

Pierre Pech, Romane Séguier, « Quelle approche « réaliste » de la montagne en géographie : L'exemple des bourrelets de marge passive », *L'information géographique* (2/2020), pp. 48-69, Armand Colin. <https://www.revues.armand-colin.com/geographie/linformation-geographique/linformation-geographique-22020/quelle-approche-realiste-montagne-geographie-lexemple-bourrelets-marge-passive>

Pierre Pech et Romane Séguier, 2020. What is a "realistic" approach to mountains in geography: the example of passive margin mountains, *Information Géographique*, 2: 48-69

Abstract

The mountain is an essential object of geography but, like other objects, it opposes an approach offering elements of description and explanation based on a realistic, and above all geological representation, to another one more recent taking counts the representations of the populations. For the geography taught but also for the use which is made of it from a legislative point of view in France with the Mountain Law, the realistic approach dominates. The question is to know if this one, which bases a normative approach of the mountain is still valid in the light of the most recent scientific advances. The passive margin mountains, emblematic mountains of physical geography, are used here as an example of a type of mountain. From an in-depth analysis of the scientific literature, two points stand out: the recent genesis of these mountains, like all mountains on the surface of the earth, and the variety of their evolution. Putting geographic science into debate here does not consist in destroying its status in its function of cognitive action, in particular in the service of uses requested by society, but in recognizing the biases and limits of certain knowledges.

Key words

Realistic perceptions and representations of the mountains; Passive margin mountains; cognitive and normative function of geography.

Mountain: which geographical object?

A frequent issue in geography, the question of the opposition between representation and reality is not, however, specific to the discipline (Putnam, 1990; Molinier and Guimelli, 2015). John Searle (1998) contrasts the real world, which he calls the physical world, and the world of representation. For Searle, there are facts that make sense only because we believe in them, such as democracy, the law, respect for others, the rules of football, and then there are realistic facts that manifest themselves independently of human issues and consciences, such as an earthquake or a hurricane. However, humans develop the capacity to perceive and represent these real facts. These capacities are very varied, depending on the individual and his or her group or society. For example, in the case of the phenomena mentioned above, if we compare the populations of Japan and Haiti, these capacities can vary considerably due to factors that the human sciences are debating and that may be linked to differences in social classes (Bourdieu, 1980; Boltanski, 2008), to cultures forged by varied cultural trajectories (Molinier and Guimelli, 2015) or they may be constructed collectively by groups structured in a contingent manner (Latour, 2007).

The mountain is an unavoidable geographical object but, like other objects, its approach contrasts a tradition that offers elements of description and explanation based on a realistic and above all geological representation with a more recent tradition that aims to give an account of what the populations who represent the environment they occupy, use, develop or pass through have to say about it (Bernier and Gauchon, 2013). As a relief, mountains occupy an important part of the surface of continents but also in the oceans. In fact and from a purely realistic point of view, it can be considered that there are many mountains listed on the surface of the earth. However, the main criterion for this realistic geography is based on geological and geomorphological criteria.

Human societies experience, develop, inhabit, fantasize in their imagination what they call or not the mountain. In the Himalayas, as the ethnologist M. De la Soudière (2019, p.70) writes: "peaks of less than 3,000 metres in altitude are called hills, hills". Conversely, for Hallégouët et al. (2008) and for Bétard (2010), it seems indisputable that the Armorican Massif, which peaks at 417 m, is considered a mountain, according to these authors, like so many geomorphologists, because, for geological reasons, one can distinguish elements whose origin corresponds to an ancient mountain range structure, even if this has been levelled for hundreds of millions of years, justifying the use of "ancient massif" used in the geographical literature.

Similarly, the Massif Central was invented in the mid-19th century by geologists to define the ensemble that they distinguish from other geological regions in central France (Poujol, 1994). Poujol demonstrates that there is a transfer of knowledge from the scientific world to collective representations. For Berdoulay (1981), in the history of French geography, the movement is in both directions: geography was legitimized in its construction as a scientific discipline because of the demand for expertise from the Third Republic, but French geography provided the scientific basis for legitimizing the national territory (Berdoulay, 1981).

The mountain object rests, to a large extent, on this transfer from a scientific approach to representations. The question is whether the genesis of the concept that goes hand in hand with the emergence of a scientific interpretation does not give rise to an authority (Latour, 2005) leading to the freezing of knowledge as it evolves due to advances in science and technology. Real geographical knowledge, "physical", in the sense of Searle (1998), which is the knowledge developed by physical geography, has taken over the mountain object not only for the geography taught but also for its definition from a legislative point of view in France. The question is whether these concepts used in teaching and in legislative discourse and considered as emanating from scientific knowledge are still valid in the light of the most recent scientific advances. This article proposes to look at one type of mountain, the passive margin ridges (see Table 1 and map in Figure 1), which have a very important place on the surface of our planet and which are traditionally part of ancient massifs or even old mountains, all paradigmatic concepts that should be explored in the light of current advances in knowledge.

Passive margin beads

The mountains, which largely border the Atlantic Ocean and other oceanic areas, correspond, in cross-section, to geological areas consisting of a continuous tectonic plate combining oceanic and continental crust. These mountains border the emergent part of the tectonic plate and dominate a submarine complex that slopes gently down to a steep slope that connects to the sea floor consisting of abyssal plains several km below sea level.

These mountains are called passive margin ridges and have been identified by geographers who have incorporated the findings of plate tectonics (.Birot, 1982; Pigeon, 1984; Gunnell, 1998; Peulvast and Vanney, 2002). For Pigeon (1984), these mountains "are among the major relief groups on the planet" (p.12).

It is accepted that the emplacement of these mountains is to be associated with the entire passive margin and the entire ocean (Battiau, 1991) according to an evolutionary pattern that is summarized in Figure 2. For example, the opening of the Atlantic began around 180 million years ago with the separation of the NW from Africa and N America, then in the Jurassic (150-140 million years ago), and continued with the opening of the South Atlantic between South America and Africa. On both sides, mountains are individualized on the continental parts (Dupré et al., 2007 and 2011). The tectonics and morphology of the passive margins are affected by movements induced by the dynamics of oceanic opening (Blenkinshop and Moore, 2013). Baby et al. (2018) distinguish between the inner sectors of the passive margin, consisting of the continental, emergent part, and the outer sectors, on the ocean side. From a geomorphological point of view, we pass successively from the outermost to the innermost sectors to a set of distinct forms making the transition between the ocean and the continent with:

- at a depth of more than 4,000 m under the sea, the abyssal plain, consisting of a sediment-covered bedrock made up of the oceanic crust from basalt linked to the oceanic opening at the level of the ridges, where the undersea mountains are located, and stakes of exploitable mineral resources such as polymetallic nodules,
- the continental slope, between 4000 m and less than 500 m deep, a long slope inclined over several hundred metres, more or less rectilinear in appearance and therefore fairly uneven, made of the same materials as the continental shelf (Regnauld and Thomas, 1991),
- the continental shelf, consisting of a bedrock formed by the continental crust, often crystalline and of pre-triassic (> 255 million years) or even Precambrian (> 500 million years) origin, covered by sedimentary series, posterior to the opening of the rift (more recent than 180 million years for the Atlantic), a vast plateau that can be deformed into a succession of basins and shallows parallel to the coastline (Baby et al., 2018), with distension faults linked to the continued opening of the ocean and sinking, and here again the stakes are high for the exploitation of underwater hydrocarbon deposits,
- in continuity with the plateau, the littoral plain, with sedimentary deposits of more recent continental origin; these plains are areas of high human concentration, such as the American megalopolis,
- one or more mountainous massifs behind this plain, the passive margin ridges, always made up of rocks from the bedrock of the continental crust.

As specified by Baby et al (2018) and all the authors, this is the current pattern, depending on the general level of the oceans which has varied over geological time, causing the extension of the discovered coastal plain to vary (more during the ice age and much less during the warmer periods such as 30 million years ago). These mountains are geologically located at a transition between the two crusts forming what is known as a passive margin. The ridges correspond to part of the continental crust, faulted into a succession of blocks lowered towards the ocean basin. They are generally narrow mountainous massifs, straight, some of them extending over hundreds of km (Pigeon, 1984), forming a ridge line opposing two asymmetrical edges: one steeply sloping, consisting of steps dropping towards the oceanic part and the other more gently sloping towards the continent. These mountains are considered as elements of the basement and geographers see in them the permanence of ancient geological constraints (Hallégouët et al., 2008; Bétard, 2010). As a result, it is common to add among these mountains massifs that are far from the continental limits but characterized by quite similar shapes with blocks and ditches, rift initiations, with for example the Vosges (Flageollet, 2008) or the Massif Central (Olivetti et al., 2016).

Most of the passive margin beads, especially at the ridges, consist of ancient rocks, dating back more than 255 million years. These mountains served as a reference for establishing the model of the ancient massif with the idea, still strongly anchored, that there is a fundamental opposition between young and old mountains. In the 1980s, numerous works gave rise to geographical study days devoted to these mountains. A session of the Association of French Geographers on marginal ridges was organized in 1982 under the direction of J-R. Vanney who asserts the direct link between these mountains and the ocean. Similarly, Y. Battiau organized another one in 1991 on the passive margins, but it mainly dealt with the ridges of these passive margins. The session is moreover largely devoted to the geomorphology of the bases.

According to the totality of the bibliographical references studied, the passive margin mountains or passive margin ridges have reached their present mountain altitude since recent phases of geological history, less than 150 million years ago and even much less in most of the mountains concerned, whereas in all cases the summits are made up of very old rocks, dated more than 255 million years ago. They are moreover quite often rocks of the base of the continental crust, sediments but especially crystalline rocks such as granites or gneisses, initially put in place at great depth and outcropping thanks to the lasting action of erosion and uplift caused by the tectonic dynamics involved in these mountains. The bulging of the upper, viscous part of the mantle favours the bulging of the lithosphere, which thins, fractures and

gives rise to an oceanic rift with the production of an oceanic crust at the level of volcanic ridges immersed in the heart of the ocean. By means of what is called isostatic compensation (like a cork that is pushed into the water and raises the water level laterally), at the top of the viscous mantle, called the asthenosphere, a bulge in the centre of the ocean causes subsidence at the margins, which are made up of an older lithosphere topped with sediment. The uplift of the passive margin bulges is either continuous (more rarely) or characterized by seismic episodes corresponding to fault activity, such as the Lisbon earthquake in the 18th century. There is a strong asymmetry between the rim facing the ocean basin, made up of steps progressively dislocated by faults, giving the slope its mountainous aspect, while on the continent side there are, especially on the African and Brazilian sides, basins (Pigeon, 1984). The uplift concerns pre-existing reliefs that are generally not mountainous (Peulvast and Vanney, 2002; Flageollet, 2008).

According to the scientific literature, the geographical ensemble consisting of an abyssal plain, currently at a depth of around 4,000 m, the continental slope, the continental shelf, the coastal plain and the mountain of the bulge is a model with varied evolutionary dynamics.

In simple cases of evolution of the oceanic lips, such as on both sides of the South Atlantic, the current tectonic evolution of the passive margin bulge mountains is related to isostatic compensation under the effect of the sinking of the sediment-laden passive margin into the asthenosphere. The margin in Africa, particularly in Gabon, is well documented due to the many boreholes that have been drilled there for oil exploration. It shows the evolution of continental platforms, with blocks and trenches sloping down towards the slope. These blocks and ditches are made of sedimentary rocks that are folded, thus proving that the folded structures are not in the compression phase, as has long been taught in geography, but in the oceanic phase of distension: the compaction of rocks that cannot be folded then only takes place when the rocks emerge, as in the pre-alpine massifs of the Alps (Dupré et al, 2011; Zuodong and Jianghai, 2011; Childs et al., 2017; Dupré et al., 2017).

On the other hand, for the continental margin of the Iberian Peninsula, there is currently a very original phenomenon. Off the coast of Portugal, where potential seismic activity is known, there is a shallow area called the Gorringe Bank, which corresponds to the upwelling of the mantle, due to isostatic uplift. Some authors interpret it as the beginning of a subduction movement of the Atlantic rim under a portion of the European plate, while others consider that this original configuration is linked to the continuing collision between Africa and Europe (Borges et al,

2001; Terrinha et al. 2003; Cabral et al. 2004; Jimenez-Munt et al. 2010; Duarte et al. 2013; Sallares et al. 2013; Dean et al. 2015; Somoza et al. 2019).

Conversely, the very significant uplift of the mountains of South Africa is largely linked to the particular configuration of the tectonic dynamics of Africa: the significant uplift of the edge of this continent results both from the isostatic compensatory movements described above but also from the impact of the significant uplift of the African continent centred on the great eastern rift and the opening of the Red Sea (Braun et al., 2014; Richardson et al., 2017; Baby et al., 2018).

Similarly, some continental regions, such as in the Vosges Mountains or in the northeastern United States, at the foot of the Appalachians, are characterised by significant seismic activity to the extent that American nuclear security has addressed the issue of plant siting (Neely et al. 2018). Similarly, Suleiman et al. (1993) report seismic activity of magnitude greater than 5 in many passive margin areas, particularly on both sides of the South Atlantic. The foci are shallow, just over a few tens of km and often with a distensive component. The western sector of North America, from the axis of the St. Lawrence Valley to the southeastern Appalachians, is clearly one of the sectors where earthquakes of high magnitude (> 7) are expected, since many studies show that some have occurred in recent centuries (Ebel and Tuttle, 2002; Neely et al., 2018; Byrnes et al., 2019). Seismic activity is related to the opening dynamics of the Atlantic Ocean, although the authors include the role of the rebound of the continent that has been recovering since the last ice age (Ebel and Tuttle, 2002). Like other mountains in passive margin areas, the Appalachians, in their current mountain configuration, have been established in relation to passive margin tectonics, i.e. since recent geological times (Byrnes et al., 2019).

The case of the tectonic dynamics of the French Atlantic passive margin, from the Armorique to the Massif Central through the Charente and the islands, notably Noirmoutier and Oleron, is complex. Earthquakes affect the coastal margin in the south of Brittany. According to the national seismic monitoring network (Reness), an earthquake evaluated with a magnitude of 4.9 was recorded on 20 March 2019, in south-western France, in Charente Maritime. It occurred close to an old earthquake that occurred in the 18th century. According to geologists from Reness, it corresponds to an earthquake that occurred 10 km deep. It is the activation of a fault at the limit of the Armorican geological entity. Not far away, on February 12, 2018, an earthquake of magnitude 4.7 SW of Niort occurred in the department of Deux-Sèvres (French Central Seismological Office, 2018). An earthquake of magnitude 5.2 was recorded on 28 April

2016 west of La Rochelle, towards the island of Oleron. Relatively frequent earthquakes are therefore occurring in France, located on this sector of the Atlantic coastline. If they are shallow to medium depth faults (less than 10-15 km), in this sector, they correspond to the activation of stalled faults, moving the most littoral sectors towards the northwest and the most continental sectors towards the southeast. These faults also have a component of normal, distensive faults, with subsidence of the littoral sectors towards the Atlantic and uplift of the continental sectors (Mazabraud et al., 2013). Here, we should mention the combination of movements that must affect the continental margin, as for the other passive margin oceanic lips, but also the continuation of tectonic movements of displacement from the Iberian Peninsula towards the rest of Europe, especially in the Pyrenees. The case of the Massif Central is also linked to an uplift due to the effects of the isostatic compensation of the continent following the continued oceanic opening, but also to the undoubted effects of alpine tectonics. In particular, the deep sinking of the roots of the Alps into the asthenosphere has been causing uplift and dislocation into blocks and trenches for at least 30 million years, with volcanic activity. Here again, the summits of the massifs that make up the Massif Central, outside the volcanoes, are made up of ancient rocks, but which are in continuity with the rocks of the summits of the Western Alps, in the central massifs. For example, the Belledonne massif above Grenoble is made up of rocks identical to those of the Cévennes (Vivier et al., 1987; Bogdanoff et al., 1991; Billant et al., 2015). The evolution of the former passive margin into a collapse ditch occupied by the Rhone valley and then further east by the folded sedimentary massifs of the Pre-Alps corresponds to alpine tectonics, and the blocks of the central alpine massifs, from Mont-Blanc to Mercantour, are portions of the same continental crust that currently borders the eastern edge of the Massif Central.

The inexorable work of erosion on the earth's surface

One of the objects of study of geomorphology, from the beginning of the 20th century (Pigeon, 1984) consisted in questioning the levels of flattening that affect these basement mountains. In the absence of dating methods and witnesses to the evolution and tectonic dynamics of the ensemble, which combines, in a geological unit called the passive margin, the mountain of the bulge, the submerged continental platform and place of important marine sedimentation, as well as the part of the oceanic crust that is solid, it was difficult to understand how the mountainous relief could have evolved. The main arguments were based on the hypothesis that since there were very ancient rocks, dating from the Paleozoic (> 255 million years ago) or even the Precambrian (older than 550 million years ago), there was a form of tectonic permanence linked

to the original emplacement of these rocks. The mountain massifs were considered to have been maintained as an axis of mountain rejuvenation. However, the reliefs that were put in place several hundred million years ago have been subject to intense erosion activity and cannot have been maintained as mountain reliefs on a sustainable basis.

In any case, many authors agree that the extent of destruction by erosion on these passive margin mountains is highly dependent on sea level stability and that under these conditions planation processes are rare. Bonow et al. (2014) found for Greenland that there are probably Mesozoic (> 65 M.a.) levels of levelling. However, for these authors, the vicissitudes of the opening of the Atlantic Ocean, which begins around -56 M.a. in the north, on the eastern rim of Greenland, is carried out by successive phases of seismic and volcanic activity leading to uprisings which, even since less than 145 M.a., have been more than 1000 m, greater than what erosion, even in a glacial context, can remove. Erosion has been estimated at 300-400 m during the Pliocene and Quaternary, i.e. since 5 M.a. (Steer et al., 2012). The presence of volcanic flows at the top of this passive margin mountain east of Greenland is evidence of the relative weakness of erosion compared to the magnitude of uplift (Bonow et al., 2014). Bonow et al. (2014) thus again emphasize the young tectonic development of these mountainous landforms. With Japsen et al. (2019), Bonow et al. (2014) demonstrate that it is impossible that reliefs have been able to maintain themselves durably with altitudes exceeding 1000 m, including since the Cretaceous, i.e. more than 65 million years ago: erosion would have destroyed these mountains.

One of the peculiarities of planet earth is the activity of erosion on the surfaces and reliefs of the continents. This issue of erosion assessment has been the subject of work for many years, initially with an assessment based on the calculation of volumes torn from the continents from stocks in rivers or debris accumulated in sedimentary regions and, since the end of the 20th century, the use of dating based on the measurement of the isotopic degradation of certain minerals under the effect of cosmogenic radiation (Bierman and Steig, 1996; Ferrier and Kirchner, 2008; Olivetti et al., 2016). Erosion rates are variable depending on the resistance of the rocks and the action of processes related to bioclimatic conditions (Binnie and Summerfield, 2013; Perron, 2017). However, the geological durations make it possible to generalise fairly frequent denudation rates on the surface of the earth, particularly by combining various methods of analysis which concern either the filling of sectors of sedimentary accumulation or dating by fission traces and in particular the use of apatite (Thomas, 1995). For example, Flageollet (2008) estimates that there has been an average erosion of 1 to 2.5 km on either side of the Rhine ditch since the Eocene. Average erosion rates are around 0.1 mm/year (or 100 m/M.a)

(Demoulin, 2002), including in regions considered stable (Burket and Gunnell, 2008; Braun et al., 2014; Webb, 2017; Braun, 2018) and even 0.8 to 1.7 mm/year in Angola (Guiraud et al., 2010) 17 to more than 50 m/M.a for the mountains of western Brazil (Soares Cherem et al., 2012; De Souza et al., 2019). The work of Vanney and Peulvast, who conducted a review of the scientific literature on this subject, results in a mean rate of 40 mm/1000 yr. These authors conclude that: "the uplift of a mountain massif implies a lower rate of erosion than crustal uplift" (Vanney and Peulvast, 2002, p.70). Climatic and sea level variations are responsible for the development of erosion and accumulation levels (Peulvast and Vanney, 2002). The fact remains, however, that the mountain's development as a mountain dates back to geological periods contemporary with the opening of the rifts (Peulvast and Vanney, 2002; Flageollet, 2008) and therefore owes nothing to the permanence of mountainous reliefs for long periods of geological history.

Conclusion

Geography has early invested the mountain as a geographical object. Some mountains emerge from scientific knowledge, such as the Massif Central. From its origins, French geography has defined the mountain as a type of environment offering constraints that are original enough to develop particular lifestyles and generalised models have been established, such as the tiering and opposition between high and medium mountains. Mountain forms are dependent on the action of erosion processes determined by past and recent climatic conditions: cold, glacial as in Norway, humid tropical as on the Mayombé mountains in Gabon, the Guinean ridge, Mount Nimba and Mount Fouta Jallon or the sierras of eastern Brazil, Diamantina, Espinaço and Do Mar. Can we consider the glacial and cold landscapes of the lower slopes, on the coastal plains of Greenland, as high mountains? Like Génin and Alexandre, who criticize the mountain tiering model, it is necessary to recognize landscape types by insisting on the conditions imposed locally by the mountain without necessarily imposing a nomenclature that is impossible to generalize (Génin and Alexandre, 2011). Bernier and Gauchon (2013) but also M. De La Soudière (2019) insist both on the antiquity of the standardized representation of the mountain by geographers but also on the variety of representations by populations elsewhere in relation to that of the reality of mountains. The ethnologist M. De La Soudière insists on the experimental character: after all, climbing summits is "making a contract with the mountain, making a contract between oneself and this conquered relief" (2019, p.63). This is also the basis of the mountain classification in the Tour de France, whose polka-dot jersey can be built by climbing steep slopes that are not only the mythical cols.

Garzanti (2017) describes what he calls the myth of maturity in science, including geography. For Garzanti this myth of evolution towards maturity, perfection and purity of mineral forms (2017), is part of "an ideal of purity common to all cultures and religions" (Garzanti, 2017). The same applies to mountains, for which French physical geography has long wanted to establish a reference with these basement mountains, these ancient massifs. Yet, as previously considered in this article, mountains are a complex materiality on the surface of continents due to the variety of origins and dynamics that characterize their genesis and evolution. Due to the knowledge on the action of meteoric agents and the biosphere that control rapid erosion activity, on a geological time scale, the scientific consensus is that the current volume of mountains is related to recent tectonic activity. The balance is temporarily favourable to over-erodication. What is seen, what is perceived, what is measured, what is defined as a mountain is of recent establishment with regard to geological time on earth where erosion processes lead to the destruction of these landscapes. The history and the vicissitudes of environmental changes imply infinitely varied modalities in the evolution of mountain massifs, whatever the scale. All of them are made of materials that inherit a varied geological history, and are the result of recent tectonic movements, which are indispensable in the context of the conditions specific to the earth, which is characterised by intense erosion activity, against which few reliefs resist in a few million years, but also by internal dynamics responsible for the displacement of tectonic plates and isostatic compensatory movements. There are no more ancient massifs than there are ancient mountains. Even the Massif Central, the heart of the development of the "ancient massifs" model can only be considered, according to Olivetti et al (2016), in its current mountainous state, because the reliefs were raised in a recent period, contemporary with the Alps and with movements of bulging inside the mantle.

This has been amply seen here with what have been described as passive margin massifs, which are sufficiently exemplary of the history of the evolution of concepts in geography to have been successively considered as archetypes of ancient massifs to be currently considered as generally tectonically active mountains (Battiau-Quenet, 1991). In mirror image, human societies experience, develop, inhabit, fantasize in their imaginations what they call or not the mountain. If Y.Lageat makes the observation (Lageat, 1989) that very little place is given to the forms of base regions and especially to shields and ancient massifs in the French geomorphological literature, it is probably because there is a problem with these notions, in what they cover. Recent advances in structural geomorphology, achieved mainly through cosmogenic dating

methods and geophysical surveys of the seas accumulating sediments at the foot of these same mountains, cast doubt on the antiquity of these massifs.

This analysis raises the question of the authority of science and in particular the claim to define nomenclatures that cannot be considered definitive and, above all, as B. Latour (2005) invites us to put science into action. This calls for the terms of new approaches and new geographical terminologies to be defined in the light of new scientific approaches and knowledge. Putting science into debate here does not mean destroying the status of science in its function of cognitive action, but rather acknowledging that discourses are marred by considerations that bear witness to a theoretical and epistemological anchoring that has become obsolete due to the very progress of scientific knowledge.

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