Natural risks

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Natural hazards are an integral part of the history of our planet. Storms, cyclones, floods, heat waves, volcanic eruptions, earthquakes, tsunamis, landslides, meteorite falls,... are all natural phenomena that contribute to the Earth's incessant evolution. The concept of natural risk is defined as the attribute of a natural manifestation (hazard), the consequences of which with human heritage can be harmful (vulnerability). In this article, we revisit the fundamental notions attached to the concept of natural risk, trying to illustrate the subject with examples relating to gravitational risks in the mountains. We will conclude by discussing the approaches and tools currently being developed to ensure the management of natural risks.

1. What does the concept of natural risk mean?

The notion of natural risk has been around for a very long time. In France, according to article L 125-1 of the Insurance Code"... *Are considered as the effects of natural disasters, direct "uninsurable" material damage having had as a determining reason the abnormal intensity of a natural agent, when the usual measures to be taken to prevent such damage have not been able to prevent its occurrence or have not been taken...* ». On average per year, from 2000 to 2012, natural disasters around the world cost nearly $130 billion, affecting more than 220 million people, of whom more than 92,000 died.

In line with the previous definition, it could be assumed that the notion of natural risk emerges when the human species comes into contact with the natural environment. The lack of knowledge of an environment, which generates processes that can manifest themselves in an unforeseen, sometimes violent way, and which acutely interferes with human projects (material or immaterial), leads to the idea of risk. From this first approach, two ideas emerge:

On the one hand, it is about man's projects, through which his relationship with nature is manifested. These reflect a cultural situation, but also an ideological posture, defining not only humanity's place in nature, but also its prerogatives over it.

On the other hand, we have highlighted the fundamental role played by the concept of knowledge. Since all knowledge is incomplete, the notion of risk is therefore of a probabilistic nature, justifying the introduction of chance.

The notion of natural risk is therefore evolving over time and space. It reflects the type of relationship that man perceives with nature, but also the degree of evolution of a given society in relation to the natural environment. Finally, it expresses the quality or weakness of our intellectual capacities, and thus of our technological means, to understand the mechanisms that govern our environment, as well as the phenomena and processes that occur within it. It is therefore understandable that the way in which natural hazards are treated has probably not always been the same, and has probably evolved over the past centuries, or even decades.

Today, it is accepted to define **risk** as the *product of* **intensity** and the **probability of occurrence of** a naturally occurring event. The intensity of an event can be related to the volumes of materials mobilized, as well as to the dynamics of the phenomenon (e.g. material travel speeds).

The **vulnerability of** a given site to a phenomenon expresses its degree of exposure to it, and the degree of damage expected in the event of the phenomenon occurring. We are talking about vulnerability for human equipment, facilities or infrastructure, but also generally for a social entity (a valley, a commune, a district, etc.). The notion of vulnerability therefore includes both physical and social values.

Figure 1. Montroc Avalanche, February 1999. [Source: Archive Irstea Coll.]

For example, when a landslide obstructs a communication axis, the description of the phenomenon (extent and height of deposition) relies largely on the mechanics of soils and rocks, while the assessment of societal consequences (traffic modification, direct or indirect psychological impact, impact on tourism, various economic impacts, etc.) is based more on the human and social sciences.

When a site is vulnerable to an identified hazard, it is called a **risk**. The notion of risk is therefore defined as the *product of* a hazard by a vulnerability:

ALEA = INTENSITE X PROBABILITE D'OCCURRENCE

RISQUE = ALEA X VULNERABILITE

It should be noted that a risk refers to a phenomenon. If this phenomenon is of natural origin, then we will speak of a *natural risk* .

2. The Alpine territory, a laboratory for natural risks?

It is quite clear that natural risks potentially extend to all territories, insofar as the origin can be terrestrial (continental or oceanic) or meteoric. These two origins can also be coupled, since extreme climatic phenomena can induce disorders affecting the continents. Thus, a cyclone or tropical storm will have direct destructive consequences on the exposed continent.

The notion of natural risk takes on its full meaning in mountain regions, where mineral architecture nevertheless suggests a deceptive calm. As an illustration, we can therefore use the example of the Alpine arc, which is often the scene of sudden and violent demonstrations. Let us mention mudflows (Grand Bornand, 1987), torrential lava (Bourg-Saint-Maurice, 1981), snow avalanches (Montroc, 1999), rockfalls (Isola 2000, 2015). From a more historical perspective, we cannot omit the collapse of Mont Granier, which occurred in November 1248, mobilizing several hundred million cubic metres of material; the imprint of this catastrophic event is still present on the ground, through the modelling of the soil surface modified by millions of cubic metres of rock.

A natural manifestation is dangerous for the human environment because of its suddenness and the energy mobilized. If we assume that gravity (the source of the force of gravity) is one of the essential components of this energy, then we understand the magnitude of these events in mountainous areas, where the height of the slopes induces considerable potential energies (the potential energy of a mass M, located at a height h in relation to a reference value, is equal to the product $M \times g \times h$, g being the acceleration of gravity).

The specificity of the Alpine valleys lies in particular in the slope of the hills or mountains, which is often steep. This aspect is inherited from the glaciations of the Quaternary era (Würmien episode), shaping the trough-shaped valleys, whose slopes were later eroded by torrential action. In addition, the fractured state of the rocky slopes is often important, highlighting the *tectonic* heritage of the Alps.

It should also be noted that the former presence of glaciers at the bottom of the valleys is the cause of the current moraine landscape, whose ultimate state of alteration is the formation of a granitic arena containing an often significant clay fraction. The presence of clay in the surface horizon of the soil is an element to be considered with great attention, due to the extreme sensitivity of the mechanical behaviour of clays to water content. In particular, a period of heavy rain, changing the hydraulic load in the soil, can cause major disorders such as landslides or mudslides.

Figure 2. Vulnerability and rockfall, March 2014. [Source: Irstea Coll. Archive]

The alpine building we are now familiar with is the result of a long history (tectonic, climatic). If the current structure seems frozen in apparent stability, it is only because two very different scales, time and space, are opposed. Man lives only a very brief episode in the long history of the *orogenesis of* the Alps, whose dimensions surpass those of his daily life and appreciation. It is therefore necessary to make the intellectual effort to avoid this contrast of scale, in order to perceive and analyze the geophysical and mechanical processes that take place there. The accidents that occur on the surface (block falls, slips,...) are ultimately only brief episodes that allow the two time scales to be confused from time to time. However, if the consequences of such manifestations remain very insignificant on the general morphology of a mountain range, this is not the case when they are reported on a human scale: loss of human life, destruction of facilities and infrastructures, disruption of communication routes, are all dramatic consequences from a human, social and economic point of view.

3. Towards a social culture of risk

At the beginning of the 20th century, the industrial explosion led to a socio-economic upheaval in developed countries. On the one hand, industries have established themselves in sectors that are sometimes inhospitable (potentially exposed to the occurrence of hazards), in order to take advantage of natural resources (mining resources, and hydroelectric resources). On the other hand, as mountain ranges constitute natural barriers to trade (flows of people and goods), communication routes have developed and become more dense.

At the same time, urban society has taken over some areas of these mountain regions for leisure and rest; in this respect, winter tourism has been the driving force behind massive and increasing seasonal migration.

Finally, the urban spirit that accompanies the industrial era penetrates into mountain regions, thus opposing very disjointed postures towards nature. Indeed, man's relationship with nature has been the completion of several millennia of history. In regions as hostile as some internal mountain valleys, people are becoming aware of the precarious balance that unites people to their environment: a work of patience, imposed by a daily labour by which people unite to their environment. The necessary solidarity and sense of collective action led to everyone being concerned about the sources of potential danger. In this context, careful attention to the maintenance of the natural heritage was part of the collective approach to protecting against natural hazards. This task was everyone's business; everyone, through their experience, their sense of observation in close connection with the elements, contributed to the maintenance and preservation of the heritage.

The introduction of new thinking, combined with a less traditional way of life and economy, is significantly disrupting the data on the problem. It is therefore a question of containing a capricious nature, so that it does not compromise man's plans. In addition, individuals are increasingly relieved of their responsibility for the management of natural heritage.

To conclude, we can therefore conclude that:

The concept of natural risk is defined as the attribute of a natural manifestation (hazard), the consequences of which on human heritage can be harmful (vulnerability).

Natural risk management must be understood as a civilizational fact through which the conceptualization of nature, defined at a given time and place by ideological and socio-economic criteria specific to a given society, dictates the rules for human intervention in its environment.

4. Modern natural risk management

Natural risks differ from technological risks in that the cause (hazard) is not (a priori) linked to man, to what he has built, but to a natural cause. On the contrary, technological or industrial risks have an anthropogenic origin, linked to an installation, an infrastructure, or a way of life of a given civilization. The explosion of a chemical plant with diffusion of pollutants by land or air is a very illustrative example.

Natural hazards may or may not be of gravity origin. Gravity natural hazards mainly include landslides (boulder falls, landslides, landslides), snow avalanches, and torrential floods (including mudflows). Risks of glacial origin are less frequent, although the risk of emptying subglacial water pockets must be considered (example of the Glacier de Tête Rousse, in the Mont-Blanc massif).

Figure 3. Example of torrential lava, occurring in July 2003, in the Valgaudemar valley (Hautes-Alpes). [Source: Coll. M. Bonnefoy, Irstea]

Among the natural risks of nongravity origin, we will mention the seismic risk, hydraulic risks (floods and floods), and storms (associations of heavy rainfall and extreme wind gusts). More marginally, the volcanic risk concerns areas of the globe where volcanoes are still active. Damage on the ground can be considerable (e. g. recurrent lava flows affecting the southern part of Reunion Island).

The management of these risks is based on two perfectly complementary strategies: observation or monitoring and forecasting. Observation makes it possible to better understand the mechanisms associated with a given phenomenon, to better understand the conditions of occurrence, to assess the return periods; in addition, observation and monitoring networks are effective means of collecting physical data (movement measurements, accelerated recordings, etc.) which can then be used in conjunction with modelling work. The forecast is based both on the observation and monitoring network, by analysing real-time data (e.g. flood monitoring network), and on more upstream work to understand the mechanisms and integrate them into a numerical model to simulate the evolution of phenomena in the medium and short term. It is this vast field that is referred to as *numerical modelling*.

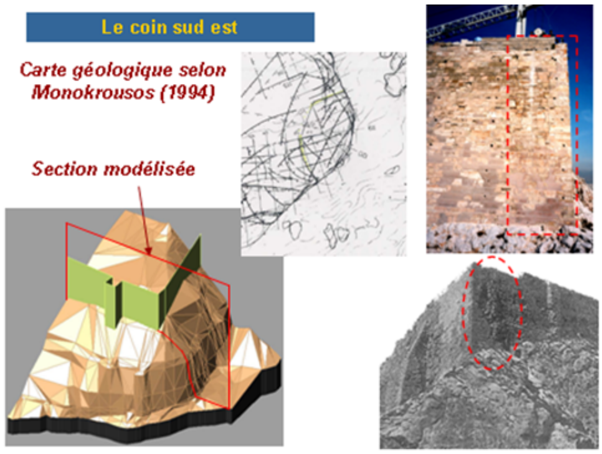

Figure 4. Numerical modelling (by the "Discrete Element Method") of the stability of the southeast corner of the Acropolis of Athens. [Source: PhD thesis of C. Lambert, coll. F. Darve, Grenoble INP]

The advent of numerical methods and the generalization of powerful computing means make possible today the numerical simulation of complex phenomena such as avalanches or landslides. However, it is important to keep in mind that these calculations are based on a priori knowledge of data specific to the phenomenon (fractured state of a rocky escarpment, constitution of the snowpack) which is subject to many uncertainties. This fully justifies the introduction of probabilistic methods to incorporate a level of uncertainty on the input data, and to treat the propagation of this uncertainty to the output results. This field is still booming today, and is a very active and still very open field of research.

References and notes

Cover photo. Aussois in Savoie, risks of block falls and more generally gravitational hazards. [Source: © François Nicot]

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