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The Provence Coalfield: trajectory, assessment and prospective

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Human Environment Observatory

The Provence Coalfield: trajectory, assessment and prospective

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Abstract. The trajectory taken by the Provence Coalfield (or Bassin Minier de Provence), located between Aix-en-Provence and Marseille, is explained by its long mining history, disrupted by the closure of the mine in 2003. We approach this space from a global perspective, considering the social, economic and environmental dimensions of the socio-ecosystem. The conclusion puts forward scenarios for the evolution of the territory and the perspectives for research, underlining the growing role of the energy transition, especially in the context of the closure of the coal-fired power plant.

Keywords. Alumina, Coal, Energy transition, Human–environment interactions, Interdisciplinarity, Bassin Minier de Provence, Reconversion.

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1. General introduction

The need to give expression to the work of the Human–Environment Observatories (OHM) through some major themes was interpreted collectively within the Provence Coalfield Observatory (referred to as the OHM-BMP). The longevity of this research facility entered its fifteenth year in 2022. The OHM-BMP was launched in 2007 and has produced a diverse body of work since then. An initial synthesis of the origins and development of this pioneering observatory was published in 2014 [Robert and Batteau, 2014] as part of a book on human–environment interactions [Chenorkian and Robert, 2014]. The following discussions naturally use this text as a starting point. Firstly, they aim to analyse the responses of the socio-ecosystem to the *disrupting* event underpinning the OHM BMP, then the research facility and its main results. Finally, they look at the perspectives for research and the OHM-BMP's involvement in action research.

The trajectory taken by the Provence Coalfield (referred to by its French acronym BMP or Bassin Minier

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de Provence), located between Aix-en-Provence and Marseille, is explained by its long mining history (*structuring fact*); its *disrupting event*, the closure of the mine in 2003, is antagonistic to the structuring fact. We approach this space from a global perspective, considering the social, economic and environmental dimensions of the socio-ecosystem [Berkes and Folke, 1998, Lagadeuc and Chenorkian, 2009, Ostrom, 2009]. According to the terminology specific to human–environment observatories [Chenorkian, 2014], the aim is to examine how upheaval takes place, the resulting transformations, and the subsystems most affected, within a perimeter (the former employment area of the mine) made up of 17 municipalities (the focal object) representing just over 100,000 inhabitants. Here, the trajectory is studied in two distinct sequences: the first, which precedes the disrupting event, takes a retrospective observation approach; the second, following the disrupting event, seeks to highlight the points of disrupted.

To study the research system, we look at the various calls for projects, the contribution made by the different disciplines [Chenorkian, 2020] and the use of the science/society interface. The themes are analysed via a lexicographical study of the titles and research projects selected. The research results focus on the two fields that have accounted for more than half of the research projects, namely (i) alumina and the issue of bauxite residues and (ii) the question of slag heaps. However, since 2020 the energy transition has come to the forefront with the scheduled closure of the coal-fired power plant. It should be noted that these fields of research lend themselves particularly well to an interdisciplinary approach combining the physical and chemical sciences, ecology and the social sciences.

2. The transitions underway in the Provence coalfield before the *disrupting event*

2.1. *Peri-urbanization and industrial reconversion: a twofold transition starting from the 1970s–1980s*

In the final quarter of the 20th century, the Provence Coalfield followed a course similar to that of many European coalfields [Daviet, 2005, Daumalin et al., 2006], against the more specific background of French energy policies, marked by the decline of coal, the oil crisis and the development of nuclear power.

At the territorial level, the decline of coal was accompanied by a series of industrial conversion measures after the 1960s and 1970s, with different impacts depending on the mining basins and their geographical environments [Daviet, 2006]. Just outside Marseille, a twofold transition began in the 1970s–1980s, some thirty years before mining ended (2003).

On the one hand, there are the reconversion measures, which were stepped up between 1985 and 2005 through the *Fonds d'Industrialisation du Bassin Minier* (FIBM) fund, fostering the emergence of a new high-tech industrial hub focused on microelectronics, the epicentre of which was located in the northern part of the coalfield, in the municipality of Rousset [Daviet, 1999, 2002, Garnier and Zimmermann, 2006]. This new centre of activity, in one of the oldest industrial areas in the department, surpasses the former mining centre in terms of jobs (around 5000). However, it has undergone some cyclical adjustments. For example, it had 7000 jobs at the end of 2000, before the Atmel factory was wound up in 2013; its site remained unoccupied until 2022. Nonetheless, this hub is firmly anchored in a sector with metropolitan and regional scope demonstrated by the creation of the SCS (Secure Communicating Solutions) competitiveness cluster, of which Rousset is the headquarters [Dang and Longhi, 2009]. On the other hand, there has been a general trend towards peri-urbanization [Ferreira, 1988, 1991] and metropolitan expansion, affecting the whole of the area and the agricultural and rural communities in the east and south of the basin in particular, with them forming a commuter belt for people working in Aix-en-Provence and Marseille. Against this background, we witness the ongoing artificialization of land, as documented in a series of interdisciplinary studies of the BMP observatory [Keller et al., 2012].

This two-pronged development, with the emergence of a new high-tech industrial centre, on the one hand, and a process of peri-urbanization/metropolization on the other, has not occurred in a uniform manner across the region. Reflecting the components of the structuring fact, it follows a centre/periphery model in which we can distinguish two subsystems: the *Gardannais* subsystem, which is the

epicentre of the Provence Coalfield and retains its traditional attributes, and the subsystem made up of the evolving peripheral areas.

2.2. *A centre/periphery dichotomy*

2.2.1. *Gardanne, the epicentre of the Provence Coalfield*

First of all, it is necessary to observe how the area has changed over time. The mine and all the related elements (shafts and headframes, slag heaps, the mining population and miners' housing) developed from east to west over two centuries, turning Gardanne into the most emblematic town in the Provence Coalfield [Daumalin, 2005]. The alumina plant was established there at the end of the 19th century [Mioche, 1994] and the highest slag heaps, with their iconic conical shapes, are found there. The major industrial infrastructures are also concentrated there, e.g. the Gardanne–Meyreuil power station, with its high cooling towers and its 297 m chimney, the highest in France. Gardanne also hosted the last Yvon Morandat pit, with a 1109-m-deep shaft, active from 1989 to 2003. One of the last remaining communist municipalities in the Bouches-du-Rhône department remained in place here until 2020, a symbol of the labour struggles, persistent trade unionism and the socio-political identity of the basin.

2.2.2. *Evolving peripheral areas*

While the mining heritage is apparent in the landscape and in the social, political and environmental components in and around Gardanne, which stands like a fortress beleaguered by the inexorable decline of the mine, the new dynamics were first felt on the edges and in the peripheral areas of the former coalfield, crossed by the motorways to the north (A8), east (A52) and west (A51). These roads have served as centrifugal forces connecting the margins and peripheries of the basin to the metropolitan area, shaping new landscapes and welcoming new inhabitants and new activities, as can be seen in the Rousset-Peynier industrial zone. In the north, east and south of the coalfield, exogenous dynamics have become predominant [Daviet and Robert, 2012], while Gardanne has remained influenced by endogenous forces. A retrospective observation of the territorial socio-ecosystem therefore points to an open and differentiated system in the Provence Coalfield where the centre/periphery dichotomy was consolidated well before the disrupting event (Figure 1).

3. Since the disrupting event: the disruptive forces at work and the shift in the system

With a disrupting event that is antagonistic to the structuring fact, it is only natural that from 2003 onwards we head into a period of disruptions. Here we distinguish between the endogenous systemic upheavals specific to the territory itself, which mark multiple transitions, and the forces at work outside the territory.

3.1. *Post-mining disruptions within the territory*

3.1.1. *The period from 2003 to 2020 was marked by the metamorphosis of the slag heaps and the Yvon Morandat Pit*

Although the mine's structural legacy remains present in the landscape, with elements such as the headframes and slag heaps, they are increasingly considered as heritage features. In Gréasque (see Figure 4), for example, where a mining museum now occupies the former shaft of the Hély d'Oissel pit, which operated from 1919 to 1962; its headframe is listed in the inventory of historical industrial buildings. Globally, slag heaps have also been given a new vocation [Beets, 2009]. After being used exclusively for mining during the time of the Charbonnages de France (CDF) national mining company, they were transferred to municipal ownership at a time when new uses were emerging, converting them to recreational areas, solar farms, etc. This was a real godsend for municipal authorities faced with urban land pressure, providing them with new resources in the context of the energy transition [Duruisseau, 2016]. For example, on the Sauvaires slag heap (Gardanne), 17 hectares were converted for a ground-based photovoltaic plant in 2013. The company Urbasolar, in charge of the operation, is paying the municipality a concession fee of €200,000 per year over approximately thirty years. This has set an example for other slag heaps and other municipal councils.

Meanwhile, the main mining site, the Puits Yvon Morandat pit, has been closed in 2003 and has since

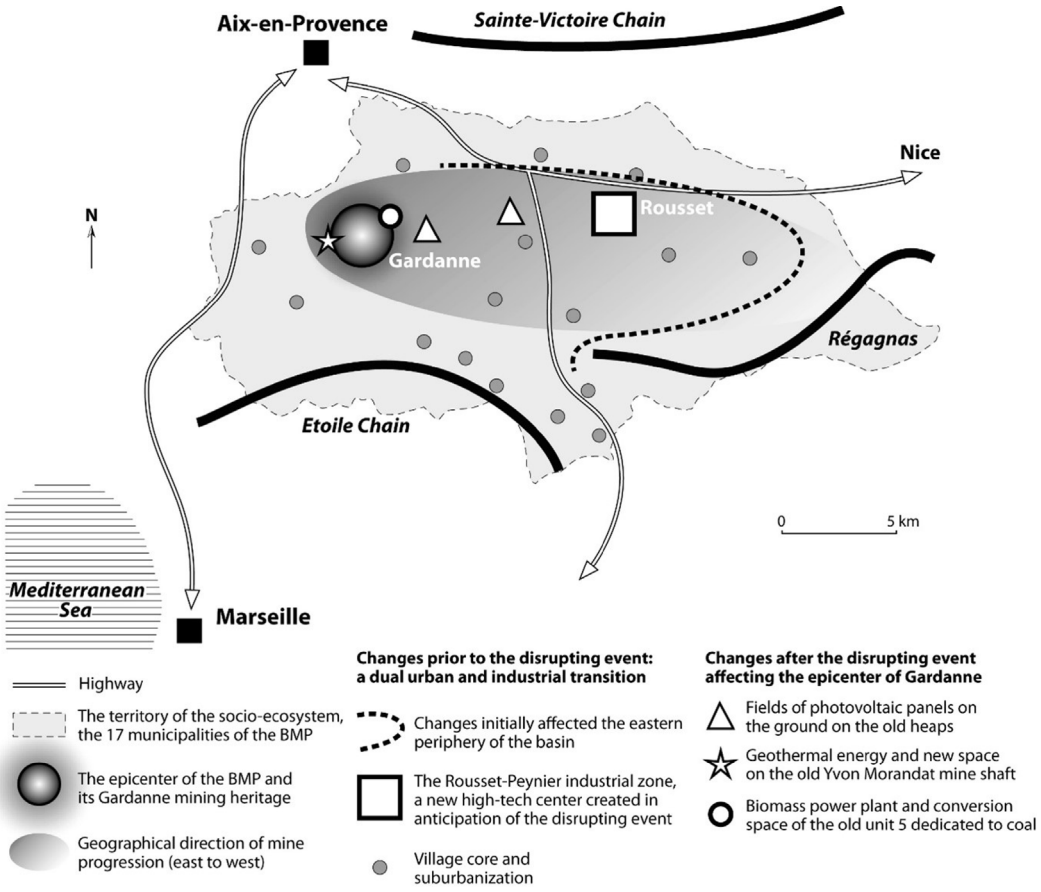

Figure 1. The Provence Coalfield and the reconfiguration of its territory.

undergone extensive redevelopment in a project spanning 14 hectares. This is undoubtedly the largest post-mining development operation in the coalfield. The former pit was acquired by the municipal council in 2004 and earmarked to become an economic, energy and cultural centre, with a business park for innovative technologies and a city of science serving the whole metropolitan area (the new city council subsequently abandoned the science city project). The whole complex will be powered by a geothermal energy network using water recovered from the old mine galleries. The operation was originally led by a municipal public–private structure, the SEMAG. With the slogan "Gardanne terre d'énergies" (Gardanne, land of energy), the municipal council (which was communist-led until spring 2020) wants the energy transition to be a major focus of its regeneration policy for the area, while maintaining a parentage with coal, insofar as the new energies use the infrastructures inherited from the mine. As a result, the territory is influenced by "path dependence" and witnesses a strong capacity of evolution [Boschma and Martin, 2007, MacKinnon, 2008, Chabrol, 2016]. In other words, by showing that the infrastructures inherited from the past become resources of the present, we underline a certain "path dependency" but also "a path of transformation". Through this example, we can thus see that the disruptive phenomenon shifts into a path of resilience, as we will specify in the conclusion.

3.1.2. *The three key events of 2020–2022*

As for the last remaining symbols of the industrial heyday, 2020–2022 marks a real turning point. The first key event concerns the coal-fired power station. In view of the energy and climate policies

designed to decarbonize the economy, in January 2020 the French government announced the closure of the last four coal-fired power stations still in operation in the country (Le Havre, Saint Avold, Cordemais, Gardanne) [Perroux, 2022].

The Gardanne plant, which has been acquired successively by different operators since the cessation of the national company Charbonnages de France (SNET, ENDESA, EON, UNIPER and GazelEnergie), comprises two units still active: the Unit 4 which is converted to biomass, since 2012, and has the backing of the public authorities but is disputed by various environmental organizations. The Unit 5, which was coal-fired, was closed in 2022 following a long labour dispute.

The alumina plant, which has also changed hands several times (Péchiney, Alcan, Rio Tinto and Alteo), has regularly hit the headlines because of its "red mud" residues [Mioche, 2011]. Since 2016, only liquid effluents have been discharged into the sea. Alteo was placed in receivership in December 2019 and on 7 January 2020, the Marseille Commercial Court rubber-stamped the only bid still in contention from Guinean company United Mining Supply (UMS). It has decided to halt the transformation of bauxite using the Bayer process (which dates back to 1893) and which is responsible for the infamous red mud. Speciality alumina is to be produced from alumina hydrate purchased from European suppliers, and this is expected to result in the redundancy of around fifty employees (according to Alteo's statement to the site monitoring committee on 3 March 2022).

Finally, the spring 2020 municipal elections resulted in a new mayor for Gardanne, Hervé Granier, representing the right-wing Les Républicains party. After 43 years under a communist mayor, Roger Meï, the town of Gardanne is now led by a new majority. This is a major socio-political shift and its impact on municipal policy remains to be seen. However, from the same sociological mould as the previous municipal council, the left-wing CGT trade union at the power station has maintained resolute action at the site, firstly against the closure of Unit 5, and then as the backer of a new industrial venture, the Green Gas project. In April 2022, Green Gas Gardanne gained recognition from the public authorities for the first time, alongside the Hynovera project led by GazelEnergie and Hy2gen.

3.1.3. *The great transformation now affects the heart of the socio-ecosystem*

These three significant episodes (the end of the coal-fired power station, the shift away from the Bayer process at the alumina plant, and the end of the communist administration in Gardanne) are the outcome of multiple twists and turns that deserve lengthy discussion in their own right. Almost 20 years after the end of coal mining, they symbolize, at the same time, new ruptures related to the old system but also mark the opening of new chapters in political, economic and socio-environmental terms. It is important to highlight the pervasiveness and power of environmental conflicts [Boutin, 2018, Boutin et al., 2019], which now tend to take precedence over the historical labour disputes. The local debate echoes international awareness and mobilization around global change and environmental conservation. The concomitance of the three key events mentioned above constitutes a marker in the post-mining trajectory of the Gardanne cluster, as the historical heart of the mining legacy. The *great transformation* [Polanyi, 1998] no longer affects only the peripheries of the socio-ecosystem, but also shakes it at its core, which nonetheless continues to regenerate through new initiatives.

There are two lessons to be learned here: firstly, the disrupting event is like an earthquake with a series of aftershocks (such as the closure of the coal-fired power station almost twenty years after the mine closed); secondly, the shockwave of the disrupting event, with the transformations brought about, does not necessarily run from the centre to the periphery but, in this case, from the periphery to the centre (the municipalities of Gardanne and Meyreuil are mainly concerned).

3.2. *A new metropolitan framework and change of scale for the BMP*

The first stone of the new Pôle Yvon Morandat economic, energy and cultural centre was finally laid on 2 April 2021, in presence of the new mayor, the president of the Regional Council, the senior vice-president of the metropolitan area and the financial backers. There has in fact been a change in the institutional framework, with the creation of the Métropole d'Aix-Marseille Provence intercommunal structure in 2016. This is the largest metropolitan

area in France with 92 municipalities, which is considerably more than the 17 municipalities of the former Provence Coalfield. This change in scale and power reflects the new remit of the metropolitan authority, which now steers the large planning, economic development and transport projects. The territory's industrial vocation has not been forgotten, but it is now part of new public policy mechanisms such as the "Territoires d'industrie" scheme (2018) or the national recovery plan (2020), in a context where France and its European neighbours are increasingly aware that their productive capacities have been neglected and are aiming to restore a certain degree of industrial sovereignty. At the local level, a "Territorial Pact for the Ecological and Industrial Transition of the Territory" was signed on 23 December 2020, under State authority, in order to ensure the mobilization and coordination of stakeholders within a "territorial project" in the context of the plant's closure.

However, the position of the local territory within a metropolitan area with a population of 1.9 million raises various questions. The closure of each major industrial facility in the former Provence Coalfield frees up several dozen hectares of land and creates fierce competition and power struggles over the reallocation of that land: in favor of new energies, new logistical infrastructures, new residential or recreational areas, and more rarely new manufacturing industries. The opportunity to design and develop new spaces and remodel the future is occurring in a more complex social and political arena, where the stakeholders are more numerous and diverse, where local identities are diluted, and municipal power seems to be eroded. The new equilibrium towards which the territory is evolving is not therefore settled just yet and will require further adjustments.

4. The OHM-BMP: organization and *modus operandi* of research

4.1. *The OHM-BMP and its research system*

Research within the OHM is carried out through calls for research projects (APR), which were issued annually until 2019 and on a biennial basis since then. The APR provides broad guidelines for research, with two main focuses: the relationship with the disrupting event and, as far as possible, an interdisciplinary approach. Between 2008 (date of the first call for research projects for the OHM BMP) and 2022, just over a hundred research projects were conducted by twenty or so teams, mainly from Aix-Marseille University (the three universities in the area merged in 2012 to form Aix-Marseille University, or AMU).

The annual number of projects varies between four and twelve. Given the nature of the OHM BMP's disrupting event, the themes covered by these projects can be grouped into three main categories: (1) the markers of mining history, namely the slag heaps; (2) contamination linked to the alumina plant and the associated conflict; (3) the energy transition. The share of each of these themes has varied over time. The energy issue was very prominent in the first few years but declined after three or four years, only to return in force in the 2022 APR, when the coal-fired power plant was closed down and plans were made to convert the site. The study of slag heaps developed gradually until 2019, but the theme is now on the decline. The issue of the alumina plant and its conflict emerged in 2010 with strong growth from 2014 onwards with the new method for managing bauxite residues; the new industrial process set up in 2022 is expected to be studied further. By their very nature, these three themes lend themselves well to an interdisciplinary approach.

While the contribution from the physical, chemical and ecological sciences has gradually developed and become predominant since 2012, the role of the social sciences (geography, sociology, economics, etc.), which were highly represented between 2008 and 2012, has decreased with the emergence of the Labex, or "laboratories of excellence" (two Labex in particular are indicative of this change: LabexMed, which is home to the AMU's social sciences focused on Mediterranean issues, and the AMSE Labex for economic sciences). The social sciences have made a significant comeback since 2018 with respect to two issues: the environmental conflict concerning the alumina plant and the energy transition.

4.2. *Disciplines and interdisciplinarity*

Analysis of human–environment interactions is based on two principles that underpin the OHMs: firstly, interdisciplinarity, which is key to understanding complex issues relating to hybrid topics involving the natural sciences, the humanities and social sciences [Chenorkian, 2020], and secondly, the link

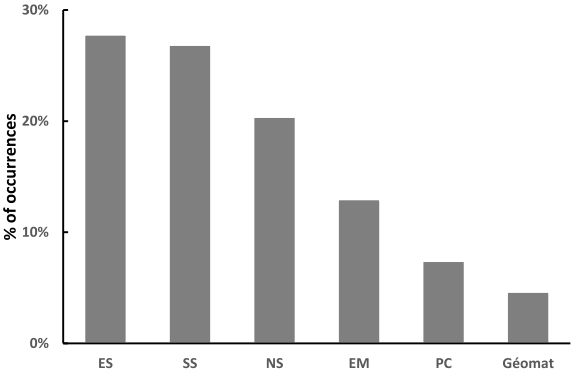

Figure 2. Disciplines declared by project leaders. ES = Earth Sciences; SS = Human and Social Sciences; NS = Ecology and Biology EM = Economy and management; PC = Physico-chemical Sciences; Géomat = Géomatics.

between science and society, which facilitates a mutually beneficial exchange between scientists and local stakeholders. These principles are applied and deployed in the research projects whose themes we analyse over the following pages.

For the record, in the context of the calls for projects, the OHM BMP and the Labex DRIIHM (Interdisciplinary Research on Human–Environment Interactions) funded 108 research projects. These projects were submitted by 59 different applicants (on range, between 1 and 11 projects per applicant). These applicants are mainly from the Social Sciences (31%), Earth Sciences (24%) and Natural Sciences (17%), as shown in Figure 2.

The disciplines involved in the project are also stated in the project submission files. Overall, 34 disciplines were cited for a total of 247 mentions (on average, 2.3 disciplines are cited per project) (Figure 3).

The Social Sciences disciplines represent 30% of the citations (geography and sociology are the most frequent) and are present in 43% of the projects, followed by the Natural Sciences cited at 24% (ecology and biogeochemistry are the most frequent) and present in 37% of the projects, then Earth Sciences at 21% (geochemistry and pedology are the most frequent) and present in 32% of the projects. The Health Sciences are very poorly represented (only 1 project supported: presence in only 9% of the projects). More than a third of the projects in the Social Sciences, Economic Sciences or Management Sciences cite only these disciplines, compared to only a quarter of the projects in the Natural Sciences or Earth Sciences. Social Sciences are predominantly associated with Economics and Natural Sciences. Natural or Earth Sciences are equally associated with the other groups.

Overall, we can draw two main conclusions from these tables. The first concerns the balance of the forces involved. It underscores the role of the Natural and Earth Sciences and the Physical and Chemical Sciences, which together account for half of the applicants or disciplines mentioned. This reflects the significance of the Arbois-Mediterranean Environment Technology Park within the metropolitan area. The Social Sciences and Economic and Management Sciences rank second with approximately 40% of applicants. The various disciplines are therefore relatively well balanced within the OHM, with the exception of Health Sciences, which are a major focus at metropolitan level, but make a small contribution to the OHM BMP. The second lesson concerns interdisciplinarity. The associations between disciplines give rise to a number of different combinations, but the research projects are evidence of genuine interdisciplinary practice involving different disciplines within the same group, or cross-sectoral practice involving different disciplinary groups.

4.3. *The science/society interface*

The science/society interface, i.e. the relationship between research and local stakeholders, was assessed from three perspectives: the strategy adopted for the annual seminars, the scientific outreach activities, and participation in various official bodies. Figure 4 shows these different situations.

The most significant interactions between science and society occur during the annual seminars (red circle), which take place each year in a different town in the Provence mining basin or at the OHM headquarters in the Arbois-Méditerranée Environmental Technology Park in Aix-en-Provence.

During these seminars, the results obtained by the research projects financed over the previous two years are presented to an audience made up of both researchers and representatives of the wider community (elected representatives, socio-economic operators, associations, citizens). These community stakeholders can account for between 25% and 50% of the audience each year. This choice to open up

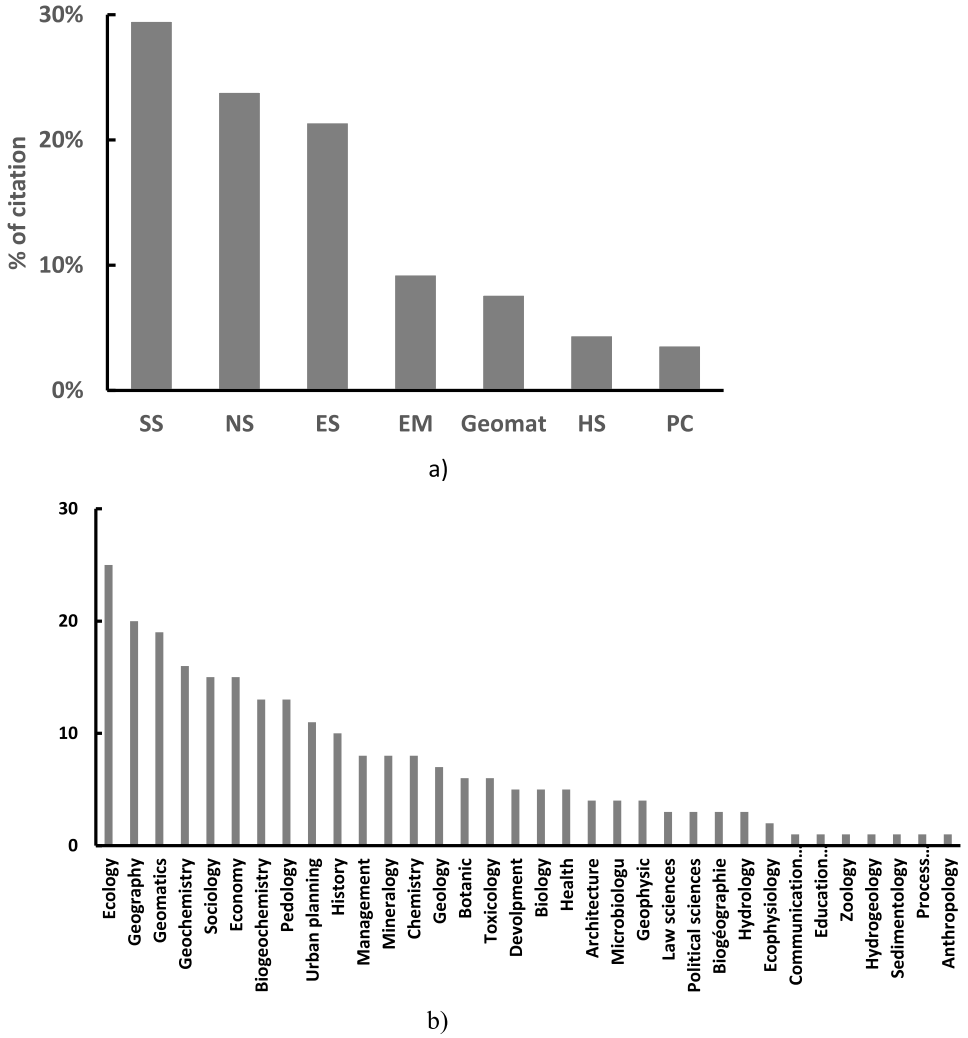

Figure 3. Distribution of disciplines mentioned in the projects. (a) Percentage of citation per discipline group. SS = Human and Social Sciences; NS = Natural Sciences (Ecology and Biology); ES = Earth Sciences; EM = Economy and Management Sciences; Géomat = Géomatics; HS = Health Sciences; PC = Physico-chemical Sciences. (b) Number of projects concerned for each discipline.

interaction with society is a specific feature of the OHM BMP (shared with the OHM Pays de Bitche, for example). Of the 13 seminars organized since 2009, three have been held in Aix-en-Provence, three in Gardanne, and others in Bouc-Bel-Air, Fuveau, Meyreuil, Simiane-Collongue, Trets and Rousset (see Figure 4). These debriefing seminars are therefore an opportunity to visit communities with different profiles within the OHM-BMP territory.

The dissemination of scientific culture (black triangle) is also an important activity of the OHM BMP and has been done in different ways: (a) several participations in the Fête de la Science, in Gardanne; (b) public conferences, both on the theme of mining activity and on that of atmospheric pollution in the territory; (c) the theme of the conflict around the alumina plant fueled several forum theater sessions, with the active participation of local residents or association activists; (d) introduction to the scientific approach, on the theme of atmospheric pollution, in schools. Finally, the OHM BMP had the opportunity to present its work to various official commissions

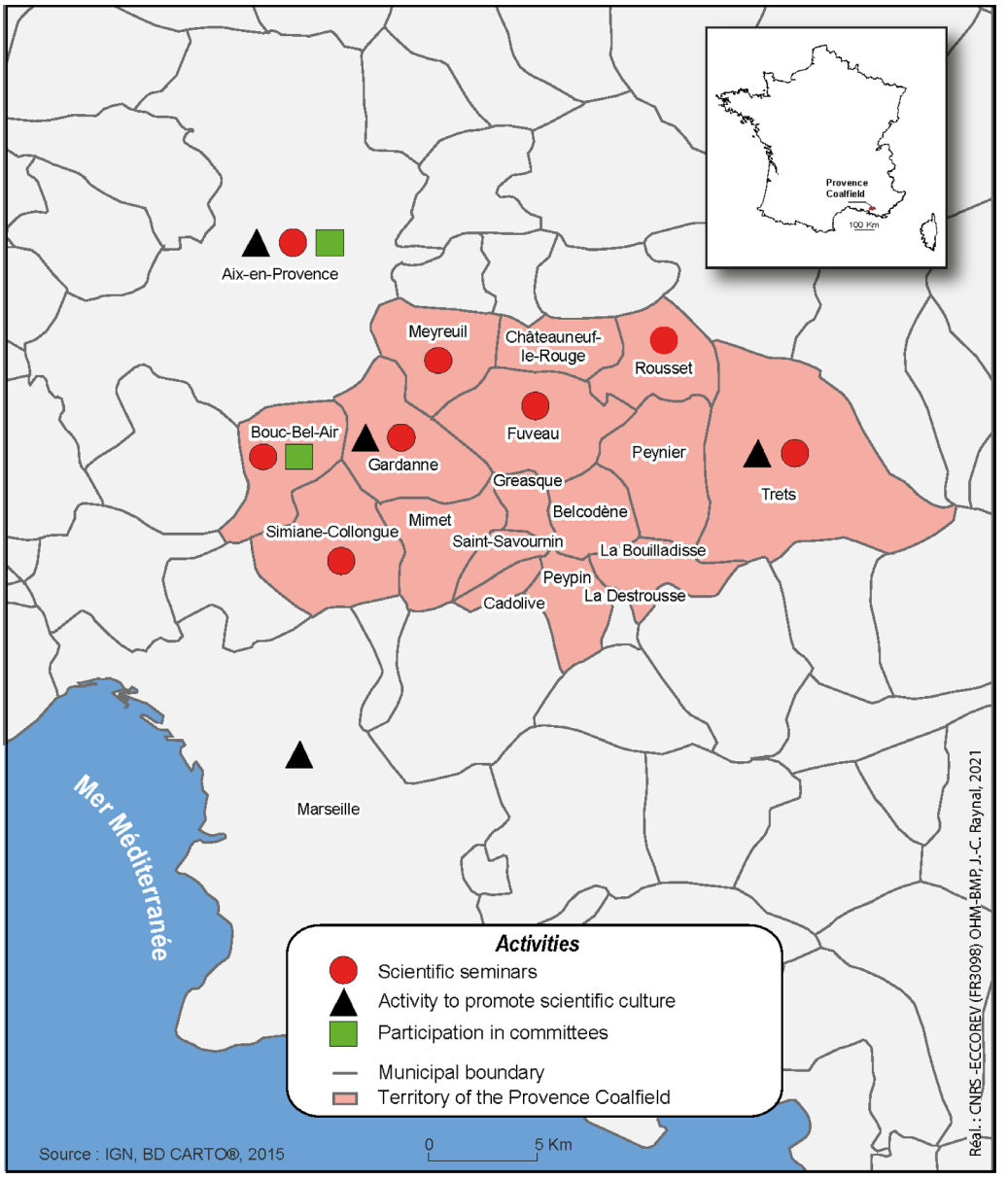

Figure 4. Map of the science/society interface within the OHM-BMP.

(green square) such as the environmental commission of the Pays d'Aix territory, the Lafarge Site Monitoring Commission (CSS) and especially the CSS Alteo of which the OHM is a permanent member in the College of Experts.

Over the years, the science/society interface has thus become firmly anchored in the research landscape and practices, gradually covering the territory under study and a wide range of topics.

5. Research themes and results

5.1. *Analysis of the themes addressed in the selected projects*

As part of our assessment of the OHM BMP's work, our aim was to identify the predominant themes in the projects selected since the OHM's creation. To do so, we undertook a lexicographical analysis of the 108 research projects selected between 2008

and 2020. First, the entire corpus was analysed, then the prevalence of certain themes according to year was verified. The corpus contained 1782 occurrences (=textual elements) and 701 forms (different words), including 501 hapax (words that appear only once).

The quantitative analysis was conducted using textual analysis software IRaMuTeQ [R Interface for Multidimensional analysis of Texts and Questionnaires; Loubère and Ratinaud, 2014]. The software performs lemmatization (pooling all the words that share a common root) which simplifies the analysis. We completed this lemmatization process in a multidisciplinary team to link, for example, words like "environnemental" and "environnement". The term "Bassin-minier-de-Provence" (Provence Coalfield) or "BMP", included in the vast majority of titles, as well as the location "Gardanne", which dominated the frequency count but did not provide any information differentiating the projects, were deleted. Some terms such as red mud were hyphenated to be treated as a single word.

For our analysis of the titles, only two categories of root words were retained: nouns and adjectives. IRaMuTeQ enables different types of analysis, from the simplest (counting word frequencies, counting associations between words) to the most complex (class formation by top-down hierarchical analysis).

The results are presented in different forms: word cloud (Figure 5), association graph (Figure 6), and class hierarchy (Figure 7). In the word cloud (Figure 5), all the words that appear at least three times across all titles are shown. The larger the size of the word, the more frequent it is in the corpus. We can see that the most frequent words are (the French words for) "environment" (18 occurrences) and "soil" (with 17 occurrences), followed by "slag heap" and "red mud" (each with 11 occurrences), then "analysis", "industrial", "impact" (10 occurrences each). These reflect the two main groups of projects selected in the framework of the APRs: on the one hand, projects concerning the alumina plant and the management of bauxite residues (30 projects); on the other hand, projects on slag heaps (structure, vegetation, etc.—25 projects). During the period 2008–2020, the study of soil and the study of the environment were central to the projects selected by the OHM BMP. While the term "soil" seems to be clearly anchored in the natural sciences (geochemistry, biology, etc.), the term "environment" is less easy to characterize without further information. We will therefore look at which words are frequently associated with these two terms (Figure 6).

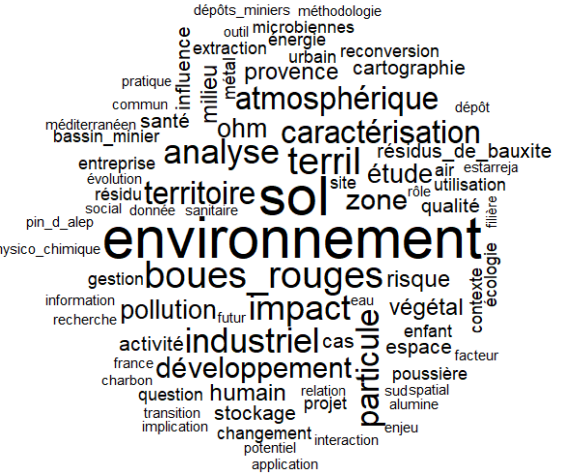

Figure 5. Word cloud derived from the titles of projects selected between 2008 and 2020.

The graph shown in Figure 6 illustrates all the associations between words that appear at least three times (frequency detailed in the legend). The two central terms: "environment" and "soil" are more easily interpreted, as they are linked to other significant terms. In particular, the word "soil" is associated with "characterization" (six times), "red mud" and "OHM" (five times each), as well as "slag heap", "quality" and "microbial" (four times each). In the work carried out within the OHM BMP, the studies on soils—concerning either slag heaps or red mud (or bauxite residues)—have mainly focused on their characterization and their reconversion possibilities/potentialities.

The other key term—"environment"—is more comprehensible and interpretable in this context. It appears to be equally linked to the natural sciences (five times, with "atmospheric", itself linked eight times with "particle", not to mention "impacts" and "pollution"), and to the history of the coalfield, with its "industrial" "environment" (five associations) and its "territory" (four associations). Aspects concerning health risks and health also revolve around the term "environment", which thus relates to issues of interest to the human and social sciences. Particulate air pollution is a theme concerning around 10% of all projects; with its impacts extending to the whole

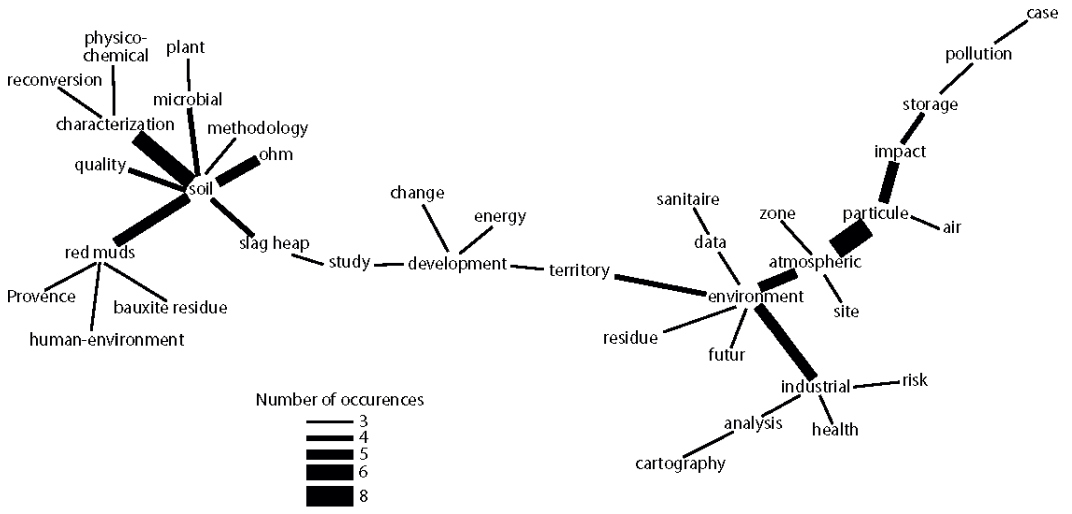

Figure 6. Graph showing word associations at threshold 3.

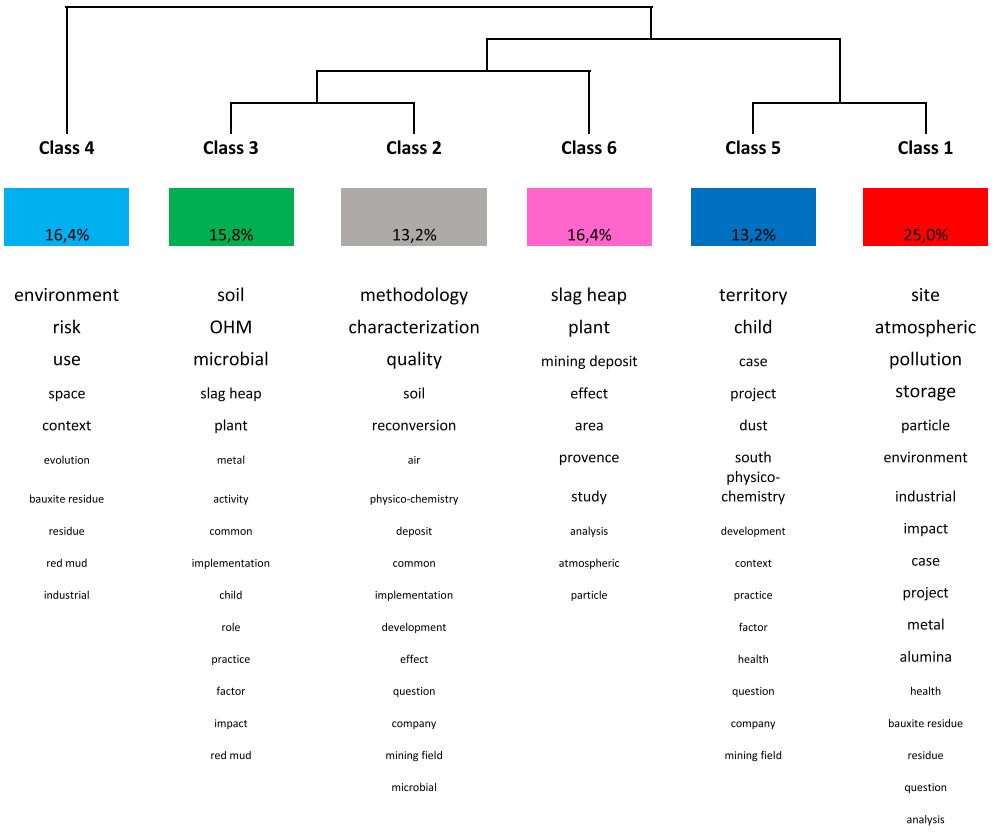

Figure 7. Dendrogram obtained by top-down hierarchical classification.

"environment" around the point of emission, with consequences for health. However, industrial environment is also observed with the conversion of the territory's industries, studied in the early years of the OHM.

These two dominant terms are in turn linked to each other by the chain of "slag heap", "study", "development" and "territory". The term "development" has at least two meanings: on the one hand, the development of methodologies and study procedures (numerous in the framework of the projects funded), connecting in this context to the word "soil", and on the other hand, development in the sense of change, transformation (sustainable or economic) of the territory, in connection with the "environment".

An analysis based on discourse classes reveals five classes of roughly equal size, which confirms the previous analyses (Figure 7).

The first class, which stands out from all the others, significantly ($p < 0.01$) combines the terms "environment", "risk", "use" and "space". This class brings out a theme which was not very apparent from the word frequencies (the word "risk" is only mentioned five times in the project titles and only three projects really deal with this notion), but which underlies many projects: the question of risks associated with pollution and the use of space in this environment of industrial heritage. This term, as well as the terms "context", "evolution" and "red mud residue" reflect the main questions raised in the projects.

The other branch (see Figure 7) brings together five other classes, reiterating the two main groups seen earlier: one group composed of classes 3, 2 and 6 related to "soil" issues, and another group, comprising classes 1 and 5, dealing with atmospheric pollution (class 1) and the environment (class 5). In detail, class 3 represents studies on soils affected by bauxite residues and is closely linked to class 2 focused on soil characterization methods to specify soil quality. Class 6 singles out studies on "slag heaps" and in particular their "plant" communities.

Class 1 details the risk (at $p < 0.01$) of "air" "pollution" of the "site" by "particles", in particular linked to "storage" in an "environment" described as "industrial". Meanwhile, Class 5 takes up the notion of environment, significantly associating the economic environment via "territory" with the human environment via "children" and "health". The years are not associated in any significant way with these themes; in other words, these themes are found throughout the period, with no particular clustering in a given year.

To sum up, lexicographical analysis shows that two issues have been studied particularly with an interdisciplinary approach by natural, earth and social sciences, with classic or innovative methodologies, over the last 12 years: Mining-related slag heaps and the physical and human environment threatened by the pollution from the alumina plant. The research results related to these issues will be detailed in the following section. Lexicographical analysis also shows that these two main issues are articulated through the question of the development of the territory, and its changes regarding its traditional "energy identity". This might be a strand of research that could be deepened in the future, and we will come back to this question in the conclusion.

5.2. *Focus on the results concerning alumina and slag heaps*

Diagnoses carried out on around ten slag heaps examined the danger linked to the contaminants present in mining waste and the potential offered by these deposits in scenarios ranging from reallocation to ecological rehabilitation [Folzer et al., 2015]. This insight, obtained by combining geographical, historical, geochemical and ecological data on the slag heaps in the Provence Coalfield, has opened up perspectives that were not possible when a regulatory approach to hazard and risk management was applied alone. Such perspectives mean that slag heaps can no longer be considered merely as land for development or remains of industrial waste that require management, but instead as a legacy of the past, capable of evolving alone or supported by ecological engineering, capable of acquiring biodiversity and ecological functions despite the constraints of the environment, capable of offering ecosystem services (recreational, cultural and scientific) and, under the direction of the Labex DRIIHM and the OHM BMP, of serving as a genuine open-air interdisciplinary laboratory.

The work focused on the alumina plant has proved to be similarly rich. Since 2009 and even more so since 2014, the OHM-BMP has applied an interdisciplinary approach to the question of potential health and environmental impacts of the storage facility for residues from bauxite processing at

the Gardanne plant. This work first focused on atmospheric particles from the storage site and their health and environmental impacts [Noack et al., 2012, Bonnefoy et al., 2017, Bley et al., 2019, Pourcelot et al., 2021]. Further work was then carried out on the possibilities of revegetating the site to avoid dust emissions [Fourrier et al., 2020, 2021] and on the opportunities for recycling the residues [Lallemand et al., 2022]. It also focused on the views of the site's neighbours and residents of Gardanne regarding the operation, development and future of the industrial site, opening up the prospect of more transparent management [Mainard and Rouchier, 2019]. In this respect, the convergence of several disciplines has enabled the scientists within the OHM BMP to communicate with all stakeholders in a relevant way on questions that continue to be explored [Noack, 2020].

The events surrounding the takeover of the alumina plant by United Mining Supply are now raising some new questions. As discussed above, the new owner plans to stop using bauxite and to import alumina hydrate in 2022. This would have multiple consequences locally: (a) cessation of the bauxite treatment (red) will lead to job losses; (b) the depositing of particles over the town of Gardanne should decrease but not disappear completely (the alumina refinment (white) is also a source of pollution); (c) as residue production ceases, atmospheric pollution around the residues deposit site should also decrease, provided that the site continues to be monitored and maintained; (d) the rehabilitation of the 50-hectare storage site will need to be addressed; (e) in the longer term, what future lies ahead for the Gardanne plant? (f) in a broader perspective, what impact will these changes have on industrial sovereignty, now that the focus is on reindustrializing the territories? Geopolitics is firmly back on the agenda and priorities are changing, which is why we need to approach the possible scenarios and the prospects for a new equilibrium with caution.

6. Conclusion: Towards what new equilibrium? Scenarios and perspectives for research

At the very least, we can imagine two to three scenarios for the former Provence Coalfield. The first is one of deindustrialization, based on the socio-demographic trends observed. The residents who have settled here because of the attractiveness of the landscapes and the living environment, along with environmental associations and certain elected representatives are generally hostile to industry. Even in Rousset, where the dominant industry is high-tech, many stakeholders acknowledge that the idea of a production sector is difficult to defend. A business-as-usual scenario giving preference to this trend could lead to significant deindustrialization of the former coalfield, which would then mainly be promoted as a residential area. A second scenario of negotiated equilibrium takes into account more recent trends such as the taking into account by the actors of the territory of the energy transition, the need to limit commuting, and the emergence of selective reindustrialization policies for the territory. Shortages or disruptions in the supply of electricity and goods could make production activities more acceptable, to a certain extent, within the framework of a new negotiated balance between economic activity, residential needs and environmental protection. While scenarios 1 and 2 assume the existence of a relatively coherent territorial governance, a third scenario of upheaval could imply difficulties in local governance caused by the overlapping of layers of power and by interest groups. This would result in an incoherent land use strategy and discordant dynamics between the different parts of the area, which, it should be recalled, are not brought together within any specific intercommunal structure.

Without pre-empting future balances, the research is deployed on an empirical and theoretical level. The text for the 2022–2023 call for research projects has already set out the research areas that remain relevant, such as the fate of the major industrial establishments that merit ongoing observation, together with the emerging research areas: energy and ecological transitions affecting industry and agriculture, against the background of climate challenges; or metropolitan development, mobility, socio-demographic and socio-political changes, plus the issues of governance and public policy. It will thus be crucial to closely monitor the implementation of the "Territorial Pact for the Ecological and Industrial Transition of the Territory" signed in 2020 [Perroux, 2022]. Initially focused on Gardanne and Meyreuil, but with the possibility of extending it to other communities in the area, what impact will this Pact have on preserving a shared identity within

the former Coalfield? What will be the future of the Hynovera project (a platform for producing fuels from non-fossil sources on the site of the Provence coal-fired power station), following the referral of the project to the National Commission for Public Debate (CNDP), a French entity in charge of concertation? Particular attention will be paid to this participatory democracy process, which will allow the OHM BMP to position itself as an observer and participant in the public debate.

More generally, the transition from a coal-based industrial regime to a post-carbon system [Durand et al., 2015] is a key interdisciplinary research topic for a human–environment observatory, the founding event of which is energy-based. A number of studies have been undertaken since the 2010s and now need to be expanded to consider social, environmental and technological factors. This is actually the case, for example, with the ENERGON programme, a cross-cutting initiative involving six OHMs focused on the role of the energy transition in reshaping socio-ecosystems (SES). The study of the *energy transition* is more generally focused on the challenges of transitions (in the plural) and *resilience*, in line with the very purpose of human–environment observatories [Chenorkian, 2019]. We should acknowledge that concepts are tools enabling us to chart new paths. The emergence of the concept of *transitions* in scientific and political circles and among territorial stakeholders is requalifying processes and opening up new perspectives. The concept of *resilience*, however, has been relatively overlooked in OHM-BMP research, despite its heuristic potential. For Carl Folke, who was involved in the founding work on SES, resilience is not only the capacity of a system to absorb shocks and sustain itself, but also its capacity to renew, reorganize and develop [Folke, 2006]. We will thus be able to explore to what extent the current transformations illustrate this concept of resilience as well as the evolution towards a new equilibrium.

Conflicts of interest

Authors have no conflict of interest to declare.

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