Figure 1. Several puys in the Auvergne district, France. Photo by Sarah Trevino.

Auvergne District, France: How Places, People, and Ideas Influence the Mind

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Geology logline: *The recognition of volcanoes and basalt flows of the Auvergne district, France, resulted in the rejection of the Neptunist model of the Earth proposed by Abraham Werner. Yet some geological thinking influenced by the Neptunist model—looking for worldwide patterns of deposition—remains and is useful.*

Cognitive science logline: *Collective understanding builds among minds over time as individuals contribute their experience to form ideas, which no one might have had on their own. This collective understanding, in geology, is guided by the information from the world—particularly places that have influenced the geological mind.*

"Let us consult nature herself, who usually leaves recognizable traces of her operations… [Consultons la nature elle-même, qui laisse ordinairement des traces reconnoissables de ses opérations,…]"

—N. Desmarest (1753, p. 97; English translation adapted from Taylor, 2001a, p. 44)

The Auvergne district has an outsize influence in the history of geology, in large part because it is one of the most accessible volcanic fields in western Europe. These volcanoes of central France first erupted ~100,000 years ago and stopped ~10,000 years ago. The Auvergne volcanic district is also known as the Chaîne des Puys, with a "Puy" referring to a rounded hill (Fig. 1). When geologists first worked in the Auvergne district, Neptunism was the dominant model

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for thinking about the Earth. The Neptunists believed that all rocks observed at the surface today were a result of deposition from ocean water. The idea was advocated by German geologist Abraham Werner, a mineralogist of some distinction and a charismatic lecturer. He was responsible for attracting students from all over Europe to the Academy of Freiburg, Germany. Werner attempted to provide a stratigraphic order that would work anywhere on Earth. In this model, all rocks were formed as chemical precipitates or clastic sedimentary deposits in a worldwide ocean.

The geology school at Freiburg had previously introduced a universal system for classifying minerals (Werner, 1774). Werner's attempt to classify deposition applied a similar strategy to rocks at the scale of the Earth. The competing worldview at that time was that of the Plutonists, whose proponents included James Hutton. Plutonists interpreted igneous rocks as the result of cooling magmas.

Nicolas Desmarest was one of the first geologists to study the Auvergne district. He started working in the region in the 1760s, published on it in 1771 (Desmarest, 1771), and finally produced a geological map in 1806 (Fig. 2). In a narrative of science that focuses on individual discovery, Desmarest has a credible claim to be the first person that did geology in a manner that would be recognizable to contemporary practitioners (Oldroyd, 1996; we note that a reasonable case could also be made for Nicolas Steno or James Hutton). Desmarest recognized that the Puys were volcanoes, and that molten rocks flowed from these edifices. He identified the basaltic rocks, observed cross-cutting relations and differential weathering to determine a chronology of the basalt flows, and constructed a plausible sequence of events (e.g., a history) that would explain his observations.

Desmarest's work influenced the Plutonist versus Neptunist debate at the time. When Desmarest was asked about which camp he fell into, he apparently told others to "go see for yourself." And they did, including Charles Lyell, George Scrope, and—most importantly—Werner's star student, Leopold von Buch. In the Auvergne, von Buch was convinced that Neptunism was incorrect, at least as to the origin of basalt. The geology of the Auvergne district itself was sufficiently convincing that the region is called the "Graveyard of Neptunism."

Or so goes the story. The reality is more complex and more nuanced. Desmarest was an outstanding geologist, but it was not only his contributions that pushed the debate to its conclusion. We have often focused on a single geologist (e.g., G.K. Gilbert, H. Whittington) in a "great geologist" approach for this essay series, because it simplifies the narrative. The same is true for the role of the mind; we have simplified the cognitive science narrative to focus on a point for each essay. The downside of such an approach is that it promotes a simplistic understanding of the Earth and the mind and suggests that scientific progress is linear. To atone for our past narratives and to address these issues, the main theses of this essay are: (1) science is done by communities, not individuals; (2) science practice is influenced by prior researchers and their mental models; and (3) places are foundational to geological thought. We end this final essay with an articulation of a cognitive science–informed perspective of geology.

#1: SCIENCE IS DONE BY COMMUNITIES

The history of geologists' understanding of the Auvergne illustrates how ideas emerge from being passed among minds. Consider our modern understanding of who contributed to that understanding. Desmarest reasoned about temporal sequences using the apparent ending and continuation of linear distributions of basalts, a form of spatial reasoning now referred to as cross-cutting relationships. Antoine Lavoisier, who would go on to achieve renown for his work in chemistry, saw differentiation in rocks (e.g., mudstone versus sandstone) and linked rock chemistry to the environmental conditions where the rocks formed. Scrope observed that smoother basalt flows were connected to vents and rougher basalt flows were not connected to vents. Using this evidence, he suggested that the former basalts had experienced less weathering and were younger.

The ideas from the Auvergne were not the only ones relevant to the Auvergne. Ideas from the mining district around Freiburg, Germany, were particularly influential. Despite pursuing a theory that was grounded in a Noachian flood, in which a single event caused layering from the erosion of primitive original rocks, Johann Gottlob Lehmann nevertheless observed discrete layers that align with major stratigraphic boundaries. Even absent a theory of deep time, he could perceive part of the story the rocks were telling him, and that there was a significant change at the Paleozoic–Mesozoic boundary.

In the Auvergne, we can see that many scientists had useful contributions; Desmarest did not figure out the Auvergne in a solo effort. What has gotten lost in a narrative of science—which emphasizes testing, rejecting, and accepting theories—is the way ideas intermingle. The role of communities in science has been highlighted in a variety of ways including cognition distributed across a social group (Hutchins, 1995; Giere, 2002), and science communities as a type of community of practice (Wenger, 1998; Kienle and Wessner, 2005).

Given the role of the community, why do scientific narratives tend to focus on the individual? To answer this question, we focus on an insight from the social sciences: How we think about the mind influences how it is used. For the past 250 years, there has been an analogy of the mind being like a machine (de La Mettrie, 1749). As part of the cybernetic revolution of the 1960s, with the earliest public gleanings of how computers work, the analogy gets updated to the mind being like a computer. This approach will bias the believer toward an "industrial" model of thinking: Input from the world, in the form of perception, is processed, the result is sent on for yet more processing, and still more processing, until a final output in the form of an idea or action emerges (Neisser, 1976). Moreover, it implies that the mind will work at its best alone, without interruption.

Yet science is not built piece by piece. Despite the mechanical/computational narrative of the mind, no scientist moves smoothly from data collection or theoretical calculation (input) to generating a fully formed final interpretation (output). Multiple authors have made the case that this approach is flawed for experts in the workplace (e.g., Epstein, 2019) and students in classrooms constructing knowledge in pieces (e.g., diSessa, 1993). This essay series too argues against the assumptions that underly it (Shipley and Tikoff, 2025). The isolation of ideas in the mind of a single person may be analogous to seeing discrete objects and discrete events, reflecting a tendency to segment the world into packets to aid thinking and communicating. To credit individual scientists reflects a particular way of thinking about the way the mind works, and misses the point that science is the most effective and profound group effort in human history. One approaches doing science as a one-mind job at the peril of missing the opportunity to do even better science with multiple minds.

A better analogy for science and the mind is a conversation where a good idea emerges from the passing of ideas back and forth between participants. Here, the participants could even be the same person at different points in time, such as when one writes notes for a future self to support reengaging with the ideas to come to a new understanding. The conversation acts both as a test to filter for ideas that are not working and a way to construct new ideas. Both the filtering and constructing are distributed among the conversationalists. Thus, despite a human propensity to focus on discrete objects, a single isolated mind is not the best "scale" to understand new ideas. To understand this concept, we make an analogy to ecology. Within an ecosystem, the order often exists at a systems level, rather than the level of an individual organism or species. That is, studying any single organism or even species, which may be highly salient features of the system, nevertheless misses the point. Rather, the most fundamental regularity exists at the interactions among species (e.g., a negative feedback loop in predator-prey systems).

Even in our community narrative of understanding the geology of the Auvergne, our credit to individuals is suspect. Narratives of science commonly hold out an individual scientist as the person with a critical insight. This approach often reflects a gross simplification. Kuhn (1963) makes this point about who discovered oxygen: A credible case can be made for Joseph Priestly, Lavoisier, or Carl Wilhelm Scheele. The focus on a uniquely responsible person misses the point—it was all of them, and many others. We emphasize that this approach does nothing to diminish our esteem for any individual scientist, including Desmarest. It does suggest, however, that they are perhaps better regarded as human milestones (to use a rock-based analogy) along a path to our current understanding.

#2: SCIENCE PRACTICE IS INFLUENCED BY PRIOR RESEARCHERS AND THEIR MENTAL MODELS

We are unambiguously influenced by past researchers, how they chose to study, and the places that they chose to investigate (e.g., Oreskes, 1999). This situation occurs, at least in part, because prior research influences mental models and disciplinary practice, and hence the training of scientists. An informative example from the history of natural science contrasts the work of Linnaeus and Buffon. Although Linnaeus is well known to science students, his approach arguably interfered with recognizing the complexity of the natural world. He had worked to advance biology by the application of careful, but rigid, categories. His categories were guided by religious theories that were not tied to information in the world (Roberts, 2024). In contrast, Buffon's approach to natural history (Buffon, 1749–1767) was to make careful observations and withhold classification until constellations of observations began to cohere into patterns. Desmarest was influenced by Buffon's approach of letting the world inform categories (Taylor, 2001b).

A historical summary of the era might offer a simplistic idea that Plutonism was correct and Neptunism was incorrect. After all, the Auvergne district is the "Graveyard of Neptunism." The story, however, is more complicated. Science is not a competition, akin to a sporting event. The language of competition—"winners" and "losers"—reveals a tendency for black-and-white, winner-takes-all thinking. Even if the theories held by early Neptunists were incorrect, their approach yielded significant contributions to geology, because the theories did not prevent useful observations. We now know that there are worldwide patterns of sedimentary deposition, an idea recognized and popularized by Laurence Sloss (the so-called Sloss cycles; Sloss, 1963). Sedimentological records, including observations originally made by Neptunists, allowed the development of a worldwide sea-level curve that goes back to the Mesozoic (Haq et al., 1987).

We make a more specific ecological analogy to emphasize this point. Just as removing all predators does not benefit a prey species in the long term, so too discarding theorists and entire theories likely detrimental to science. We see, in the history of geological thinking about the Auvergne, evidence of parts of ideas coming together and moving into disciplinary practices so completely that today they barely register as a theory. By acknowledging how ideas merge, we may avoid ignoring the parts of competing theories that are fractionally correct.

The downfall of Neptunism reflects two aspects of science that contribute to both its successes and failures. First, when Werner extrapolated, he went far beyond the data to offer a theory. The extrapolation addressed aspects of the world for which it simply did not apply. Second, his model did not change after problematical observations came to light. It is important to recognize that both defects are the downside of a strength of the mind. Categorizing and building models requires extracting regularities from variability, and doing so requires going beyond what is at hand. The extraction of regularity in model building requires ignoring some of the variability, implicitly assigning it to be either noise or minor to-be-explained-later aspects of a model. Sometimes noise is just noise, and perseverance is warranted; other times, variability is the motivation to construct a better model. The scientific challenge lies in correctly discerning signals, or partial signals, when faced with this uncertainty.

The “bundling” of ideas, because they were jointly held by an individual, is another consequence of our focus on individual scientists. In the Neptunism versus Plutonism debate, the associated theories were Catastrophism versus Uniformitarianism, respectively. Because Neptunism was associated with a catastrophic flood, it makes sense that it is associated with Catastrophism. But the story goes beyond the scientific into the social considerations. Because Hutton was both a Plutonist and a Uniformitarianist, those two viewpoints are often associated, but they are not logically dependent on each other. Consequently, a person can be correct about one theory and wrong about another (or more right about one theory and less right about another). This lumping or bundling of theories is a pattern observable in the history of geology. Awareness of mentally bundled theories provides an opening to recognize and retain the correct parts in order to facilitate progress.

One might argue that Plutonism/Uniformitarianism “won” in the 1800s. However, the adherence to this unimodal approach was arguably to the collective detriment of geology. Consider the difficulty of acceptance of ideas that called on catastrophic events, including floods in the Channeled Scablands (J Harlan Bretz, J. Pardee, and others) or the end-Cretaceous meteorite impact (W. Alvarez, L. Alvarez, F. Asaro, H. Michel, and others). To insist that a particular viewpoint is the only way to address a problem impedes scientific progress because, among other reasons, it stifles creativity by shutting down conversation.

#3: PLACES ARE FOUNDATIONAL TO GEOLOGICAL THOUGHT

Choose any historical contingency and follow it, and you will see potential for an altered development of scientific ideas. If Desmarest, with his intense curiosity, had found something else to study, he would not have worked on the Auvergne. Whatever made Lavoisier chose chemistry over geology could have worked in the opposite direction and would have altered the course of both fields. On a personal level, almost all scientists recognize that their careers were altered by subtle and seemingly arbitrary personal decisions (e.g., Greene, 2015). Our individual destinies are controlled, more than we care to admit, by blind chance.

However, in our view, replace any individual or theory and a community of minds capable of extracting information from the world will converge on similar models of the world. This conclusion is at odds with observers of science who focus on the influence of social interactions in construction

A

B

Figure 2. Part of the key (A) and part of the map (B) of the Auvergne district by N. Desmeret (1771). From the collection of Bibliothèque nationale de France, as reproduced by Szaniawska (2018); available under Creative Common License 3.0.

of meaning (e.g., Latour and Woolgar, 1986); this viewpoint downplays the availability of Earth’s patterns that directly inform the mind of the causal processes. Scientists do not add meaning; rather, they discern the patterns that can be noticed as a record of a process. It is statistically true that the patterns are unlikely to be noticed if theory does not predict them. But critically, once the pattern is seen, it cannot be unseen, regardless of the popularity of extant theories. This emphasizes the power of empirical, place-based data to correct errors in theory.

For the geological mind, thinking to understand the geological history of a place and the place itself are intrinsically and intricately linked. The locale constrains plausible interpretations and offers evidence for new ideas. While preconceptions can moderate both processes, geologists would have eventually figured it out, regardless of the interpretations of earlier workers. For example, if the Auvergne district was inaccessible, determining the relative chronology of different lava flows would have been worked out somewhere else where the same patterns occur. Nature leaves its traces, as per Desmarest’s point, and these traces have an order that allows conclusions independent of belief systems. These places—particularly exemplars—can reveal previously unrecognized processes and change minds. In the Auvergne, we can see belief systems change in response to observations, such as in the case of von Buch.

This literal and metaphorical grounding is not a property of all sciences. Consider, in contrast, the history of economic behavior, where arguably introducing a theory that humans respond to economic incentives created the conditions where the theory became true (see Schwartz, 1986; Graber and Wengrow, 2023). Believing that humans respond to economic incentives led to imposing systems of economic incentives, which led to people responding to incentives that had not previously controlled their behavior. In the social sciences, one could credibly argue that humans can invent their own reality; in the natural sciences, to accept the same statement is a route to catastrophe.

The importance of places in geology is the equivalent of the importance of reproducible experiments in the experimental sciences. They are the empirical foundations from which science proceeds. Places can be revisited with new ideas and analytical tools, in the same way that more precise experiments can be run. Places are essential to our understanding of Earth.

TOWARD A COGNITIVE SCIENCE–INFORMED PERSPECTIVE OF SCIENCE

In this section, we address both naïve perspectives on conducting science and criticisms of scientific discovery. Our perspective on science—gained by working on the interface of natural science and cognitive science—argues against two contradictory models: (1) scientific knowledge is an accumulation of truth through the application of the scientific method (scientific determinism); and (2) scientific knowledge is the society of scientists' agreed-upon socially constructed beliefs (social constructivism). We argue that neither is correct, but similar to Neptunism and Plutonism, there are attributes of both that are useful.

Scientific determinism is incorrect for a variety of reasons, many of which were discussed in this essay series. First, studies in the history of science indicate that there is no single scientific method (e.g., Oreskes, 1999). Second, human perception is not wholly accurate (e.g., Shipley and Tikoff, 2025). Third, the social milieu in which scientists work affects their preconceived notions. The mind is not a precise machine uninfluenced by others, but neither does understanding of the world come completely from others. Fourth, other minds may guide what patterns are noticed. Consequently, it takes a long time to change people's minds (Oreskes, 1999; Tikoff and Shipley, 2025).

Social constructivism is based on the idea that all knowledge is socially constructed. The reasons to adopt social constructivism are all the problems listed above for scientific determinism. Social constructivism fails as a model, however, because scientists in the natural sciences are not wholly constrained by surrounding beliefs. Each essay in this series describes a different example of a place that allowed geologists to understand Earth, regardless of their *a priori* beliefs.

Scientific knowledge as a social construct fails because Earth—and nature more generally—does not change its processes in response to what humans believe. In this respect, we return to Desmarest's quote at the beginning of the essay. It illustrates his belief in a process of science, and his thinking that science is self-correcting because erroneous bias cannot survive input from the world. Perception provides the patterns that conform, or not, to expectations. When the patterns of the world do not conform to our beliefs, the mind changes to align with the world. Although this change may take some time, it does occur.

In summary, both scientific determinism and social constructivism individually fail. But there is a middle path that lies at the intersection of the social and natural sciences.

Throughout this essay series, we have investigated individuals or small groups of people who have made major conceptual leaps that led to new understanding, based on observations in a place. There is a commonality to those investigators: They were intellectually flexible, creative, and had insights that relied on the nonlinearity of the human mind. While the essays often dealt with the limitation of the mind, we have also tried to illustrate the capacity of minds to develop clear insights about the world. Moreover, in the arena of scientific research, multiple minds can cooperate to build a powerful idea to see something new about an area that has been present for eons.

One of the many ways in which the human mind is wonderful lies in its ability to take a small number of observations and infer patterns. The unexpected success of this process is the accuracy of the conclusions, given the paucity of input. This achievement relies on a capacity to link ideas and observations that, on the surface, bear little resemblance but share enough structure that allow alignment of past experiences to the present sparse input. Furthermore, this process is not dependent solely on memory. Rather, when confronted with novel situations, the mind can use the available patterns to make accurate inferences and interpretations. These thinking skills support both individual action and group communication. The human capacity to find patterns endows a community of minds with creativity, collaborating to build ideas that are bigger than any single mind could achieve (Woolley et al., 2010).

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Postscript: Our Individual Reflection on the Places and Minds

HOW PLACE INFLUENCES THE GEOLOGICAL MIND: A PSYCHOLOGIST'S VIEW

"The mountains are calling and I must go, and I will work on while I can, studying incessantly."

—J. Muir (1873)

Places keep on giving. Geologists revisit places to ask new questions and revisit old questions. The observations of previous generations of geologists are still useful, despite changes in theories; pre-tectonics maps are still valuable for the practice of the science. Geologists are both figuratively and literally grounded by "place."

As we wrote these essays, I mused about whether psychology had an analog to place. In the end, I think that there is no equivalent touchstone for my field. There are studies that were done 50 years ago and more that are considered important, but you cannot go find those people who were the participants in those studies to ask a new question. Even if you could find a few of the people that participated in the study, they are no longer the people that they once were. As cognitive scientists, we do not have the equivalent of 100-year-old maps that we cite in our work. Furthermore, psychology data are closely bound to the theory that generated them and as such tend not to survive theoretical revolutions. In that way, the psychology of 50 years ago is not as useful as the geology of 50 years ago. By connecting thinking to places, I hoped to offer some observations about how the mind works that will transcend specific minds and specific theories of how minds work.

I have worked with geologists for over 20 years, and it has transformed my perception of the world. Twenty years ago, mountains and islands just were. Now those places ask "why?" You, expert geology readers, will be adept at asking of the Earth "why is this the way it is?" With the aid of the geology community, I aimed to expand the scope of this simple interrogative to see where together we can improve both the sciences of the mind and of the Earth. I did not intend to wag my finger and point out all the suboptimal reasoning the human mind might engage in, but rather to look for opportunities to avoid the mind's pitfalls and use the mind's strengths toward advancing science.

Along the way I hoped to convey a sense of my own wonder. I have been moved by geologists as they experience wonder, seeing this world anew with eyes informed by knowing past worlds. Wonder, the eminent psychologist William James suggested, formed the roots of philosophy. It allows the discipline to see the world anew as it "breaks up caked prejudices" (James, 1911). In my experience in the mountains "wondering" with geologists, I have learned a lot that I did not know about the mind. I find it particularly fascinating that, to a first approximation, psychology has no satisfactory explanation for how geologists answer their most fundamental "how" and "why" questions.

HOW PLACE INFLUENCES THE GEOLOGICAL MIND: A GEOLOGIST'S VIEW

"There is only this solid sense of having had or having been or having lived something real and good and satisfying, and the knowledge that having had or been or lived these things I can never lose them again. Home is what you can take away with you."

—W. Stegner, about his adopted hometown of Salt Lake City (Stegner, 1969, p. 168–169)

For me, this essay series ends where it began: by the shorelines of Lake Bonneville outside of Salt Lake City. I was born and grew up there. In the valley of my childhood, horizonal lines—stripes on the mountains—were visible from nearly everywhere, to the east on the Wasatch front and to the west on the Oquirrh Mountains. I find it satisfying that the shorelines of my youth were the topic of one of the most influential papers on geological thought (Gilbert, 1886). If the shorelines are subconsciously part of who I am and my home, then so too are the geological reasoning and awareness of my own thinking when I consider how the shorelines formed and were uplifted.

As a geologist, however, I also have attachment to the other 11 places that we have written about. Geological exemplars and type localities embody something about the profession of geology. They are places where geologists, as a community, figured out something important about the world. Or, really, it is the place in the world where a pattern is significantly clear, that one can discover something that is more difficult to think elsewhere. Perhaps Siccar Point, Scotland, is the easiest place to make this point. I, similar to most geologists, have an attachment to this location. I recognize it immediately in a photograph. I felt compelled to go visit it. It was amazing when I got there (but that is a very steep slope).

But why do I feel an attachment to Siccar Point or the Auvergne? Tim suggested that perhaps there is a community-based "response to discovery" that is still there. The geological investigations that occurred in any of these exemplars have influenced the field of geology, and hence the training of a geologist. For example, many geologists are taught the concept of an angular unconformity—with its implications for geological time—based on a photo of Siccar Point. Because perception is tied to cognition, you remember not only the angular unconformity but you also remember having the insight about what that means. That is, it is a place—even if you only saw a picture of it—where you expanded your mind. Having your mind expanded is a compelling case for "having lived something real and good and satisfying," to use W. Stegner's (1969) words. And what I know after working with cognitive scientists is that you really do take it away with you. The geological exemplars and their interpreted processes are available to geologists anytime in the form of a mental model or a runnable mental model. If home is really what you can take away with you, then visiting one of these places is, in some ways, like visiting home. It makes geoscientists at home in the world, which is a superb side benefit for a profession.

But why should other geologists engage with cognitive science? I will make two arguments, one practical and one motivational. Here is the practical argument: Science for the sake of discovering something new about the world will likely be eclipsed by science needed to maintain a habitable planet. Scientists need to become better communicators if we are going to survive any of the potential catastrophes, many of which are self-inflicted by the human race. That goal requires knowing about the world and what goes on in the mind as it makes sense of the world and then communicating it all in an understandable way that we are not yet doing (e.g., using salience; Nelson et al., 2024). Here is the motivational argument: It allows you to do better science. To immerse yourself in the interplay between the science and the do-er of the science is to achieve yet another level of science. It provides another layer of satisfaction and will probably stop a few costly mistakes. The closest analog that I have to working with Tim is doing geological fieldwork. The immediateness of research-oriented fieldwork—with its physical and mental challenges—allows one to do "something real and good and satisfying" and know it while you are doing it. The same is true, at least for me, for understanding what is going on in the mind while doing science.

I now accept that my thinking—both consciously and unconsciously—is affected both by my past and the nature of the human mind with its strengths and limitations. Since I started working with my cognitive scientist colleague Tim, it has been a slow, hesitating, and long journey to acceptance and understanding of how my practice of geology is affected by the foibles of the human mind. I can summarize the experience in the words of an acquaintance from East High School in Salt Lake City, describing her experiences in life: It has been humbling, in a generally positive sort of way.

CONCLUSION (FROM BOTH OF US)

Thank you, reader, for joining some or all of our worldwide tour of places that have influenced the geological mind. We have made a case in this essay series for considering both the mind and the world. We argue, for the geological mind, that they are intrinsically and intricately linked. Knowing the mind's strengths and weaknesses will hopefully both make you a better scientist and make the journey more enjoyable.

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