended by the RK&M program is adopted, one could think that the observed fragility of the markers will—possibly—be compensated for by mediated approaches seeking to provide continuity. In this perspective, during our fieldwork, one of Andra's communication managers, in charge of the local 'memory group' (composed of inhabitants of the Bure area and set up by the agency), clearly explained to us that the aim was not to think about memory solely in terms of a 'great leap' into the future, but rather to promote a local dynamic of reflection and intergenerational transmission. Instead of targeting a recipient whose characteristics can obviously not be clearly defined, the members of the 'memory group' that she leads attempt to transmit the memory of the radioactive waste storage sites to their children and grandchildren. This is done, for example, through the production and distribution of a comic book (Juillot & Munasinghe 2019). This comic book tells the story of a young adult 'in the very distant future' who, by chance, discovers in a forest a surface marker in the form of a red sphere that will gradually lead him to discover what lies deep down. Through this type of undertaking and modest objects, the members of the memory group progressively build a future that reveals its irreducible part of uncertainty when one seeks to abruptly move away from the present, in a single leap. They try to develop a form of perseverance, step by step, by updating, with every step, the position of what should be maintained within the flow of time. It is clear, however, that there remain more unforeseen events than foreseen ones and, this permanent construction of the future, aimed at the near future more than the distant future, cannot exclude the emergence of the unforeseeable events.

Pondering the discolored, broken markers as well as those which were quite probably stolen, the researcher we accompanied felt some bitterness. The fragility of this 'mechanism' is already visible today and places us in a situation quite different from those described in the recommendations provided in the RK&M fact sheets and the comic strips mentioned above. But, for transmission to occur, one must risk taking the first actions. Is it necessary to maintain the perseverance of local actors over the generations? Where and when does the multi-millennial future discussed in Andra's 'Memory for Future Generations' program and the RK&M reflection, begin?

The answer to these questions is not obvious, but it is constructed here and now, in the interaction between an industrial project that seeks to become real, international, and national recommendations concerning the safeguarding of information and knowledge, and the irreducible complexity of a concrete territory. By projecting the markers directly into the most distant future, or by trying to transmit information from generation to generation, the goal is to escape the unpredictable jolts of history. To avoid an accident, one of the solutions refers directly to a future that has not yet arrived, the other invites us to ensure the meaning of the information concerning the sites lasts over the generations. It is therefore difficult to claim that these projections and this perseverance participate in a regime of 'presentist' historicity, without a past or future (Hartog 2003).

DISCUSSION AND CONCLUSION

This article presents an analysis of how the actors in charge of radioactive waste management seek to convey information and warnings about the existence of disposal sites. We wish to highlight below the underlying foundations of their reasoning and conclude by considering the fact that grappling with the territories within which the geological disposal projects must be embedded necessarily.

PERSEVERANCE AS A BASIS FOR CONTINUITY

Our analysis of the 'toolbox' developed in the framework of the RK&M program has, first of all, shown that its designers envisage the need to use two modes of memory transmission. In this respect, it should be noted that these two modes differ in their relation to the future. Indeed, in the context of the creation of a mediated link to the future, the authors of the RK&M reports attempt to produce continuity by relying on a logic of transmission, on the scale of the generations that will follow one another, enabling each generation to take measures likely to affect the availability and intelligibility of the information for the next one.

In parallel with, but conversely to this, the authors make the hypothesis of great and sudden cultural transformations occurring and envisage a sort of historical short-circuit, an unmediated leap through time towards the future recipients of messages and information regarding radioactive waste. In this case, they focus particularly on what will happen at a key moment of encounter between an addressee and the message they address to her/him – whatever the temporal distance that separates them.

While the designers of the 'toolbox' emphasize the need to adopt a 'dual-track strategy' in order to mitigate the strengths and weaknesses of each mode of transmission, this strategy does not eliminate the risk of degradation or even disappearance of the artefacts used, and therefore of the information and memory. Thus, to compensate for the impossibility, for certain 'mechanisms' to preserve themselves over time, the participants in the RK&M program deemed it necessary that each of them be accompanied, or even backed, by other forms of 'memory.' It is with this in mind that they recommend associating surface markers (such as monuments) with commemorations, commemorative architectural works as well as with entries into heritage inventories that would remind future readers of their existence and designate them as objects worthy of attention. In this respect, one should keep in mind that the history and practice of archaeology demonstrates that this attention is central, as Alain Schnapp emphasizes in his book entitled 'A Universal History of Ruins' (2020).

Similarly, they have deemed it necessary to produce a multiplicity of geographically and widely distributed copies of informational documents and consider that their large number would help to mitigate the degradation or the disappearance of their 'duplicates' (for example, the case of Key Information File). It should also be noted that, from the point of view of their physical material, each occurrence is irreducibly different from the others. All the copies are stored in various places; they are in the hands and under the gaze of different people. For this 'mechanism' to reinforce the preservation of information, knowledge, and memory, it is necessary for the media to be materially distinct and geographically dispersed, though the message they carry is identical.

However, preserving this identity also raises a problem. The conservation of information that escapes change risks disconnecting it from material and symbolic changes in the context that has given it meaning. The designers of the RK&M 'mechanisms' do indeed constantly raise the question of these possible breaks in intelligibility and dissonances of meaning. Thus, the cognitive gap produced by the opening of a time capsule, far from making a fraction of the past intelligible, could reinforce certain cultural tensions. A good example of this is the controversies around the simple recognition and interpretation of Altamira paintings. To try to overcome the problem of a break in the intelligibility of the message, it is recommended that time capsules be opened at regular intervals. These openings can help the collective memory to be revived through the combination of these two forms, namely recollection memory and habit memory. In this way, the relevance of the information can be maintained through changes, or even thanks to them.

In order to better understand what is preserved through such regular and periodic adjustments, we can reflect anew on the story of Theseus' ship as told by Plutarch. It is known that the ship of Athens' founder was piously preserved by the citizens. But it was preserved only thanks to the regular replacement of the parts that had worn out over time. Philosophers have used this situation as a kind of exemplary exercise for reflection on identity: when more than half of the ship's parts have been changed, can one say that it is still the same ship? Since the previously existing parts are still more numerous than those that are replaced, one can think that the ship stays the same more than it changes, but is the identity of the whole maintained when a situation is reached where all the components of the ship have finally been changed? It is, ultimately, by transforming itself that the ship is maintained in time, thanks to the continuous efforts of the Athenians. From the perspective of our discussion, it is relevant to note that the ship is preserved because the Athenians care about it and it is therefore still meaningful to them. What matters is much less the permanence of its physical properties than the perseverance of those who keep on repairing it by changing its parts. Without this fidelity to an initial commitment, the ship would have been broken up long ago. As a counterexample, one can refer to the Buzludzha monument erected in 1974 to the glory of Bulgarian communism, monument whose state of disrepair seems to reflect more the absence of desire to preserve the memory of this country's political history, than a mere lack of maintenance (Minard 2018).

Following from the considerations above, it is probably appropriate to consider the intangible and collective dimension of perseverance to better understand the scope of RK&M 'mechanisms.' *Mediologists* thus express what the designers of RK&M mechanisms emphasize in their own way:

> If I do not include communication in a community, that is to say if I don't create a chain of people who will possess the memory, a chain of people who will transmit the memory, who will be able to reawaken the meaning that lies dormant in the traces, who will be able to understand what we have written, if I do not couple a dead memory with a living memory, I won't succeed in a transmission operation. In transmission, there is both the communication of a message and the constitution of a community (Debray 1998: 35).

However, examples show that the constitution of a community is not necessarily a guarantee of successful transmission (Harmansah 2015). If perseverance in the transmission of memory is indispensable, it is not sufficient.

THE COMPRESSION OF TIME AROUND THE DECISIVE MOMENT OF INTERPELLATION

The designers of the RK&M 'mechanisms' also recognize that collective perseverance is fragile, that it can be lacking and that alternatives must be considered. Thus, it is important to emphasize that, along with the reinforcement of memory and the efforts to structure different forms of time periods, they attempt to minimize the effects of the emergence of hazards by organizing the format of possible encounters. Regarding the markers, one can think of coins and ceramic shards that one sometimes discovers by chance, but whose concentration calls for further investigation, sometimes leading to the implementation of archaeological excavations. As those artefacts can sometimes become 'what remains when we have forgotten everything,' they must make it possible to unleash a form of inductive reasoning based on a kind of 'encounter,' reminiscent of the logic of serendipity (Merton & Barber 2004), provided that people feel concerned or intrigued (Schnapp 2020).

Regarding markers, as one goes deeper down the geological layers, the goal is less to preserve a memory and to convey an informative content than to arouse, at the key moment when an individual might be getting too close to the radioactive waste, the feeling of being an 'intruder.' Indeed, whereas the maintained remnants or markers positioned on the surface are intended to arouse curiosity and to trigger inductive reasoning, the markers buried under the surface or in the deeper layers give less detailed information, and instead provide short and sharp messages intended to provoke recoil and retreat. At this depth, the need to inform is not eliminated but this function is entrusted to other 'mechanisms' such as time capsules which could contain relatively detailed information, and the function of markers is more to warn of an increasingly immediate danger.

Faced with the possible deterioration of a symbolic universe common to the transmitters and receivers of the message they carry, the markers present under the surface (or in deep geological layers) seem to alarm those who discover them more than they inform them or arouse their curiosity. The intention is no longer to invite a 'discoverer' to investigate what is there and to make a series of corrective adjustments relative to the situation s/he has put her/himself in, but to spur the person now designated as an 'intruder' to leave as soon as possible. It is important to be fully aware of the fact that with the deeply buried markers, the response must be instantaneous, that there is no time to waste and that one should not hesitate to move away.

What is involved here is no longer an effort towards a construction of time, but, on the contrary, a compression of time around a key moment. The last marker must appear at the very singular moment preceding the encounter between an 'intruder' and the radioactive waste when everything could swing out of control.

At this point, to be effective and produce the expected effect, the message must possess what in ballistic terms could be called a 'stopping power' capable of abruptly stopping a course of action that would otherwise become dangerously irreversible. Far from mobilizing a prerequisite form of vigilance or discernment, this stopping power must be founded in the immediate effects of a sharp call to attention. 'Hey, you, over there!' calling out in this way to the individual concerned must make her/him turn around immediately and stop her/his activity. S/he must then bring her/himself to attention, in the manner imposed on him: that is to say, as an 'intruder.' Knowing immediately that the message is addressed to her/him, s/he must accept a kind of assignment of identity that redefines both the place s/he occupies and what s/he is doing.

The sudden call to attention causes, in the manner of a sudden break, the cognitive shift specific to a realization. For this to happen, the deeply buried marker must have the same capacity to call one to immediate attention as a sound signal would. This is how the phases of a course of action can be segmented into a 'before' and an 'after.' Doesn't this correspond to *Kairos*, which, in Ancient Greece, designated 'the critical moment when all reversals are possible?' (Trédé 2015: 46). In this regard, we can recall that *Kairos* was represented as a runner with winged feet, without hair on the back of his neck (to show that no one could grasp him from behind) and holding a razor in his hand to signify that he was 'cutting' the before from the after. With the deep markers, the authors of the RK&M reports project themselves just *before* the accident. They try to prevent it until the final moment.

We note here that that the opportunistic choice of taking charge of this moment seems to contradict the perseverance mentioned earlier, and that with the ultimate markers, the authors of the RK&M reflection become, as it were, 'engineers of opportunity' (Jankélévitch 1957).

THE CONFRONTATION OF A PROJECT WITH THE ENTANGLEMENT OF LOCAL HISTORIES

Are we, here, faced with a form of contradiction between the reflection conducted by the actors concerned by the projects for radioactive waste disposal facilities and the imperatives of action? We cannot say. But the results of our investigation point to the necessity to emphasize that the site is not a simple receptacle or a mere surface on which the radioactive waste disposal project would land, like an alien ship. Nor can it be reduced to its strictly spatial dimensions, and even less to any capacity to house such a project. It must be defined as that populated portion of space (and time) where a *project* and a *territory* meet.

In the French situation we investigated, speaking of 'Bure' to refer to the place where the waste is likely to be buried, or of 'Cigeo' to refer to the project itself, carries the risk of masking, rather than clarifying, what is at stake in this encounter. The local situation must be thought of by considering the fact that Cigeo is a fiction that is trying to become real, in Bure, specifically, and not in a 'mere' geometric space. The site constitutes a set of more or less interdependent points of encounter between the components forming the project and the local actors. Geological folding, fields and forests, road infrastructures and businesses, land titles, farmers, and elected officials, etc., 'encounter' drilling machines and heaps of soil produced by the excavation of underground galleries, activity reports, academics, Andra engineers, opponents, and helicopters regularly flying over the area. All of them have their courses of action and characteristics mutually altered. The dirt road that used to connect the fields to the farms acquires a different meaning when it is used daily by construction equipment, geological researchers and/or security patrols. Similarly, the construction of the storage facility's decline must adjust to the occupation, by opponents to the project, of the land where it was planned to take place. All involved must redefine their place, learn to situate or resituate themselves in an environment that may now seem confusing, which can sometimes create great tensions. It is in this sense that it seems important to point out that the question of memory is in some way 'entangled in histories' (Schapp 1982).

CONCLUSION

Whether it is by setting up warning signs addressed to an addressee so far from the present that s/he cannot be figured and may be inaccessible, or by taking the trouble of ceaselessly repeating, from today till tomorrow, for millennia, the action that is constitutive of memory, it is necessary to initiate a beginning. It is in the complexity, or even the confusion, of this moment that the relation to time takes shape; time whose "genealogy" we have proposed here (Foucault 1971).

NOTE

1 Given the radionuclides concerned, the time required for this decay to occur is measured in thousands or even hundreds of thousands of years.

ADDITIONAL FILE

The additional file for this article can be found as follows:

- **Appendices.** Appendix 1 to 3. DOI: https://doi.org/10.5334/wwwj.75.s1

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