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A framework to assess mining within social-ecological systems[☆]

Claude Le Guill¹ and Franck Poupeau²



In recent years, 'sustainable mining' projects have been promoted as a means of extracting minerals that respects the aspirations of local peoples and is ecologically responsible. However, in light of new international mining regulations, the effect of such projects remains difficult to evaluate. In this paper, we attempt to provide a framework for analyzing 'sustainable mining' by critically applying Elinor Ostrom's socialecological systems (SES) framework. Thus, our objective is to compare cases from Arizona, USA and Peru, by following the same mining company. In so doing, we analyze in effect the application of the company's model and examine its management strategy, while taking into account the diversity of the protagonists involved in extractive activities. The modeling effort proposed here, while building on a critical approach of Ostrom'

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Introduction: objectives of the article

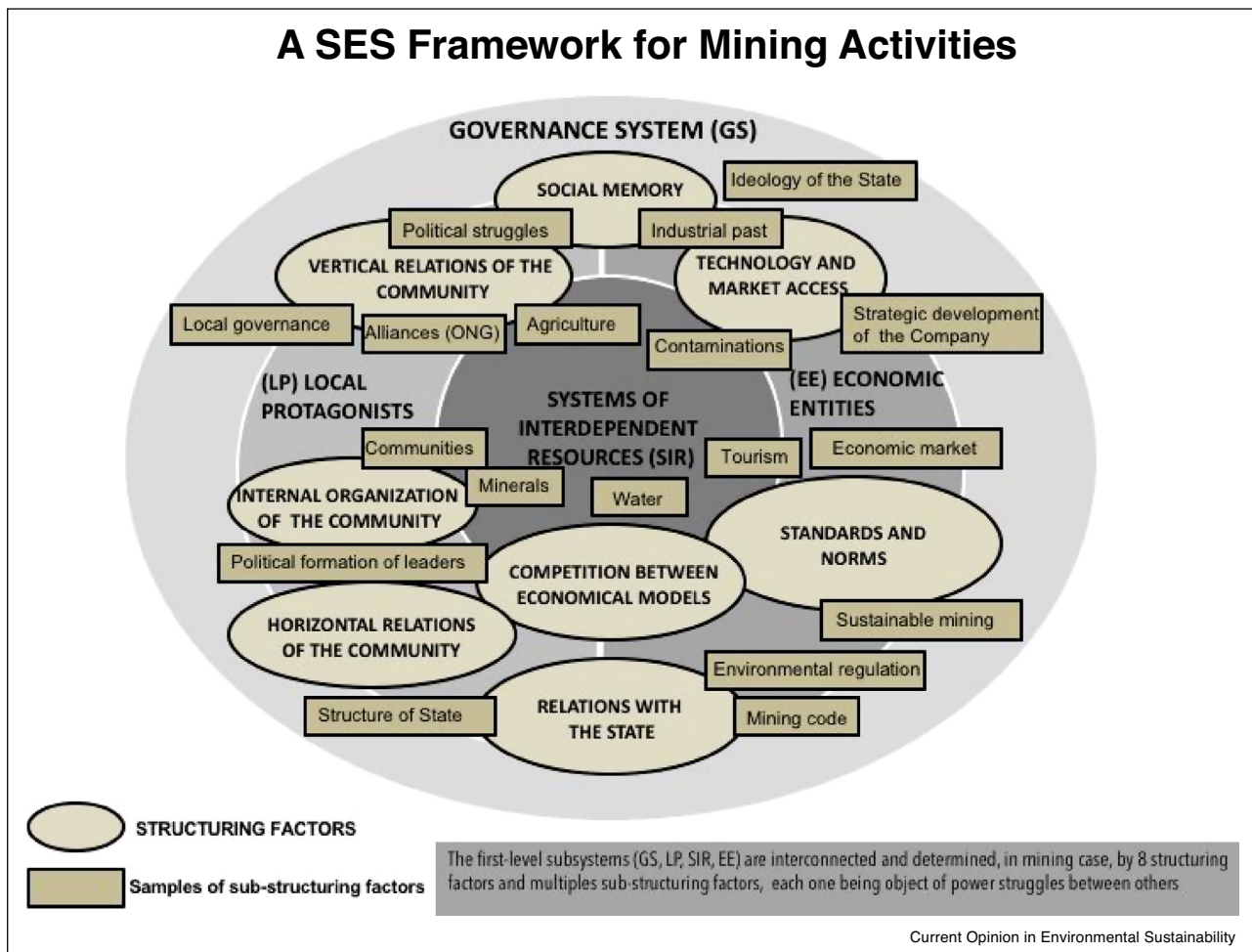
The aim of this article is to apply the social-ecological systems (SES) framework developed by Elinor Ostrom [1] to the debate on the analyses of new mining processes and especially on the 'sustainable mining' practices which are being promoted as new international norms and rules for companies. This framework aims to analyze the sustainability of SES [2] in order to understand complex interactions within different systems and scales around natural resources governance [3].

The SES framework is applied to cases of 'common pool resources' (CPR) [4] that provide a limited quantity of extractable fringe units and might be overused, such as water or fish; it aims at identifying how social groups benefitting from a sufficient degree of autonomy are able to organize the way in which a resource is managed according to internal norms. However, the SES framework has not been applied to CPR issues such as mining resources and other extractive activities, and have focused on the study of non-deteriorated, rare or renewable resources (irrigation systems, fishing grounds, pastures, forests, etc.), whose stocks are relatively small and easy to quantify, and which have few links to positive or negative externalities or common property rules, thereby making open access dilemmas irrelevant [5]. Moreover, property rights, as defined by Ostrom, do not cover underground property issues.

While certain studies have addressed the question of institutional arrangements [6], most analyses of mining activities have been carried out by researchers in the field of critical geography focusing on extractivism in the context of neo-liberalization [7] and of the commodification of nature [8]. However, the great diversity of technical approaches to mining and the various relationships between communities, companies and states [9,10] provide a pertinent framework for examining Ostrom's theories by providing a socio-political perspective. Following these approaches, the objective of this article is to model relations of power in the SES framework in order to understand the specificity of the mining case as opposed to previously studied CPR issues. It refers thus to a system based approach and not an actor-oriented approach [11] as it focuses on the relations between the components of the SES considered as dynamics, interconnected [12]. As we consider the interactions between social and ecological dimensions of the system have to be modeled [13], the analytical goal of the paper is to determine the 'structuring factors', as systems of variables referring to environmental regulations, institutions, communities, cultural patterns, and so on, impacting mining activities, how they have to be included by a renewed SES framework (Figure 1), and how they encourage the modification of the categories used to build this SES framework (Box 1). This critique of the SES framework, is based on a comparative approach, following the case of a Canadian mining

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Figure 1



A SES framework for mining activities.

company (Hudbay), which operates in Arizona (USA) and Peru (Box 2).

The SES framework and the limits of its extension to mining activities

According to Ostrom [14], SES are composed of multiple nested subsystems: Resource System (RS), Resource Units (RU), Users (U) and Governance System (GS), and their interaction produces outcomes on the SES level. Some rules specify a common understanding of authorized actions [15], and they may evolve over time as those involved in one action situation interact with others in a variety of settings or self-consciously change the rules in a collective-choice or constitutional-choice setting (boundary rules, position rules, etc.). Rules define a set of instructions of how to produce the structure of relationships among individuals that is also affected by the

biophysical world and the kind of community in which an action arena is located [16].

We argue that if the SES framework provides a systemic understanding of resources management [17], its application to mining activities reveals specific difficulties, related to the categories used to build the framework. First of all, the category of ‘Users’ takes into account the characteristics of local groups (number of users, socioeconomic attributes of users, history of use, leadership/entrepreneurship, norms/social capital, knowledge of SES, importance of resource, technology used), which constitute “potentially relevant variables and their subcomponents to use in the design of data collection instruments, the conduct of fieldwork, and the analysis of findings about the sustainability of complex SES.” [18]. However, the SES framework does not fully consider

Box 1 Categories and structuring factors

- **Local protagonists (LP):** which includes the populations imparted by the founding element, without benefiting directly but also, associations, ecological NGOs, Environmental organization/1 Informal institution
 SF 1: Horizontal relations of the community organization
 SF 2: Vertical relations of the community organization
 SF 3: Internal organization of the community
 SF 6: Social memory
- **Economical entities (EE):** active players usually on the initiative of the founder, who will benefit commercially from the latter. They can also be local protagonists, on other levels of action
 SF 5: Competition between economical models (mining., tourism, agro-industry) and promotion of sustainable mining
 SF 7: Technology and market access
- **Governance System (GS):** administrative or private entities that control or regulate SSEs and the founding element
 SF4: Relations with the slate.
 SF 5: Standards and norms (sustainable mining, SLO, etc.)
- **System of interdependent resources (SIR):** natural resources (water, fauna, flora, minerals, landscape, etc.), their interactions and their potential ecological impacts (tsunami, earthquake, etc.)
 SF 8: Interdependences of resources impacting other resources and other subsystems (local protagonists, economical entities and the governance system).

the internal heterogeneity of local groups, and it leads to an idealization of forms of self-organization [19,20]. The framework has also been criticized for employing a decontextualized top-down perspective that fails to take into consideration the **historical aspects of community building** [21*,22].

If the role and creative capacities of communities should not be neglected, it may display a weakness in terms of its lack of organization, its inability to exert a direct influence on negotiations, and its failure to impose its vision of the development of the territory. To this can be added accusations of corruption and of the company indulging in bribing politicians. In this sense, the company's strategy of providing the community with a central role without providing it with the tools required to act effectively, has had the effect of **deepening the ambivalence of local people's attitude to, on the one hand, a desire for autonomy, and, on the other, a need for company jobs in order to meet the needs of the moment** [23**]. As Le Meur [24*] has pointed out, these logics of belonging have often been neglected or treated in substantialist terms ('the community,' 'the ethnic group,' etc.). This trend has had the effect of placing **insufficient emphasis on inequalities and power relations**, as well as encouraging the political use of the 'local' by hegemonic interests and counter-hegemonies [25]. The social and political boundaries in question therefore, seem to be defined by a struggle between state, company and communities, and between communities themselves, particularly in that mining generates externalities (either positive or negative) that impact territories other than

Box 2

Case studies: Huiday in Peru and the USA

Categories and Structural Factors	Constancia Peru	Rosemont, USA
1-Dependance Relationships between communities and companies	Strong political and economic dependency	None
2-Exchange Relationships between communities and companies	Conflict	Mediated by local institutions
3-Heterogeneity of communities	Divisions between local stakeholders	Dispersion of the public
4-Role of the state	Weak	Strong regulation based on federal norms
5-Standard for mining activities	Neo-liberal Regulation and Corporate Social Responsibility	Project presented as sustainable mining
6-Mining traditions and collective memory	Recent but conflicting mining tradition	Strong mining tradition but new residents
7-Technology and market access	High technology for open pit mining	High technology for open pit mining
8-Competing uses and users of the resource	Mining companies and communities	Company and ranchers against institutions for conservation and the public

those in which the resource is exploited [26]. More generally, Hinkel *et al.* [27] have raised the question of the interdependence of different systems for exploiting resources and, consequently, of inter-communal relations. However, **one of the limits of the CPR approach is that it does not take into account competing organizations for the management of the resource.** These critiques are very relevant when applying the SES framework to the study of **mining, where the socio-political analysis generally focuses on the relation between communities and companies. The inclusion of other institutional and social organizations (non-state and non-corporate operators such as international NGOs and civil society, multilateral agencies, consultants, etc), as a forth component interaction with state, companies and communities** [28,29], is thus necessary to understand **the outcomes of extractive activities and to determine the interactions between the subsystems**, as shown by our two case studies (Box 2).

Structuring factors to understand mining activities

The limits of the SES framework revealed by its application to mining activities encourage a new approach and a **redefinition of the categories defining the subsystems.** Mainly, we question the pertinence of the subsystem categories of the SES framework. We argue

that: 1) the RU/RS distinction¹ does not apply to extractive activities as the extraction transforms the mining resource and needs further operations in order to generate benefits; 2) the Users have to be differentiated more precisely and take into account a diversity of 'protagonists' in competition for resource management; they do not only 'use' the resource, but are involved in its governance, with their specific capacities and social capital. We prefer the term 'protagonists,' that does not engage an implicit philosophy of social action [30], but refers to a relational approach of social issues [31]. The research perspective is then to determine if the variables of the SES framework can be interpreted as structuring factors of mining activities.

Relationships between communities and companies in the mining context can be considered according to the communication and feedback they allow (structuring factor 1) and the vertical dependence they imply (structuring factor 2), all the more since the mining industry engenders 'network territories' that are fragmented at the local level and vertically subordinated to transnational capital [32]. However, the heterogeneity of communities and the dynamics of power within them is a crucial factor in our comparative study (structuring factor 3). Consequently, the 'social capital' pointed to by Ostrom has to be analyzed in terms of paternalistic relations and of new relations introduced by the market [33]. Moreover, the state is a fundamental protagonist to take into account in the understanding of mining CPRs, as it provides national norms for extractive activities (structuring factor 4) [34].

Moreover, like Ostrom's polycentric model, state rules have to be referred to international norms that emerged from the 70's to oversee mining contamination. Many researchers have seen in these new standards the origins of 'sustainable mining', as a response to new international standards and self-regulation process of the mining industry through a 'voluntary code' [35] (structuring factor 5). This structuring factor leads to take into account competition between mining and other economic activities generating other kinds of benefits, such as restoration plans or tourism, promoted by 'sustainable mining' norms, but also agro-industry or ranching, which uses of groundwater challenge mining activities.

¹ According to E. Ostrom ("Environment and Common Property Institutions », in International Encyclopedia of the Social & Behavioral Sciences, 2001), "common-pool resources are composed of resource systems and a flow of resource units or benefits from these systems. The resource system (or alternatively, the stock or the facility) is what generates a flow of resource units or benefits over time. Examples of typical common-pool resource systems include lakes, rivers, irrigation systems, groundwater basins, forests, fishery stocks, and grazing areas. (. . .) The resource units or benefits from a common-pool resource include water, timber, medicinal plants, fish, etc."

In that perspective, the arrival of a multinational company on a territory upsets the material and symbolic balance of communities and thus necessitates the introduction of new structuring factors in order to define the reorganization of institutional arrangements and emerging 'resource regimes' understood as 'territorialized complexes of political-economic institutions, socio-natural relations, and social norms and fields of expertise which support particular forms of resource extraction and the interests of those involved over an extended period of time' [36].

As demonstrated in the resource roller-coaster approach" [37], such factors are vital to any chronological study of the activity that takes into account the general characteristics of individual sites and explains the various experiences of local people introducing structuring factors of 'mining traditions and collective memory' (structuring factor 6) to reveal the multiplicity of temporalities associated with mining extraction [38], and specifically the importance of the industrial past in local people's perception of current environmental pollution [39] or in the definition of collective identities [40]. These structuring factors converge towards those suggested by Prno and Slocombe [41] in their modeling of popular acceptance criteria for mining projects under 'social license to operate' (SLO).

Another question refers to technology and market access [42]. Indeed, new environmental norms have encouraged private companies to invest substantially in new technologies of the kind that are, it would seem, beyond the grasp of the communities (structuring factor 7). This argument, made by the companies themselves to legitimize their access to the deposits, have generated 'industrial frameworks', like the Sustainability Reporting Guidelines (a list of 130 indicators based on quantitative and qualitative principles categorized as follows: Organization, Management, Economic, Environmental and Social Performances, Human Rights, Product Responsibility). However, these industrial frameworks do not take into account the competition for the access to information, and this shortcoming limits the analysis to the factors impacting economic performance, largely ignoring social, cultural, and political factors.

In the SES framework, most of the resources taken into account, which are renewable, are not contaminating other resources or the whole SES. Hinkel *et al.* [43] show that the articulation between Resource Units (RU) and Resource Systems (RS) is not clear, as the SES framework should include other activities affecting the stock of Resources Units, as well as the interdependences between the activities affecting not only Resource Systems but also Users competing for the same resources (structuring factor 8).

Conclusion – remodeling the categories of the SES framework

The analysis of the structuring factors of mining activities show the necessity to adjust the basic categories of the SES framework, specifically Users and Resources. The reconfiguration of categories and variables is made to incorporate the structuring factors formerly detailed (cf. Box 1): protagonists on local level, economical entities, systems of interdependent resources (cf. Figure 1). A next step will be to include the symbolic dimension of extractive activities and its implications on learning processes [44,45] and governance systems (GS), as well as the impact of contamination activities on the determination of the rules-in-use.

The new framework presented here on the case of mining activities gives more space to social relations (conflicts, violence, collective memory, etc.) and their impacts on the management of natural resources; it applies to a conflict case like Constancia as well as to a normative controversy like Rosemont. It thus allows for a finer understanding of mining production as a social-ecological system, whose existing analyses are too often reduced to interactions between mining companies and communities. The critic of Ostrom's category has also allowed us to propose a complex vision of extractive activities as 'systems of interdependent resources' with competing uses that constitute a 'resource regime' whose territorial dimension shall be explored. A next step of our theoretical and empirical research on extractive activities will thus include analysis of the notions of 'governable space' [46,47], and of 'minescapes' [48], in order to integrate more precisely the territorial dimension of extraction.

Our first case study is the Constancia copper mine in the Cuzco Region of Peru, where the state is ineffectual in terms of regulating the relationships between communities and companies, but it does not mean that it is totally inefficient or absent. The state fixes the juridical and political frames of mining governance (norms for concessions, citizen participation process, etc.), and during conflicts it plays an intermediary role when communities try to reduce the asymmetry of power with companies. Constancia is often used as an example of a successful development project. However, since the production begun in 2015, a conflict is played out against the ideas of 'sustainable mining' [49], citizen participation [50] and 'corporate social responsibility' policies [51]. In the 1990s, Peru adopted a neoliberal approach to the mining of raw materials. This approach sparked violence between communities, the state, and mining companies [52], violence which, between 2006 and 2016, claimed 250 lives.

Our second case study is the project of the Rosemont copper mine in Arizona, USA [53**]. It shows that, unlike in Latin America, problems encountered by mining projects often derive from the institutional framework — local

and state administrations — responsible for environmental regulations, rather than from social movements. The 'sustainable mining' norms have been used by local administrations (such as Pima County) since 2007 in order to prevent the mine from opening; however, in 2019, the changes in the Federal Environmental Protection Agency (EPA) gave the last environmental license that allowed the activities to be officially started. These examples serve as an invitation to further study the role of the state in the process of environmental regulation by taking into account the hegemonic processes inherent in the internationalization of norms and the difficulties associated with introducing them in countries with different political cultures.

Conflict of interest and authorship conformation form

Please check the following as appropriate:

- All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.
- This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.
- The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript.
- The following authors have affiliations with organizations with direct or indirect financial interest in the subject matter discussed in the manuscript.

Declaration of Competing Interest

The authors report no declarations of interest.

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