Ontological Analysis of Weathering

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Abstract. *Weathering is an event that changes rocks and sediments when they are exposed to the Earth's surface conditions. This paper presents an ontological analysis and proposes a model for this type of event, based on the Unified Foundational Ontology and specializing concepts from the GeoCore ontology. The proposed model details the two main types of weathering processes (i.e. Physical Weathering and Chemical Weathering) and describes them in terms of transitions between situations, detailing the involved continuants and the properties that are affected, as well as how they are arranged in the situations connected by such processes. With this structure, the result of this work can help in tracing the past states of sediment and rocks before they are transformed into a weathering event and helps modelers to understand how to model physical occurents.*

1. Introduction

A good ontology model of events[1] can aid in solving a variety of problematic tasks, such as dealing with temporal issues in information retrieval (e.g., in a large information repository which describes the states of a same entity in distinct moments, retrieve the currently valid state of a given entity) and processing or inferring past configurations of state of affairs based on the current state and a sequence of events that affected it. The oil and gas industry deals frequently with this kind of problem, on reservoir geology studies, and can benefit from accurate ontological models of geological events.

Geology, as most of natural sciences, is moving from an empirical approach of manually capturing and analyzing information to a more descriptive and quantitative model of work. The new approach demands a crescent digitalization of geological information, which requires an underline set of formal models for systematically acquiring and processing information. Moreover, the geologist activity is strongly based on abductive reasoning, trying to understand past events that bring the rocks and sediments to the current situation. The interpretation of these events allows geologists to create models of past environmental conditions and the evolution of them through time, which supports modeling the 3D distribution of reservoirs. Formal ontologies play a central role in this scenario, both for offering uniform representation of data as well as for allowing computer applications to simulate the interpretation reasoning of the geologist.

[1]In this work we will use the terms event, process, and occurrent interchangeably to refer to the things that happen in time.

Sedimentology is a sub-field of the Geology domain concerned with studying sediments, sedimentary rocks, and the events they participate in the natural world. Sedimentary rocks are important for the economy, as they are bearers of oil and gas, and some ores (coal, placer diamond, and gold). Therefore, understanding the processes that create and modify sediments and sedimentary rocks is an important part of geologist activity.

Weathering is one of these sedimentary processes, and it congregates all chemical and physical processes that affect rocks and sediments due to the influence of the weather. Weathering is important as the first process at the beginning of the sedimentary part of the rock cycle. It is weathering that breaks igneous and metamorphic rocks into the particles that will eventually become a sedimentary rock. Weathering also modifies sediments and sedimentary rocks, becoming relevant for petroleum geology as this process can either enhance rock porosity, forming networks of highly permeable karsts, or close porosity, forming layers that will act as barriers for hydrocarbon flow.

In this context, this paper presents an ontological analysis and proposes an ontological model for the process of weathering, covering its two main types: physical weathering and chemical weathering. The model is based on the Unified Foundational Ontology (UFO) [Guizzardi 2005] and specializes concepts of the GeoCore Ontology [Garcia et al. 2020] and it is intended to (i) help in identifying the chain of events that led the rocks and sediments to the actual situation, (ii) identify the participants and the roles they play in the process, and (iii) indicating the observable properties that change in weathering processes.

The remainder of this paper is organized as follows: in section 2 we bring a brief introduction to the UFO and GeoCore concepts used; in section 3 we describe weathering from the domain perspective; in section 4 we present the ontological analysis and proposed model for the weathering event; in section 5 we discuss related work; finally, in section 6 we present the most relevant aspects brought up by this work and present our final remarks.

2. Background on the Unified Foundational Ontology (UFO) and GeoCore Ontology

[Guizzardi 2005] has proposed UFO as a philosophically and cognitively well-founded reference ontology, which provides a set of meta-types to classify the universals of a domain, based on the meta-properties of rigidity, relational dependence, provision of a principle of identity, provision of a principle of individuation defined by [Guarino and Welty 2000]. This taxonomy covers two broad categories: continuant universals and occurrent universals. Continuant universals gather the individuals that are wholly present at any time they are present, as a person, a rock or a portion of water. The continuant universals are further divided into object universals, whose instances are existentially independent continuants (e.g., a person, a portion of water) and moment types, whose instances only exist in other individuals (e.g., the weight of a rock, the marriage between two individuals). Moment types include both intrinsic moment types, such as quality types (whose instances inhere in a single entity and have a value on a quality structure, e.g. weight) and relator types, comprising relational moments which depend on a plurality of individuals and mediate them, allowing the existence of a material relationship (e.g. a contract). Moments are useful in our approach because we use them to detect changes that the events cause in continuants.

Concerning occurrent types, they gather things that unfold in time, accumulating temporal parts, and that are existentially dependent on the objects that participate in them. To account for this notion, UFO defines the concept of event as the transition from an initial situation that triggers the event (e.g., some water exposed to below freezing temperature triggers a freezing event), to an ending situation that the event brings about (e.g. a wet soil after raining) [Guizzardi et al. 2013]. In this context, a situation is regarded as a particular configuration of a part of reality which can be understood as a whole, gathering a set of objects and the moments that inhere in them [Guizzardi et al. 2013].

In UFO, an event is also regarded as anything that happens to a selected set of focal qualities in a particular spatiotemporal region [Guarino and Guizzardi 2016]. Besides that, continuants may play different historical roles in the context of the event they participate in, representing the way its participation influences the event. One special type of participation is that of creation, which means that the continuant that participates in such a way is created during the considered event [Almeida et al. 2019].

The GeoCore ontology [Garcia et al. 2020] formally defines the main entities in the Petroleum Geology domain. Garcia and colleagues have conceived a core ontology to clarify the meaning of highly used geological terms and provide a set of entities that the modeller could specialize to cover any other entity in the macro scale of geological interpretation to build a Geology model. The ontology offers a conceptual background for developing or integrating more specialized Geology ontologies.

The GeoCore covers naturally existent material entities produced by a geological process. The main structure embodies the dichotomy between the independent continuants Geological Object and Earth Material. Geological objects are material entities with unifying principle and are constituted by Earth Material. Earth Material is an homeomerous amount of matter with no unifying or countable principles, including rock, mineral and fluid, such as water, gas and oil. Existentially dependent entities complete the ontology: Geological Structure (internal or external arrangement of objects), Geological Contact (surface shared by two geological objects), Geological Boundary (surface that delimits an amount of matter in an object) and Geological Age (geological age of creation).

3. The geological weathering process

Rocks and sediments are constituted by an aggregate of particles. When they are formed, the temperature and pressure conditions play a determining role in defining which minerals will constitute the particles. Most rocks are formed on pressure and temperature conditions very different from those happening at Earth's surface. Frequently this mineral assemblage is chemically unbalanced with surface conditions. Therefore, while being exposed to surface conditions, the rock mineral composition might change and the bonds holding the rock's particles together might break, forming new particles. This process of changing rocks, sediments, and their components due to Earth's surface conditions is called weathering. The process of weathering is representative, in terms of requirements for ontology modeling, to most of the physic-chemical processes described in natural sciences. They request a set of conditions in the environment to happen and a trigger to start.

Weathering is divided in two kinds of processes, depending on the kind of change on the involved entities. Physical weathering is the disintegration of the rock, breaking it in smaller particles and resulting in the formation of sediments [Boggs et al. 1995]. Chemical weathering is the process that changes the composition of the rock or sediment by altering the minerals and/or by dissolving them [Boggs et al. 1995, Selley 2000].

Physical weathering involves changing in the forces acting on rocks and sediments, breaking the bonds that keep rocks and sediment's particles indurated. This might happen with the participation of water as in freezing-thaw weathering [Nicholson and Nicholson 2000, Robinson and Johnsson 1997], when the water inside the rock or sediment freezes and melts; and in wetting and drying weathering when clay minerals composing some rocks and sediments absorbs and releases water with changing climate. Biological entities like plant roots or animals can also cause physical weathering, by increasing the stresses inside the rock or actively breaking them. Physical weathering can also happen only by changing the temperature and pressure in the rock, as in insolation weathering, when differences in temperature cause enough stress to break the rock; and in stress-release weathering, when the reduced pressure in surface conditions causes the rock to expand and break.

Chemical weathering is a process that changes the chemical composition of the rocks or sediments. It happens due to the chemical unbalance of the minerals constituting a rock or sediment with meteoric waters near Earth's surface. This leads to different reactions of water with specific minerals. It can cause the dissolution of some minerals, and formation of more stable minerals by hydrolysis, oxidation, hydration, dehydration, and other less common processes. The most common minerals appearing in chemical weathering are clay minerals and iron and manganese oxides. The changes in composition gradually reduce the consolidation of the rocks, assisting in the disaggregation of the rock.

4. Ontological analysis of weathering

This section presents an ontological model for the process of weathering. It first presents the main types of continuants which are involved in this process. Then it brings a description of the weathering process, detailing its main subtypes in terms of their triggering and resulting situations, as well as their participants. The diagrams presented use the OntoUML language [Guizzardi 2005] to represent the types of things involved in the event and a visual notation based on [Costa et al. 2006] to exemplify prototypical instances of the event and of the involved continuants in order to clarify the dynamics of the event (i.e., what is altered between the initial and resulting situations).

4.1. Continuants

The process of weathering is materialized by changes in the geological objects constituted by rocks and sediments, and as a result of the action of water, biological entities or solar radiation. Following we present the definition of the types of continuants used in this analysis (Figure 1).

GC:Earth Material is defined in the GeoCore ontology as gathering instances of natural amounts of matter which are generated by a Geological Process. *GC:Earth Material* has two specializations, ***GC:Earth Fluid*** (which is also part of the GeoCore ontology) and ***Earth Solid***, gathering materials that naturally occur in fluid or solid state

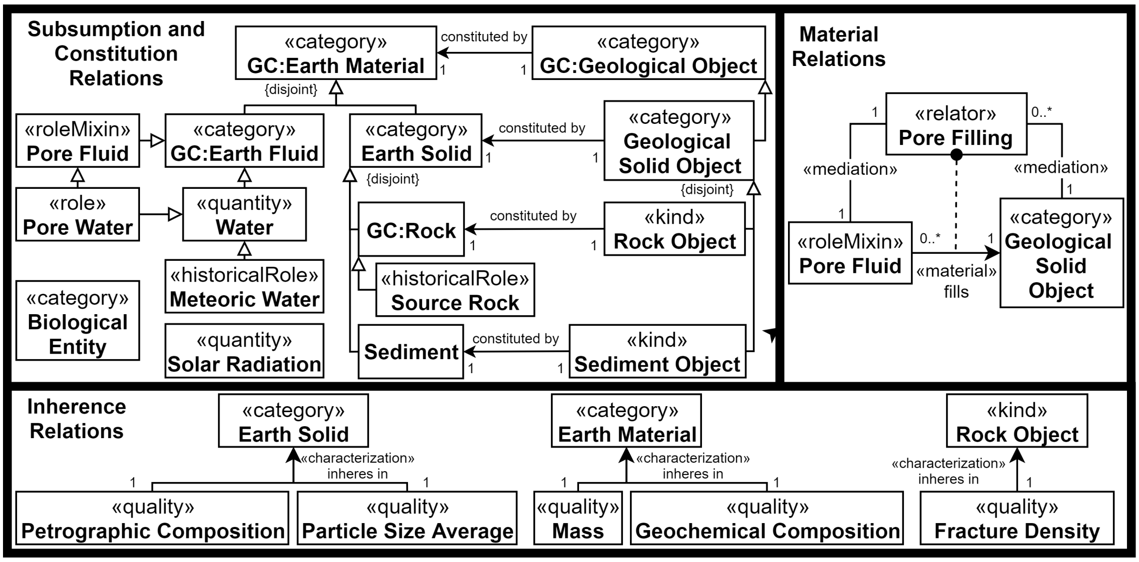

Figure 1. Main continuants involved in weathering and their relations.

respectively. As these concepts are rigid but do not provide an identity criterion for its instances, they are classified into UFO's Category.

Among the earth fluids we have ***Water***, which we defined as a portion of a fluid composed by a portion of the homonymous chemical substance and other molecular quantities that may be dissolved in it. Given that *water* provides a principle of identity criteria for their instances and has an individuation principle based on the notion of chunk (i.e., A maximally self-connected portion of matter), it is classified as a UFO's Quantity [Guizzardi 2005]. *Water* may also have the historical role of ***Meteoric Water***, which associates it with an Earth's surface event (e.g., a portion of water originated from rain).

Earth Solid is specialized into ***GC:Rock*** and ***Sediment***. *GC:Rock* is ontologically defined by the GeoCore ontology [Garcia et al. 2020] and each of its instances is an amount of consolidated solid matter constituted by an aggregate of mineral or biological particles and formed by geological processes. ***Sediment*** is an amount of unconsolidated solid matter constituted by an aggregate of mineral or biological particles and also formed by geological processes. The term sediment is used in geological literature to refer to different entities: it can be synonym to grain (a kind of particle), it can refer to a collective of particles (e.g. the sediment carried by a flow), or to the motionless mass of loose particles on the ground. Here we model sediment as the latter definition.

Both *Sediment* and *GC:Rock* are close to the idea of Amount of Matter in DOLCE [Masolo et al. 2003]. Thus, it seems that there is no suitable metatype in UFO for them. They are not portions of matter (UFO's quantities) since an amount of rock/sediment remains numerically the same even though it is divided in several portions. They could be seen as UFO's Collectives formed by collections of particles, but it is not the case either since the relation between rock/sediment and the collection of particles they are made of is that of constitution (as discussed in [Garcia et al. 2019]), with the constituted entities presenting emergent properties that cannot be found on the particle aggregate by itself (e.g., the porosity of a rock is a result of the organization of the particles). Finally, they do not seem to fit into UFO's Kind since it is hard to see them as functional complexes.

So, in this work we did not assert any metatype for either of these types and leave it as future work.

In this work we characterize Earth Material by its ***geochemical composition (GC)*** and ***mass***, which are both UFO's Qualities. *GC* represents the volumetric proportion of the different types of molecules in the entity. This quality is related to the minerals that constitute the particles forming an *Earth Solid*, and to the mixture of molecules in instances of *Earth Fluid*. *Mass* is a quality that corresponds to the homonymous physical property of an amount of matter (i.e., the quantification of the mass of an amount of matter). In addition, earth solids are characterized by their ***petrographic composition (PC)*** and ***particle size average (PSA)***. *PC* is a UFO's Quality representing the volumetric proportion of the pores and of each kind of particles in an *Earth Solid*. *PSA* is also a UFO's Quality, which represents the average size of the particles in an *Earth Solid*. Besides that, *Rock Object* is characterized by its ***fracture density (FD)***, a UFO's Quality representing the number of fractures per volume of rock in the object.

The main interaction that happens during a weathering process is that of an *Earth Fluid* filling the pores of an *Earth Solid*, represented by a UFO's Relator called ***pore filling***. The infilling fluid plays the role of ***Pore Fluid*** (a UFO's RoleMixin) or the more specific ***Pore Water*** role (a UFO's Role) when such fluid is a portion of *Water*.

Besides earth materials, we also included geological objects in our model since they are the focal participants of the weathering processes (i.e., it is the involved geological objects that endure the process, preserving their identity despite the qualitative changes). ***GC:Geological Object*** is part of the GeoCore ontology and gathers instances of material objects constituted by some *GC:Earth Material*. We specialized it into the ***Geological Solid Object***, which gathers instances of *GC:Geological Object* constituted by some *Earth Solid*. As both of these types are rigid but do not provide an identity criterion for its instances, we classified them as UFO's Category. On top of that, we define ***Rock Object*** and ***Sediment Object*** as a *Geological Solid Object* constituted by *GC:Rock* and by *Sediment*, respectively. These are rigid types that represent functional complexes into which rock and sediment amounts are arranged (e.g., geological layers, various types of sediment deposits) and that provide identity criterion for its instances, so that they are classified as UFO's Kind.

It is noteworthy that in this work we use the notion of constitution described in [Garcia et al. 2019], which is based on Baker's view [Baker 2007]. In [Baker 2007] constitution is a relation of genuine unity, so that the constituted object may have some its properties derivatively from its constituent, which applies for our work (e.g., a *Rock Object* is characterized non-derivatively by its own qualities, such as *fracture density*, and derivatively by the qualities of its constituents, such as *mass* or *petrographic composition*).

Apart from earth materials and geological objects, **Biological Entity** type gathers living things or its parts, including entities with diverse principles of identity such as roots of plants or any burrowing and sediment feeding animals. Thus, it is also a rigid concept that does not provide an identity criterion for its instances, being classified as a UFO's Category. Completing the inventory of continuants, ***Solar Radiation*** gathers portions of energetic radiation, constituted by photons and other particles emitted by the Sun and we

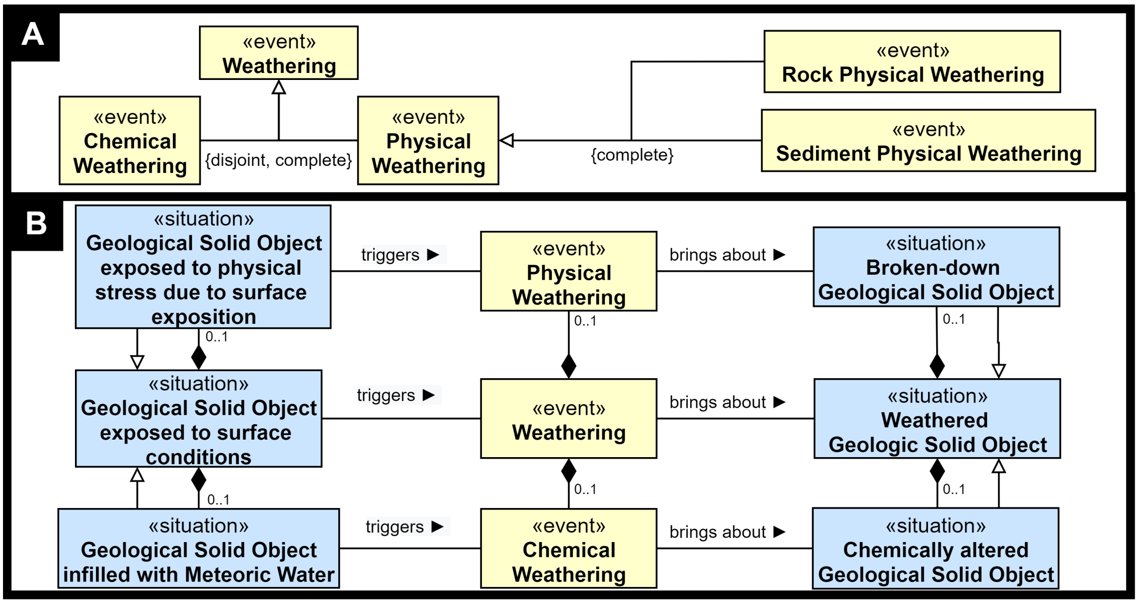

Figure 2. (A) Weathering and its subtypes; (B) Weathering and its possible partitions.

classified it into UFO's Quantity. [Guizzardi 2005].

4.2. Weathering model

As previously described, ***Weathering*** is a process that involves the interaction of an *Geological Solid Object* and some environmental element that results in change of characteristics or the creation/destruction of a *Geological Solid Object*. It is triggered by a ***Geological Solid Object exposed to surface conditions*** situation and brings about a ***Weathered Geological Solid Object*** situation.

There are a variety of classification criteria according to which we can specialize types of occurrent [Rodrigues and Abel 2019]. Regarding *Weathering*, it is specialized according to the type of focal qualities [Guarino and Guizzardi 2016] that are affected during the process. Thus it is a ***Physical Weathering*** when it affects mechanical qualities of the weathered solid (e.g., its petrographic composition, granularity of a sediment). Alternatively, it is a ***Chemical Weathering*** when the process affects chemical qualities of the solid (e.g., its geochemical or petrographic composition). These two types form a complete partition over the *Weathering* type (Fig. 2A).

Both mechanical and chemical qualities may be affected in a single occurrence of *Weathering*. In such cases, *Weathering* unfolds as a complex event, composed of simultaneous subprocesses of *Physical Weathering* and *Chemical Weathering* (Fig. 2B). With that, the triggering and ending situations of such occurrences are composed of the triggering and ending situations of its subprocesses. These subprocesses and their initial and ending situations are detailed in the following sections.

4.3. Physical weathering model

In a **Physical Weathering** event (Fig. 3A) a *Geological Solid Object* is mechanically fragmented due to physical stresses associated with surface environmental conditions. Thus,

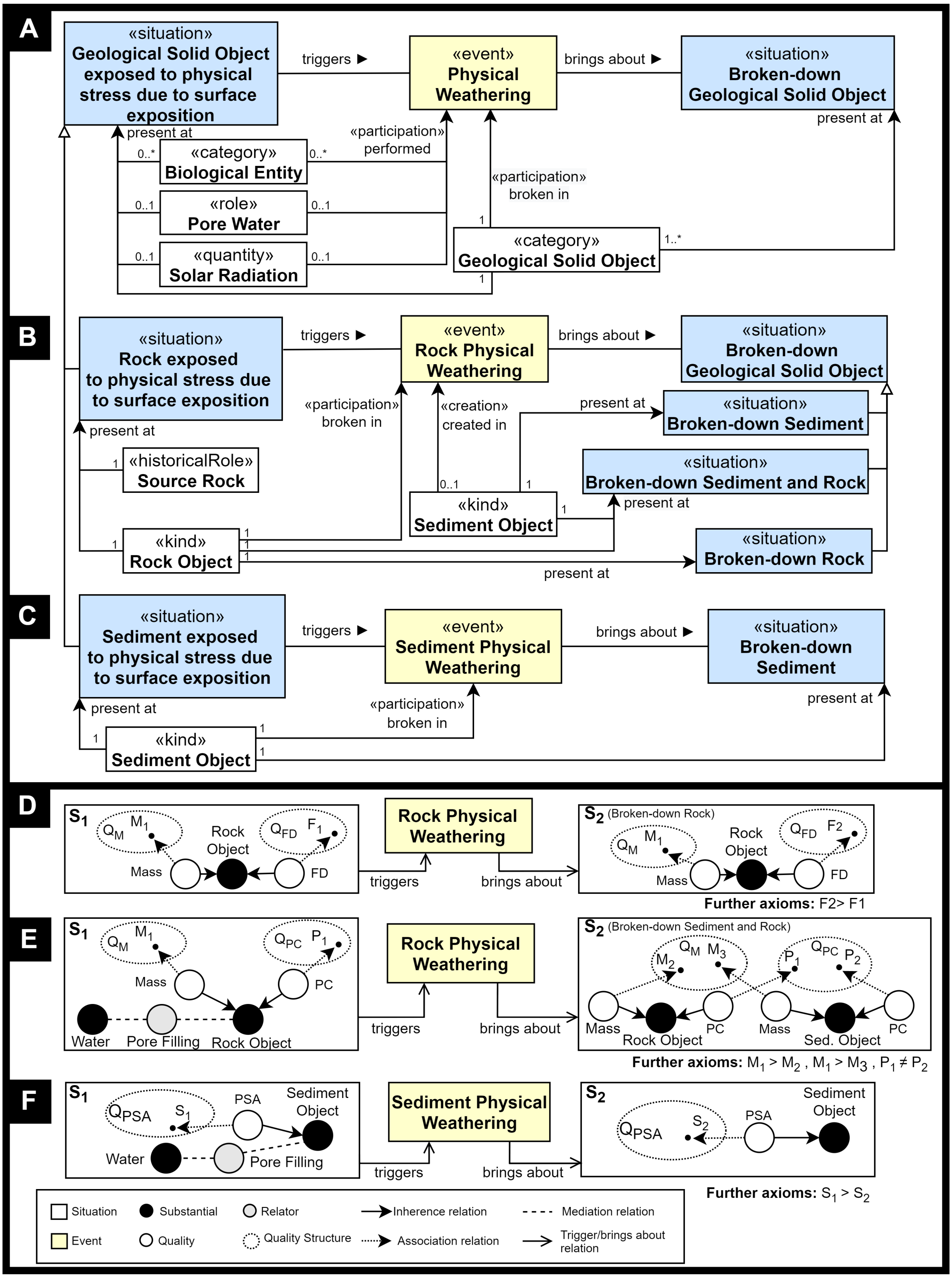

Figure 3. **(A) to (C): OntoUML model for the Physical Weathering, Rock Physical Weathering and Sediment Physical Weathering events, respectively; (D) and (E): Visual scheme notation of two instances of the Rock Physical Weathering event with different final situations; (F): Visual scheme notation of an instance of the Sediment Physical Weathering event.**

this event is triggered by a situation of ***Geological Solid Object exposed to physical stress due to surface exposition***, that mandatorily has the presence of the *Geological Solid Object* that will be broken into smaller pieces. In addition, *Water*, *Biological Entities*, and/or *Solar Radiation* are also present when they act as the agent changing the forces in the object, but they suffer no change in its properties during the event. The *Physical Weathering* event brings about a ***Broken-down Geological Solid Object*** situation containing the instances of *Geological Solid Object* modified or created during this process. *Physical Weathering* can also be specialized into ***Rock Physical Weathering*** and ***Sediment Physical Weathering*** (Fig. 2A), according to the type of *Geological Solid Object* present in its initial situation (i.e., rock or sediment object).

A ***Rock Physical Weathering*** (Fig. 3B) is triggered when the *Geological Solid Object* that is present in the initial situation is a *Rock Object*, being a ***Rock exposed to physical stress due to surface exposition*** situation. This event provides the *historical role* of ***Source Rock*** for the instance of *Rock* that constitutes the *Rock Object* that is suffering the weathering. It is important to make clear that, though being referred by the same term, this role has nothing to do with that of a rock in a petroleum system as the generator of hydrocarbons [Abel et al. 2015].

A *Rock Physical Weathering* might lead to three different resulting situations depending on the intensity of the physical stresses applied in the rock, the duration of the event and the fragility of the rock. The first possible outcome is a ***Broken-down rock*** situation, in which the initial rock object is fractured, being broken in several pieces (though it remains as the same, single object). The *Rock Object* in the initial and final situations have the same *PC* and *GC* value. However, the new fractures on the final rock object increases the value of its *FD*. This case is exemplified in the Fig. 3D.

A second possible outcome of a *Rock Physical Weathering* event is a ***Broken-down sediment*** situation, in which a single instance of *Sediment Object* is present. In this case, the rock object in the initial situation is broken in so many small parts that it can no longer be regarded as a rock object, but rather the aggregate of such little parts constitutes a new amount of *Sediment*, which constitutes the new *Sediment Object* that is created during the event. This *Sediment Object* has the same *GC* value as the initial rock object, as its particles are made of the same minerals, but it has a different *PC* value, as the proportion and kind of pores and particles is altered with the fragmentation. The mass value of the initial rock instance and the final sediment instance are the same.

The third possible outcome of a *Rock Physical Weathering* event is a ***Broken-down sediment and rock*** situation, in which an instance of *Sediment Object* is created and the *Rock Object* instance remains. Fig. 3E exemplifies an occurrence of a *Rock Physical Weathering* bringing about this type of situation. In the situation described, the sediment and the rock objects have equal *GC* value as the initial instance of *Rock Object*, but the *Sediment Object* created has different *PC* value. The mass values of the sediment and rock objects are both lesser than the previous mass value of the instance of *Rock Object* (since the new object result from the fragmentation of part of the initial one).

A *Physical Weathering* event can also be specialized in a *Sediment Physical Weathering* event (Fig. 3C). It is triggered by a ***Sediment exposed to physical stress due to surface exposition*** situation, in which an instance of *Sediment Object* is present.

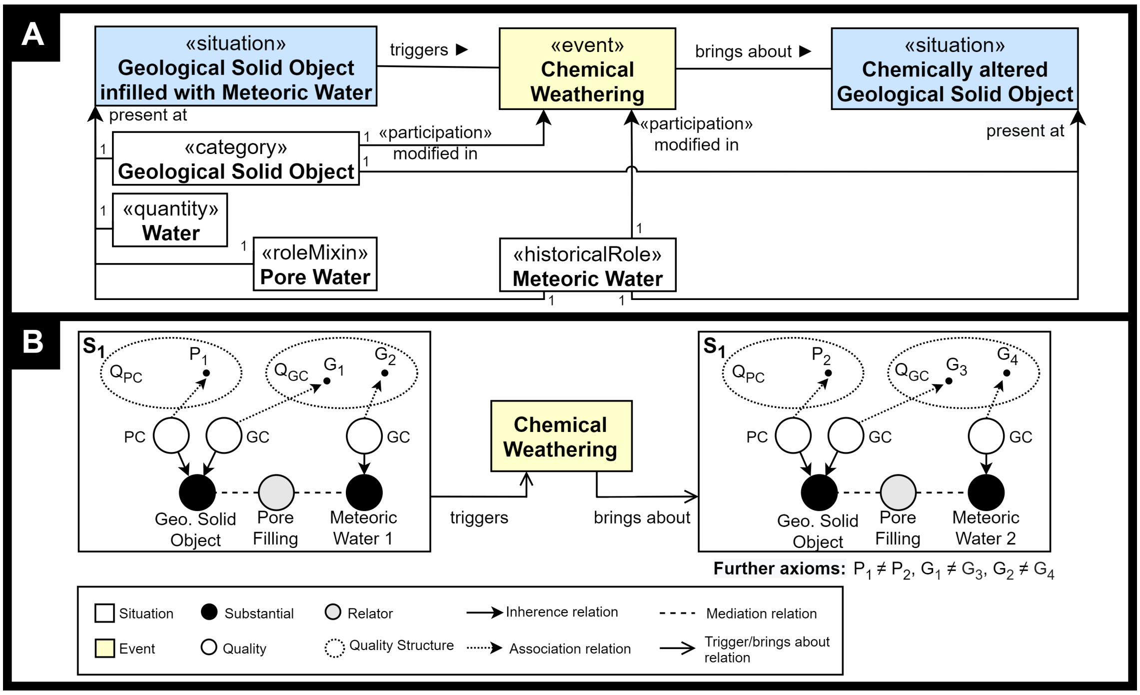

Figure 4. (A) OntoUML model for the chemical weathering event. (B) Visual scheme notation of an instance of a chemical weathering event and the situations triggering and brought about by the event .

In this event, the particles that form the sediment that constitutes the object are mechanically broken into smaller particles, bringing about a *Broken-down sediment* situation at the end. The instances of *Sediment Object* in both initial and final situations are the same, with a lesser *PSA* value at the end. The *PC* value of the sediment object might change or not, depending on whether or not the break-up of the particles changes their type, but the *GC* and mass values remain unaltered. An instance of this event is represented in Fig. 3F in which only the *PSA* value of the *Sediment Object* instance is changed by the event.

4.4. Chemical weathering model

A ***Chemical Weathering*** event is triggered by an ***Geological Solid Object infilled with Meteoric Water*** situation (Fig. 4A), in which an instance of *Geological Solid Object* is infilled by an instance of *Meteoric Water* (which plays the role of *Pore Water*). Then, it brings about a ***Chemically altered Geological Solid Object*** situation with the presence of the same instance of *Geological Solid Object* and a new instance of *Meteoric Water*. During this event the *Geological Solid Object* is submitted to a chemical unbalance with the water filling its pores, resulting in exchange of mass between the *Geological Solid Object* and the *Meteoric Water*. This is materialized by a change of *GC*, *Mass* and *PC* values of the participants in the initial and final situations. An instance of this event is represented in Fig. 4B.

5. Related Work and Discussion

Since petroleum reservoirs are in subsurface and data is scarce for direct analysis, geoscientists need to propose models to the distribution of rock bodies. The traditional approach is building statistical models that describe the geometry and distribution of rock bodies, associating them to flow properties in order to evaluate the production capability of wells. However, this method may hide important properties of reservoirs concerning spatial disposition evaluation and internal barriers for flow, leading to production misevaluation. Thus, recently, efforts have been directed to complement the quantitative approaches with knowledge-based models, including ontologies.

An example is the work in [Le Bouteiller et al. 2019], which proposes a graph-based ontology with nodes representing either characteristics of geological deposits or phenomena that may affect such deposits. Directed edges in the graph indicate the impact of a phenomenon over a deposit characteristic, corresponding to possible causes of or explanations for the presence of such characteristic. This ontology does not explicitly include weathering, but covers some related and/or overlapping processes, such as diagenesis and erosion. Despite covering an extensive list of rock-body properties and related processes, the approach lacks ontological rigor and seems to focus on epistemological aspects and inference rules rather than ontological concerns.

An account of the process of weathering can be found on EcoLexicon (ecolexicon.ugr.es), a multilingual thesaurus specialized in the environmental domain. It is structured as propositions and knowledge frames that are organized in an ontological structure, which focuses on perceptual information and semantic relations [Faber et al. 2011, Gil-Berrozpe et al. 2019]. Its top-level categories (i.e., object, event, and attribute) are configured in a prototypical domain event that is described in terms of its agents, patients and results. With that, Weathering is a type of Decomposition process that affects Rocks or Minerals, that is caused by Water, (living) Organisms, Solar Radiation or Atmosphere. It is subdivided into Mechanical Weathering (analogous to our Physical Weathering), which affects Rock and results in Sediment, and Chemical Weathering, which results in karsts. This provides a rich structure to contextualize the elements involved in this process.

As pointed out in [Reitsma et al. 2009], ontologies for Geosciences are usually more concerned with 'what' than 'why' or 'how', limiting the understanding of evolving entities in a context, which seems to be the case in the mentioned works. In this sense, we further the approach adopted in those works. Besides using the description of the process to frame the involved objects and affected properties, we also define it in terms of its initial and ending situations. Then, it makes explicit how the process unfolds by indicating the observable properties that change in the weathering process. of the involved participants. With that, besides enhancing integration of data collected about a region of interest into the context of these occurrences, the model also allows the understanding of sedimentary occurrences where the data is incomplete, leading to the geologists to fill the gaps of information on the geology records, providing a more complete view of the exploration area. Moreover, it helps in identifying the chain of events that can lead rocks and sediments to a given situation, enabling temporal reasoning and simulations.

6. Concluding Remarks

This paper presented an ontological analysis and the corresponding model of the process of weathering, which was developed based on Unified Foundational Ontology (UFO) and GeoCore Ontology. The model details the two specializations of this event, namely the physical weathering and chemical weathering, specifying their initial and ending situations as well as the involved participants and their affected properties.

By defining the weathering process in terms of its initial and ending conditions, the presented model can help in describing the chain of events that led the rocks and sediments to their current situation. Moreover, by indicating the observable properties that are changed in weathering processes, the model may allow integrating the data collected about a region of interest into the context of these occurrences. In fact, by defining the process as the change on properties of its participants or their creation/destruction, we add a new layer of meaning in relation to what was done in previous work, which can offer useful insights for those who deal with modeling and simulating events in related natural domains, such as sedimentology processes. Furthermore, this enriched model may improve the understanding of sedimentary occurrences where the data is incomplete, leading the geologists to fill the gaps of information on the geology records, providing a more complete view of the exploration area.

Besides that, by proposing the physical weathering event as a truthmaker for the source rock historical role, the model also contributes to provenance study, i.e., a branch in geology that aims at identifying the rocks from which the sediments originated. In this context, the weathering model can be integrated with other event models to rebuild the full path of sediments. Tracing the source rock of a weathering event that created sediments can also be directly useful in reservoir characterization, since they reveal characteristics that influence the quality of the reservoir.

Given this structure, we believe that this process modelling proposal can offer useful insights for those who deal with modeling and simulating events in related natural domains, such as sedimentology processes. Nevertheless, the model presented here is the foundational stone for modelling this geological process and does not exhaust the theme. In the current state, the model does not include explicit representations for some environmental aspects that affect the entities involved in weathering processes. For example, it does not include temperature and external pressure which are needed to represent insolation and stress-release weathering, nor does it cover the specific interactions involving biological entities. Besides that, the model can be improved by a clearer ontological account of the notions of rock and sediment (since they don't seem to fit any of the metatypes provided by UFO), as well as their relation with the objects they constitute, which are in progress within the research group.

Finally, future work will focus on detailing more specific types of weathering (e.g., freezing-thaw, wetting and drying, insolation, stress-release) as well as classifying it into more general types of process (e.g., natural process, creation, destruction). Additionally, we will further the modeling to encompass weathering processes in smaller scales (e.g., the effects over grains of sediment). Another horizon of investigation is the uncovering of the dispositions involved in the triggering of weathering processes in order to better support reasoning and simulation tasks.

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