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# GEOMORPHOLOGICAL SITES, PUBLIC POLICIES AND PROPERTY RIGHTS. CONCEPTUALIZATION AND EXAMPLES FROM SWITZERLAND

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ABSTRACT: E. Reynard, *Geomorphological sites, public policies and property rights. Conceptualization and examples from Switzerland*. (IT ISSN 0394-3356, 2005).
The paper analyses the importance of institutional rules for protecting and managing geomorphological sites. A framework, called Institutional Resource Regime (IRR), is proposed. It considers a natural resource, and more specifically geomorphological sites, in a systemic manner, and combines the analysis of the property rights concerning the resource and the public policies regulating its exploitation and protection. Two examples are presented in order to illustrate the analytical possibilities offered by the IRR concept and the necessity to develop specific and adequate institutional tools in order to guarantee efficient protection of geomorphological sites.

*RIASSUNTO: E. Reynard,* Siti geomorfologici, politiche pubbliche e diritti di proprietà. Analisi ed esempi in Svizzera*. (IT ISSN 0394-3356, 2005).*
*L'articolo mette in evidenza l'importanza di sviluppare regole istituzionali che permettano di proteggere e gestire i siti geomorfologici in modo adeguato. Viene proposto un quadro analitico chiamato Regime Istituzionale di Risorse (RIR), che considera una risorsa naturale, e più particolarmente i siti geomorfologici, in un modo sistemico e combina l'analisi dei diritti di proprietà concernenti la risorsa e delle politiche pubbliche che regolano tale risorsa. Due esempi illustrano le possibilità analitiche offerte dal concetto RIR e dimostrano la necessità di sviluppare strumenti istituzionali adeguati per garantire una protezione efficace dei siti geomorfologici.*

Keywords: Geomorphological sites, Protection, Public policies, Property rights, Institutional resource regime.

*Parole chiave: Beni geomorfologici, Protezione, Politiche pubbliche, Diritti di proprietà.*

## 1. INTRODUCTION

Geomorphological sites (or geomorphological assets) are defined as geomorphological landforms (and processes) that have acquired a scientific, cultural/historical, aesthetic and/or social/economic value due to human perception or exploitation (Panizza & Piacente, 1993; Quaranta, 1993). More precisely, they have a particular importance for reconstructing, explaining and recording the history of Earth, its climate and all the life it supports (Grandgirard, 1997). They can be single geomorphological objects (e.g. waterfall, inselberg, erratic block, dune, etc.) or larger landscapes (e.g. glacier forefields, marine coasts, alluvial fans, etc.). The value of a site can be of four types (Panizza & Piacente, 1993, 2003; Quaranta, 1993): scientific (e.g. a moraine representative of a glacier extension, an artificial trench allowing observation of a transition in a sediment succession), cultural/historical (e.g. a mountain that has religious or mystic value or a landform/landscape that is a support for cultural/historical activities or infrastructures), aesthetic (e.g. some amazing mountainous, coastal or desert landscapes), and social/economic (e.g. aesthetic landscapes as tourist destinations).

As indicated by Cavallin *et al.* (1994), geomorphological sites may be modified, damaged, and even destroyed, by direct or indirect impacts of human activity. Direct impacts are defined as active modifications of a geomorphological site by human activity (e.g. destruction of a morainic crest by road construction, modification of the aesthetic value of a coastal environment by the building of a tourist settlement), whereas indirect impacts do not have direct contact with the geomorphological site but highly affect it (e.g. sedimentation changes in an alluvial fan by gravel extraction upstream, reduction of the view of a geomorphological asset by the construction of buildings).

Due to their vulnerability, most geomorphological sites need to be protected against direct and indirect human impacts. The first step in a protection process is to assess the value of geomorphological sites (Panizza & Piacente, 1993, 2003; Panizza *et al*., 1995a; Grandgirard 1999a). Numerous more or less quantitative methods have been proposed for evaluating the quality of geomorphological sites (Quaranta, 1993; Panizza *et al*., 1995b; Rivas *et al*., 1997; Boyer *et al*., 1998; Grandgirard, 1999a; Coratza & Giusti, 2003), especially in the context of Environmental Impact Assessment (EIA) procedures. Proposals have also been made for conducting inventories of geomorphological sites at a regional scale (Grandgirard, 1999b).

The objective of this paper is to discuss the second step of a procedure for the protection of geomorphological sites, that is, the implementation of rules (restrictions of use, bans, access regulation, management of the material extraction, etc.), aiming to regulate the "exploitation" of geomorphological sites. The third

step should be to assess the effects of the regulation on the quality of the sites and on the sustainability of their management. I will use the Institutional Resource Regime (IRR) concept, a framework that was developed for analysing the quality of natural resource management from an institutional point of view (Kissling-Näf & Varone, 2000; Knoepfel *et al.*, 2001), and that we consider useful for developing strategies for the protection of geomorphological sites (Reynard, 2002). We will first describe the relationships between geomorphological sites and natural resources. Then, the IRR concept will be presented and applied to the geomorphological sites analysis. Two Swiss examples demonstrating the interest of the IRR concept in the area of geomorphological site protection, will finally be presented.

## 2. GEOMORPHOLOGICAL SITES AS NATURAL RESOURCES

As geomorphological sites are in contact with human activities, and because they are exploited, even from an immaterial point of view (e.g. the observation of a landscape dominated by geomorphological landforms), they may be considered as natural resources. We define a natural resource as the part of the natural environment used by humans for satisfying their needs (Siebert, 1983). In this anthropologically centered definition, natural resources are culturally defined (Grima & Berkes, 1989); nature becomes a *natural resource* only when humans give it a value. In this sense, as an example, gas and oil were not natural resources for the North American Indians of 1800 (Grima & Berkes, 1989).

In every process of resource exploitation, the *stock* of the resource and the *yield* are distinguished (Ostrom, 1990). The stock is the amount of resource that is naturally renewed in the case of a renewable natural resources (e.g. underground water that is renewed every year by the hydrological cycle) or that is not renewed in the case of non-renewable resources (e.g. oil, gas). The yield is the product of the stock. In the case of water, for example, the stock is the quantity of water involved in the natural water cycle of a watershed. The yield is the amount of water that is available to humans for satisfying their needs for consumption, irrigation, industrial production, etc. When the total amount of water uses is higher than the yield, there is overexploitation.

From an economic point of view, natural resources are considered in order to create goods and services for society (Grima & Berkes, 1989). Goods and services are produced either by the stock or the yield (Fig. 1). In the case of forests, the wood is a good produced by the yield in a situation of sustainable exploitation, and by the stock in a situation of overexploitation. The space for recreation and the protection of infrastructures against natural hazards (avalanches, debris flows) are services produced by the stock and the yield. The production of biodiversity is a good and a service produced by the stock and the yield. The goods and services are used by humans in three different ways (Knoepfel *et al.*, 2001): direct uses (e.g. direct consumption, input in the industrial production), indirect uses (e.g. air and water as receptacle for the absorption of waste), and immaterial uses (e.g. aesthetic or cultural value of a landscape).

From a geomorphological point of view, Rivas *et al*. (1997) distinguish consumable and non-consumable geomorphological resources: consumable resources are those used for construction and other material extraction, whereas non-consumable resources include all the geomorphological elements that do not imply the direct extraction and consumption of material. The authors also include in that category landforms as part of the landscape, the sites of geomorphological interest from a scientific, pedagogic and recreational point of view, and geomorphological units as support for other elements of the environment, especially ecosystems. They add that geomorphological processes may represent natural hazards and contribute to environmental change (see also Cavallin *et al.*, 1994). Extraction may be considered to produce goods (Fig. 2) coming either from the stock (e.g. extraction of gravels from alluvial terraces) or from the yield (e.g. extraction of gravels directly from a river bed or active deltaic fan). We can also consider that geomorphological (or geological) processes may be, under certain conditions, a type of natural resource (e.g. fluvial flow used for energy production, volcanic eruption and geysers as tourist resource for regions like Hawai or Iceland, geomorphological features as support for specific human activities like canyoning, etc.). On the other hand, not all the geomorphological resources are to be considered as geomorphological sites. Finally, we can consider that geomorphological assets are part of the landscape resource of a region.

As well as for other natural resources, there is increasing competition for geomorphological sites between various users or user groups that have quite different, and sometimes contradictory, interests and perceptions of the value of the resource. Such rivalries may be mitigated by defining regulations and institutions, whose objectives should be the co-ordination between rival uses in order to avoid conflicts, the plan-

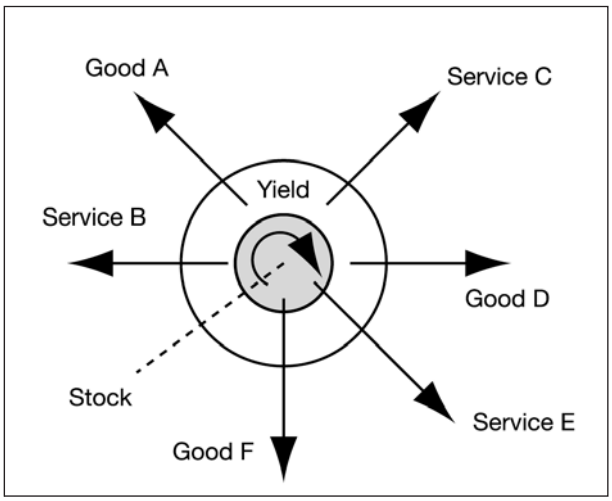


Fig. 1 - Stock and yield in relation with goods and services produced by a renewable natural resource.

*Ammontare (stock) e prodotti rinnovabili (yield) in relazione ai beni e servizi prodotti da una risorsa naturale rinnovabile.*

ning of long-term resource management and the preservation of the resource stock in order to be able to satisfy the needs of future generations (Fig. 3). I propose to use the Institutional Resource Regime (IRR) framework developed by Kissling-Näf & Varone (2000) and Knoepfel et al. (2001) as the analysis method.

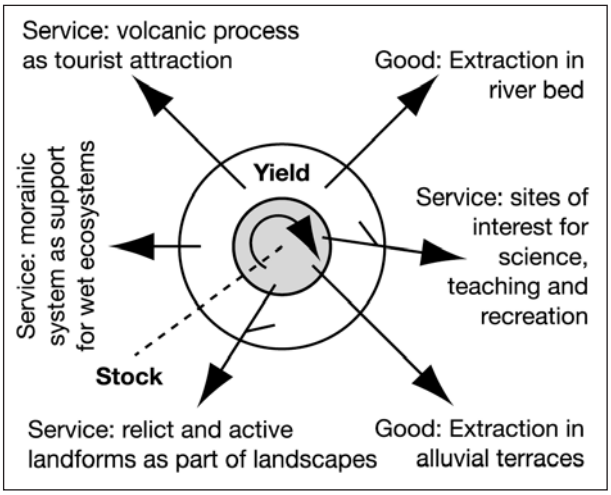


Fig. 2 - Examples of goods and services produced by geomorphological processes and landforms.

*Esempi di beni e servizi prodotti da processi e forme geomorfologiche.*

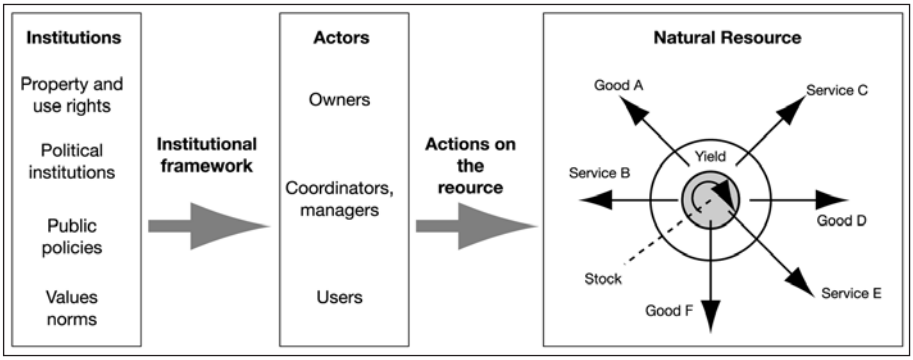


Fig. 3 - Conceptual model describing the relationships between institutions, actors and natural resources (from Kissling-Näf & Varone, 2000, modified).

Modello concettuale che mette in evidenza le relazioni fra istituzioni, attori e risorsa naturale (da Kissling-Näf & *Varone, 2000, modificato).*

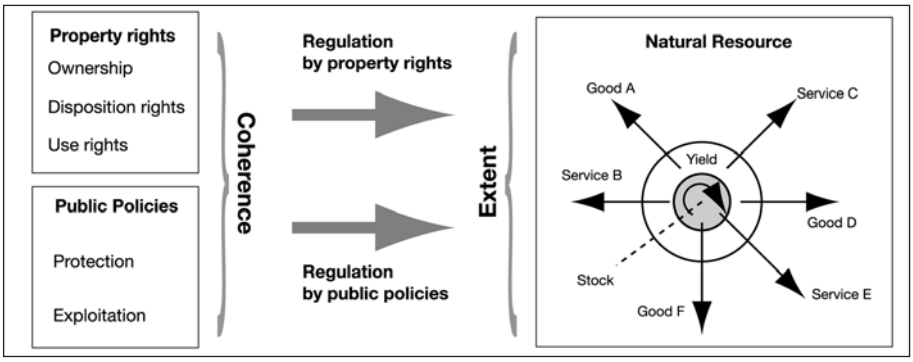


Fig. 4 - Components of an institutional resource regime.

*Componenti di un regime istituzionale di risorse.*

## 3. INSTITUTIONAL RESOURCE REGIME (IRR)

The IRR concept considers all the uses of a natural resource as a whole. A renewable natural resource is generally exploited by more than one type of users. Forests, for example, are used for various kinds of wood exploitation (e.g. fire, construction), other material exploitation (e.g. mushrooms), protection (e.g. against rockslides and avalanches), leisure (e.g. walking) and biodiversity conservation. Management of such highly heterogeneous resource use systems needs efficient institutional regulations; sustainability of resource management is supposed to depend on the institutional framework. The IRR concept allows the analysis of all the components of these institutional conditions.

An Institutional Resource Regime (Fig. 4) is defined as the combination of the property regime and public policies that regulate the natural resource management (Knoepfel *et al.*, 2001). The property regime is analysed through three types of property rights (formal property titles (ownership), disposition rights and use rights) and two categories of public policies are considered: exploitation and protection policies. Four types of ownership have been defined (e.g. Ostrom, 1990; Bromley, 1991; Devlin & Grafton, 1998): private property, state property, common property, and no property (Tab. 1). Two complementary dimensions are also considered: the extent and the coherence. The extent describes the number of goods and services explicitly regulated by the IRR. The coherence concerns the degree of co-ordination of the actors' network, mainly the co-ordination between the owners and the actors involved in the implementation of public policies.

The IRR are then classified into four regime types: no regime, simple regime, complex regime and integrated regime, by combining the extent and the coherence (Kissling-Näf & Varone, 2000 and Tab. 2). We speak of a "*no regime situation*", in cases where neither ownership, disposition, use rights, nor public policies exist. Chances are, in this instance, that a resource has not yet been discovered. This was the case for biodiversity until recently; it is certainly the case for geodiversity, a resource that has not been defined precisely until now.

If the use rights are formulated either directly and/or at least indirectly through an initial policy design (e.g. bans, limitation of access), this can be referred to as a "*simple regime*". We suspect that this kind of simple regime emerges when the central actors observe rivalry and scarcity in connection with the predominantly

homogenous use of one or several goods or services provided by a given resource and this becomes a collective problem because of the risk of overuse. In most countries, geosites and landscapes in general could be considered to be in this situation: there is a problem of management, but few regulations have been produced until now. In a "*complex situation*", we can already observe differentiation on the basis of the specific uses of the resource (goods and services provided by the resource) and the combining of the formal ownership, disposition and use rights with more detailed public policies. The heterogeneous demands and the sum of the diverse use rights could lead to a crisis and possibly even the collapse of the complex regime. Examples of such competing and excessive uses can be found in the area of land (e.g. agriculture, construction zones, roads and railways, etc.), water (e.g. fishing, energy, agriculture, drinking water, etc.) and forest (e.g. biodiversity, recreation, timber, etc.). An institutional regime which can take into account the heterogeneous demands and regulate the totality of the uses in order to maintain the capacity of the renewability of the resource is considered as an "*integrated regime*". We assume that such a regime may promote sustainability, that is to guarantee the transparent satisfaction of the heterogeneous use requirements and to conserve the resource stock.

Tab. 1 - Classification of property rights (from Knoepfel *et al*., 2001, modified).
*Classificazione dei diritti di proprietà (da Knoepfel* et al*., 2001, modificato).*

| | Private property | State property | Common property | No property Open access |
|---|---|---|---|---|
| Owner of the property title | People, private societies | State: local municipalities, region, state, etc. | Associations, corporations | Nobody |
| Exclusion | Yes | Yes | Yes | No |
| Example | Soil, forests | National Parks | Alpine meadows | Air, landscape |

Tab. 2 - Classification of resource institutional regimes (from Kissling-Näf & Varone, 2000).
*Classificazione dei regimi istituzionali di risorse (da Kissling-Näf & Varone, 2000).*

| Institutional Resource Regime (IRR) | | Coherence of the actors within the public policies and the property rights system | |
|---|---|---|---|
| | | High | Low |
| Range of regulated goods and services (derived from the resource) | High | Integrated regime | Complex regime |
| | Low | Simple regime | No regime |

The analysis of the institutional regime of a resource is carried out in five successive steps (Reynard, 2002). First, the resource perimeter is defined and a compilation of the various goods and services provided by the resource is made in order to represent the main current rivalries, the historical evolution of the relationships between goods and services, and the principal transformations of the resource stock and yield. This part of the analysis concerns essentially the resource and its characteristics. Then, the property regime (formal ownership, disposition rights and use rights) and the public policies related to the resource exploitation and protection are successively analysed. The first three steps are then combined to characterise the resource regime. It is assumed that simple or integrated regimes are more sustainable than complex regimes. The last step is dedicated to the improvement (if necessary) of the resource regime in order to improve sustainability. Thus, the systemic IRR analysis is assumed to allow a rational selection of management instruments.

## 4. GEOMORPHOLOGICAL SITES AND INSTITUTIONAL RESOURCE REGIMES

If we consider the management of geomorphological sites in a systemic manner, the IRR appears to be an adequate tool for analysing the various uses of geomorphological sites by humans and for improving management mechanisms. In this section, we successively analyse what the goods and services provided by a geomorphological site are, and in which way property rights and public policies are important tools for managing geomorphological sites.

The principal goods and services produced by geomorphological sites are presented in Table 3. Thirteen types of uses are proposed, following the typology proposed by Bisang *et al*. (2000) for the resource "landscape". These uses are grouped in three large categories of geomorphological sites: a) natural heritage (support for life and Earth science heritage), b) cultural heritage (cultural, symbolic, religious, pedagogic value), and c) objects for economic uses (support and spaces for tourist and other economic uses).

In most cases, a geomorphological site combines several values coming from the three categories. For example, the famous Uluru (Ayers Rock) in Central Australia (Fig. 5), combines the following goods and services. As it is a characteristic example of an inselberg, it has a geomorphological value (Twidale, 1978).

Fig. 5 - Uluru (Ayers Rock), an Australian geomorphological site with several rival uses.
*Uluru (Ayers Rock), un geomorfosito australiano con parecchi usi possibili, tra loro contrastanti.*

The vertically stratified sandstones testify the existence of an ancient delta that was removed by tectonic movements (Earth history value). The taffonis that can be shown at its surface give evidence of climate change (climate history reconstruction). The rock and its surroundings provide habitat for specific fauna and flora (ecological value). It also has an aesthetic, and in this case we could also add a "photogenic", value as impressive landscape, because of its varying appearance with the changes in light (sunrise and sunshine). Uluru also has a religious and symbolic value for the Aborigines; it was also used as one of the symbols for the political actions of the Aborigines for recovering the sovereignty over their land. Because of its high Earth science value, it also has pedagogic value for students, scientists and tourists. This impressive and unique landscape is the basis for very fruitful tourist exploitation, with rapid development of derived offers (camping, hostels, sunshine and sunrise observation places, guided visits, cultural Aborigine centre, etc.) around the original offer (landscape) (for an analysis of the distinction between original and derived tourist offer in the domain of geomorphology, see Pralong & Reynard, 2005) the area has provoked major impacts either on the natural values of the rock and its surroundings (ecological and geomorphological processes) or on the Aborigine culture (e.g. climbing on the rock, which is "forbidden" by the Aborigine religion). These rivalries are mitigated either by property rights instruments (e.g. limited access to some religious and ecologically fragile sites), or by public policies (e.g. 1990s amendments of the Australian legislation that gave Aborigines new sovereignty over their land, creation of a national park). New instruments (e.g. forbidden access to the top of the rock) would certainly improve the co-ordination between the tourist industry, cultural, ecological and geomorphological protection in the area.

In order to develop sustainable management of

Tab. 3 - Goods and services provided by geomorphological sites (from Reynard, 2002, modified).
*Beni e servizi prodotti da siti geomorfologici (da Reynard, 2002, modificato).*

| **Category of use** | **Type of use** | **Principal users** | **Examples** |
|---|---|---|---|
| a) Natural heritage | Life support | All living beings (humans, animals, plants) | Volcanoes (that support a large range of human settlements) |
| | Biodiversity heritage | Humanity, future generations, scientists, tourists | Deltas or alluvial plains (that are often environments with high vegetal and animal biodiversity) |
| | Earth history heritage | Humanity, future generations, scientists, tourists | Moraines or erratic blocks (that testify former glacial extents) |
| b) Cultural heritage | Support for cultural heritage | Humanity, future generations, scientists, tourists | Isolated mounts, locks (that are often occupied by castles and fortresses) |
| | Aesthetic heritage | Painters, photographs, tourists | Impressive landscapes |
| | Space for cultural and religious identification | Local population | Large natural regions (e.g. the Alps, islands), religious monuments (e.g. Uluru for Australian Aborigines) |
| | Space for political identification | Local population, politicians, State | Saharan landscapes for the Tuaregs |
| | Pedagogic sites | Schools, environmental organisations, scientists | Cross-sections in sediment deposits, sites where active processes are visible |
| c) Economic exploitation | Landscape with tourist/leisure valorisation | Tourists, tourist industry, local population | Impressive landscapes (e.g. Ayers Rock, Grand Canyon, Matterhorn) |
| | Framework for tourist/leisure activities | Tourists, tourist industry, local population | Coasts (for bathing), mountains (for hiking or skiing) |
| | Support for specific tourist/leisure activities | Tourists, tourist industry, local population | Cliffs (for climbing), reefs (for diving), rivers (for canyoning) |
| | Other economic uses | Industry, agriculture | Glacial locks (that are often sites for dam building), specific agriculture in sinkholes in the French *Causses,* gravel extraction in braided rivers |
| | Support for transport | State, industry | Valleys (used for road or rail tracks construction), mounts (for building antennae) |

geomorphological sites, the three dimensions (natural, cultural/social, and economic needs) should be taken into account. In this specific case, all three categories of uses and their respective relationships have been considered. This example also shows that rivalries and potential conflicts may be mitigated by creating and organising property rights and/or by developing public policies. Table 4 summarises the various possibilities of regulating the sites' management by using property instruments.

The management, and especially the protection, of geomorphological sites largely depends on the public policies regulating the environmental protection and the resource exploitation of a country. Restrictive policies concerning the resource exploitation (hydropower production, mining, territorial planning, etc.) are generally beneficial for the protection of geomorphological sites. Moreover, explicit mention of the protection of geomorphological sites in the environmental policies is better than more general environmental protection policies. Accurate analysis of public policies is therefore essential for guaranteeing effective protection of geomorphological sites and co-ordination with other human activities.

In contrast with other European countries, like Great Britain, that has adopted a specific law for the protection of geological heritage, Switzerland does not have a particular legislation for the protection of geological or geomorphological sites (Jordan, 1999). Until the adoption of the Nature Protection Act in 1966, the geological heritage could only be protected by the private right (Swiss Civil Code of 1912, article 724). In contrast with biotopes, that are explicitly protected, the Nature Protection Act has no specific article aiming at the protection of geosites, even if the protection of the geological particularities is mentioned as one of the objectives of the law. The Nature Protection Act introduced a new instrument: the *inventory*, which is a list of objects worthy of conservation. Since, several inventories have been established by the federal government, some of them with partial reference to geosite conservation. That is the case of the Natural and Cultural Landscapes Inventory (1977), the Moor Landscapes Inventory (1996), or the Proglacial Margins and Alpine Alluvial Zones Inventory (2001). None of these inventories are specifically dedicated to a geosite listing and the degree of protection varies greatly from one inventory to another. An unofficial geosite inventory has been produced by a group of experts under the auspice of the Swiss Academy of Science (SAS, 1999): the inventory, which lists 401 sites, has no legal incentive for the political authorities. A second group of experts has since produced a report on the opportunity of an official geosite inventory to be carried out by the federal

Tab. 4 - Categories and Swiss examples of property rights relating to geomorphological sites.
*Categorie ed esempi svizzeri di diritti di proprietà concernenti siti geomorfologici.*

| | Private property | State property | Common property | Non property (open access) |
|---|---|---|---|---|
| Formal property rights (ownership) | Geomorphological site bought by an environmental organisation<br>Example: Swiss erratic blocks bought or received as a gift by scientific associations (19th century) (Bachmann, 1999) | Geomorphological site managed by a National Park administration<br>Rock glaciers and other landforms included in the Swiss national Park (Chaix, 1943) | Geomorphological site localised in a commonly owned alpine space and managed by the communal association<br>Tortin morainic system (Valais, Switzerland), type-locality for the Egesen glacial stage in the western Alps, property of a local corporation (Kuonen, 1992) | Geomorphological site localised in elevated non productive terrains (normally owned by the state but considered as res *nullius*)<br>Periglacial and glacial landforms of the tourist area of Verbier (Lambiel & Reynard, 2003) |
| Disposition rights | Servitude to an environmental organisation<br>Servitude to the environmental NGO Pronatura for 100 years on the alpine area of La Pierreuse (Gentizon, 2004) | State decree for classifying a geosite<br>Classification of sites of interest by the Cantons or the federal State | ? | -- |
| Use rights | Fee for visiting the caves of the Hölloch system (Canton Schwyz) | Restrictions for visiting the Swiss National Park | ? | -- |

government (Gerber & Gsteiger, 2000); such an inventory is not a political priority for the moment. At a lower political level, on the other hand, several cantons and some communes have carried out geosite inventories (Jordan, 1999). The Canton governments also have the possibility of protecting sites of interest by decree.

Another way of protecting geosites in Switzerland refers to the Territorial Planning Act (1979), whose article 17 allows the creation of protection zones for sites with high landscape and/or natural value (Stürm, 1994; Strasser *et al.*, 1995; Jordan, 1999). The recent modification of the Forest Act (1991) allows the long-term protection of sites discovered by engineering works (Strasser *et al.*, 1995). Until now, reforestation after the end of the works was obligatory, a situation that could be in opposition with geosite conservation policy. Some sites are also integrated in international lists of valuable sites, like the Aletsch-Jungfrau region in the UNESCO World Heritage List or the Entlebuch region in the UNESCO Biosphere Reserve List. Some regions, like the Glarnerland-Sarganserland area, are also hoping to obtain the "Geopark" UNESCO label.

This rapid overview shows how the protection of geomorphological sites by public policies may be complex and highly dependent on the sensitivity of political authorities to the protection of the geological heritage. This latter is perceived more as pure support for the development of economic activities than a dynamic component of the environment to be protected and managed with accuracy, as well as the biotic environment. The following section is dedicated to the presentation of two cases. The first case, concerning the protection of erratic blocks in the Central Plateau of Switzerland, illustrates the protection through property rights instruments; the second example is about the karstic area of Tsanfleuron (Valais) and shows the difficulty of protecting the geomorphological heritage in the absence of a specific protection policy.

## 5. TWO CASES IN SWITZERLAND

The first example refers to the protection of erratic blocks in the Central Plateau of Switzerland (Favre, 1989; Aubert, 1989; Bachmann, 1999). These blocks were one of the indices that allowed the development of the glacial theory by scientists like Ignaz Venetz, Jean de Charpentier and Louis Agassiz at the beginning of the 19th century (Schaer, 2000). They therefore have either a paleoclimatic (as landforms allowing the reconstruction of former extensions of alpine glaciers) or a geohistorical value (as objects at the origin of the development of a scientific theory). During the 19th century, they were intensively exploited as construction material, because of their specific petrography (mainly granites). That exploitation represented an interesting financial income for their owners, who were public bodies (communes) as well as private proprietors. Therefore, there was clearly a rivalry between two competitive uses: the exploitation as construction material and the protection as heritage of the climate history and testimony of the geoscience history. In absence of a specific public policy for the Nature protection, the only way for protecting the blocks was to buy or acquire them as gifts from communes or private owners. That is for example the case of several blocks situated in the Canton of Vaud (Aubert, 1989) or Neuchâtel, that were acquired by the local sections of the Helvetic Society of Natural Sciences (now Swiss Academy of Science) or by the State. One of these blocks is the *Pierre des Marmettes* (Fig. 6), a 1824 cubic metres block, situated on a Last Glacial moraine of the Rhone Glacier, near Monthey in the Canton of Valais. In 1905, the block was to be exploited for granite extraction. Because of its height and its high value for geological sciences, the project of exploitation provoked a large reaction both among the public and in scientific circles (Schardt, 1908). In 1908, the Helvetic Society of Natural Sciences were able to acquire it for 31'500 Swiss francs, subscribed by the Confederation, the Canton of Valais, various societies and the public (Aubert, 1989). After several decades, in 1983, it was included in the Natural and Cultural Landscapes Inventory. In 1999, the block was also proposed for the unofficial geosite inventory of the Swiss Academy of Sciences (SAS, 1999).

Fig. 6 - The Pierre des Marmettes (Monthey, Switzerland): an erratic block property of the Swiss Academy of Sciences since 1908 (photography: J.P. Pralong).

*La Pierre des Marmettes (Monthey, Svizzera): un blocco erratico proprietà dell'Accademia Svizzera delle Scienze Naturali sin dal 1908 (fotografia: J.P. Pralong).*

The second example concerns the karstic area of Tsanfleuron in the Diablerets Range (Western Switzerland). The zone has a high geomorphological value because of the presence of specific landforms and processes typical of a karstic plateau recently deglaciated, and the high sensitivity of the Tsanfleuron Glacier to climate variations (Reynard et al., 2003). Since the 1960s, the area has developed either intensive winter tourism (skiing) or more extensive summer tourism (hiking). Because of the absence of a specific geosite protection policy, geomorphology was highly modified by road and infrastructure building. The main impact was the construction of a road aiming to mitigate the sharp topography of the superficial karst and to facilitate the preparation of ski runs (Fig. 7). The material used for the road construction was extracted from a Little Ice Age morainic crest. The works were performed without any authorisation and testify the absence of

geomorphological sensitivity of the local authorities (Reynard *et al*., 2003). Because of opposition, the works were finally stopped by the cantonal administration and an Environmental Impact Assessment (EIA) was performed a posteriori. The EIA recommended the dismantling of the road and the recovering of the morainic crest, which was carried out in autumn 2002. The landscape value of the moraine is therefore reconstructed, even if the sedimentological characters of the deposits are not the original ones. This example shows the difficulties associated with protecting the scientific and geohistoric value of gemorphological sites in a situation where there is an absence of specific geosite conservation legislation. Without other more biological values (e.g. presence of biotopes, fragile ecosystems, etc.), geomorphological sites present a high vulnerability, principally because of the low sensitivity of the political authorities and the public in general for the geoscientific value and for the "beauty" of mineral landscapes.

Fig. 7- An illegal road built on the karst of Tsanfleuron (Valais, Switzerland) by extracting gravels from a Little Ice Age morainic crest. The road is now dismantled and the moraine recovered after an EIA performed a posteriori.

*Strada abusiva costruita nella zona carsica di Tsanfleuron (Vallese, Svizzera) utilizzando ghiaia estratta da una morena della Piccola Età Glaciale. La strada è stata smantellata e la morena ripristinata dopo una procedura di Valutazione di Impatto Ambientale eseguita a posteriori.*

## 6. CONCLUSIONS

The aim of this paper was to point out the importance of crafting adequate institutional rules in order to protect and manage geomorphological sites. Once a gemorphological site has been assessed and its value has been shown, measures have to be taken in order to protect the site against negative human impacts. This protection is always developed within a specific institutional framework, which combines property rights as well as public policy aspects.

The Institutional Resource Regime (IRR) concept allows the management of natural resources to be analysed in a systemic way. The analysed resource is considered to produce goods and services that are exploited by the society; when the uses are numerous and heterogeneous, situations of rivalry between different groups of actors are not uncommon, and institutional rules have to be developed in order to avoid conflicts. Rules are developed following two different (but often combined) paths: the public policy and the property right paths. As geomorphological sites protection is poorly developed in most countries and vulnerability of these sites is principally due to the fact that they often combine several conflicting values, the IRR concept seems to be an adequate tool for analysing firstly the various rival uses of geomorphological sites, and then secondly, the possible ways of protecting the sites and co-ordinating their uses.

Thirteen generic types of geomorphological sites uses have been shown and classified in three main categories: natural heritage, cultural heritage, and basis for economic exploitation. The example of Uluru (Australia) has shown how these types of heterogeneous uses often combine on a particular site and necessitate the adoption of institutional rules for avoiding conflicts. One possible way is to create specific property and use rights, in order to restrict access, for example. The other way is to develop public protection policies that allow the legal protection of sites of interest. The presentation of the development of public policy instruments in Switzerland has shown that a specific protection of geosites is not common, mainly because of the absence of political sensitivity for mineral environments, which are considered much more as a support for economic development, than objects and areas with high specific natural value. The example of protection of erratic blocks in Switzerland demonstrates how property rights tools may be of high interest for the geomorphological sites protection, for example the purchase of objects or areas by scientific or nature protection associations. On the other hand, the case of Tsanfleuron has shown the difficulties of protecting highly valuable sites in the absence of specific policy instruments.

The IRR approach has not yet been applied systematically at a local or a regional level. The method should now be used for example in a region where a geomorphological sites inventory has been performed, in order to analyse the different uses of the sites of interest, to evaluate their vulnerability and to show the degree of institutional protection and the possible ways of improving it.

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