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Serra Negra: new insights into the mountain complex

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Abstract: The present work reviews the updates on the Serra Negra, a small mountain range composed of a set of mountains and rocky components, whose formation can date back to granitic intrusions that occurred approximately 952 million years ago. Its territorial division between the states of Sergipe and Bahia has been a matter of controversy over time, affecting the legal and social security of surrounding communities. The mountainous area was explored here presenting its various subdivisions, such as Serra da Voturuna, Serra do Rela, Serra da Guia and Serra Grande, each with distinct natural and/or anthropic elements. Finally, the impacts of recent changes in the interstate border for possible future research are discussed.

Keywords: Serra Negra. Serra da Guia. Pedro Alexandre – BA. Poço Redondo – SE.

1. Introduction

The Serra Negra Complex is a geological formation composed of a set of elevations that unified form a small mountain range known as Serra Negra that is located precisely on the Sergipe-Bahia interstate dividing line, making it respectively shared by municipalities in both states and cataloged in topographic maps and geoscience materials as the highest point in the Sergipe territory due to the fact that it exceeds the altitude of the others mountains in relation to sea level, with a peak located in the segment whose area belongs to the municipality of Poço Redondo.

Serra Negra is not essentially a mountain, but the largest unit of a series of mountain formations, some of which contain their own names – which are presented in a particular way by the scientific materials prepared by the people of Sergipe – adjunct to a set of rugged terrains with strong unevenness, some peaks and a large and sinuous geographical accident called Boqueirão, which in addition to forming a dividing mark of mountains in the complex, in its northern sequence results in a valley with a sandy-rocky aspect that ends up merging with the surrounding plains.

Origin of the mountainous relief

Serra Negra is the result of granitic intrusions that occurred in a very complex tectonic context, where tectonic deformations and shear zones played important roles in the formation and final configuration (figure 1). Outcrops with gneissic augen facies of the Serra Negra Granite have a geochemical signature that marks the direction of magmatic flow and indicates tectonic activity more focused on transcurrence, where the tectonic plates have slid laterally in relation to each other.

Figure 01: Topographic map showing the geographic format of the Serra Negra Complex (Lima, 2020). **Source:** Image obtained through the Map Viewer application made available by ArcGIS (2024).

The structural characteristics and distribution of the lithological assemblies point to for the subduction of the oceanic tectonic plate under the continental plate directed to the north, by the time interval between 980 and 960 million years ago, where juvenile magma resulting from mantle melting in adjacent zones formed rocks called granodiorites,

according to Carvalho (2005). After that, in the passage from the subduction environment to a transcurrent environment of the tectonic plates, the formation of the mountainous relief is concentrated.

Studies released in the last decades describe the mineralogy of the Serra Negra Granites as rich in stretches with phenocrysts of potassium feldspar and sodium plagioclase, with the presence of quartz ribbons, according to Carvalho (2005). This geochemical formation testifies to a transcurrent movement of the tectonic plate that occurred on a timescale of 952–933 million years ago, in line with the radiometric dates offered in four studies compiled in the discussions of this work.

Figure 02: Rock outcrop demonstrating the geochemical composition of the Serra Negra Complex. **Source:** Image by the author. Coin for reference of the crystal scale.

In the geochronological context, using the radiometric technique of Rb/Sr dating, to determine how old the common minerals in igneous and metamorphic rocks are, Silva Filho *et al*. (1979) obtained an age of 870 million years for the granodioritic to quartz-monzonitic compositions dated in the laboratory. Therefore, studies have emerged linking this age to the granites of these mountains, as in Carvalho (2022).

Discoveries in recent decades, however, have arisen controversies about the tectonic movement of the plates observed at the outcrop scale. With a dating involving the Th/U technique, related to the measurement of the age of minerals such as zircon, monazite and apatite, the work of Carvalho (2005) determined the age of the minerals with greater precision, reaching a value of 952 ± 2 million years for the local compositions that have zircon. Therefore, the mountainous relief would be the result of tectonic events with the intrusion of magma into the interior of the crust that occurred 952 million years ago.

Location and territorial division

Due to the territorial uncertainty between municipalities and states, which has been going on for more than eighty years, different lines of the Sergipe-Bahia interstate boundary have divided the unfolding of this set of mountains in a multiform way. In this panorama of inconsistencies, a bibliographic review about the portions whose territories belong to the municipalities of the different states can both provide more precise information to the knowledge framework and enable the use of the data for further studies.

The disagreements of the interstate dividing line date back to dates that precede the political-administrative emancipation of the municipality of Pedro Alexandre, when its territorial area still belonged to the Bahian municipality of Jeremoabo. The poorly defined state borders in the region are a legacy of the colonial period that intensified when Sergipe and Bahia received autonomy in the organization of their territories by the First Republic, causing inter-regional disputes and divergences in the maps established in the decrees promulgated individually by both federative units over the years:

However, with the autonomy granted by the central government, the intervenors of Bahia and Sergipe published state legislation on the subject – Decree 11.089, of November 30, 1938, of the state of Bahia, and Decree-Law 295, of September 2, 1940, of the state of Sergipe –, containing the definition of territorial limits in an individualized way, which ended up generating two partially discordant border lines (SEI/BA, 2019).

This imprecision of the borders brought with it a situation of confusion about the scope of Pedro Alexandre's administrative domain in relation to the other neighboring municipalities in the Sergipe territory. Therefore, to resolve possible disputes, the states of Bahia and Sergipe jointly reviewed their territories and defined a layout of the states' political-administrative boundary in a 2019 report, ensuring greater stability in the provision of services and the implementation of public policies (BAHIA, 1962).

The cartographic inputs prior to this modification, which subsidized scientific works in some way related to the Serra Negra Complex or its subdivisions that are located within the litigation area, consequently began to present an interstate dividing line that no longer corresponds to reality. Although the previous scientific studies have been organized according to the availability of cartographic resources and the new division does not affect them directly, it is necessary to have an updated graphic representation of the Serra Negra area in order to identify the territorial domain of the municipalities as well as their respective states (**figure 3**).

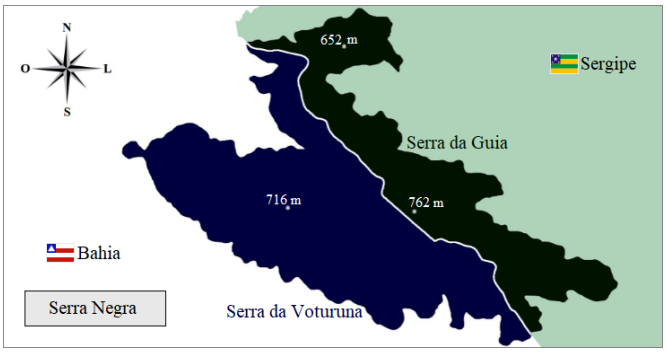

Figure 03: Sergipe holds 1,939 ha and Bahia holds 3,290 ha (sketch from 400 m above sea level)[7]. **Source:** Adapted from Lima (2020). Dividing line based on data extracted from Google Maps (2024).

By agreement between both federative entities, the update in the cartographic spatialization of the border strip that crosses the Serra Negra in the northwest direction took place in such a way that its distribution among the municipalities

remained in line with the customary law of the communities located in the mountainous region and in the adjacent areas (SEI/BA, 2019). According to the new definition, it is estimated that the Bahian municipality of Pedro Alexandre holds an area equivalent to about 3,290 hectares of this mountain range and that the Sergipe municipality of Poço Redondo holds the other 1,939 hectares.

Components of the black saw

Serra Negra is the most commonly used denomination to refer to the geographical space composed of a succession of mountains segmented by highlands, valleys, coasts and rugged terrain with strong unevenness that connected integrate a huge geological structure that is emerged within the Sergipe-Bahia territorial dispute and that forms a natural interstate border that extends for thirteen kilometers (figure 4).

The mountainous area is part of the Caatinga ecosystem and has remnants of Atlantic Forest preserved in high-altitude swamps that occur at the highest points due to the microclimates present, provided by orographic winds. According to Lima (2020), the complex encompasses an area equivalent to approximately 5,229 hectares and conserves about sixty endemic species, some of which are threatened with extinction.

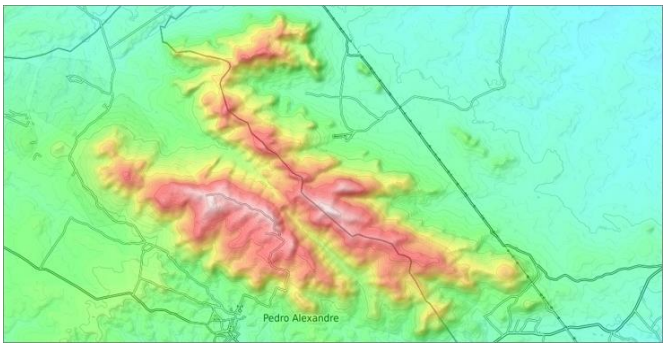

Figure 04: Altimetry map of Serra Negra with its culminating points highlighted in pink. **Source:** OpenTopoMap image obtained through the Topographic-map.com platform (2024).

The Serra Negra, in the sense of a small mountain range, consists of the largest and most extensive landform resulting from the grouping of mountains that are connected by the same rocky masses. It is composed of the union of Serra da Guia, Serra da Voturuna, Serra do Rela and Serra Grande, which were presumably originated from the same general causes. These mountains, in turn, have more descriptive names for several contiguous sections — which are often interpreted as smaller mountain ranges by residents.

Serra da Voturuna

The Serra da Voturuna is a mountainous stretch located in the mountain range, in the southwestern part, which punctuates the belonging of the municipality of Pedro Alexandre – BA. As a geological eminence, it is composed of a succession of mountains, reaches an altitude of 712 meters at the highest point and is positioned in the west-northwest-east-southeast direction, in the area that receives the historical-spatial name of Voturuna, according to Lima (2020).

The water that gradually flows from the high-altitude swamps forms runoff between its small lateral branches and supplies the local drainage network, which is mostly inserted in the hydrographic basin of the Vaza-Barris River (CPRM, 2005). In the depressions that occur between the foothills of the mountain range, suspended aquifers emerge whose natural exudation of groundwater leads to the formation of bodies of water notable for their geotouristic potential and for their water contributions to the municipal and state spheres:

• **Serra Waterfall** – is a geomorphological formation existing on the slope of the mountain, in a stretch consisting of humid forest and exposed to humid winds from the coast, composed of a watercourse whose flow is accentuated during rainy periods, giving rise to a waterfall with ecotourism potential. It is formed at a latitude of 9°59'34.5" south and a longitude of 37°54'02.4" west, at an altitude of 450 m.

• **Serra Dam** – this is an artificial water reservoir, currently in disuse, built on the slope of the mountain for storage and channeling of water from the springs to facilities in the municipality's headquarters, creating, technically, a remote supply system. The dam is located at latitude 9°59'41.8" south and longitude 37°53'39.2" west, at a mountain site whose elevation reaches approximately 530 m altitude.

• **Capivara River** – this is a river course that rises in a segment of the southern tip of the Serra da Voturuna and enters the Sergipe territory until it flows into the São Francisco River. In accordance with Sudene's topographic maps (1989), its upstream is the Rio dos Cachorros, which is also the reference of its source within the mountainous relief.

In addition to the ecotourism interest, the mountain also arouses ecological interest given the conditions of accessibility, observation and representativeness offered by the existence of endemic plant and animal species of the Northeast and Brazil conserved due to the microclimates of the humid forests in the high-altitude swamps. Its high relief attracts tourists, who travel along roads or trails to access the top, which has an exuberant view.

Serra do Rela

Serra do Rela is also a mountainous stretch located in the mountain range, in the southwest region, which points out the belonging of the municipality of Pedro Alexandre – BA. As a geological eminence, it is composed of a succession of mountains, reaches an altitude of 716 meters at the highest point and is arranged in the west-northwest direction of the complex, as an extension of the Serra da Voturuna, in the territory of the Serra Negra community.

Near the drainage network that is accentuated in the area of the village of Lagoa da Mata, there are depressions between lateral branches of the mountain where the pressure differential promotes the rise of groundwater from the aquifers saturated there and its exudation helps to supply the Guaratuba stream, according to Lima (2020). Its follow-up constitutes one of the slopes that results in a sandy-rocky valley called Boqueirão, a depression that stands out as one of the main

geomorphological elements:

• **Boqueirão Valley** – this is an extensive geographical accident currently belonging to the territory of Pedro Alexandre. It presents itself as a type of plateau that contains a community that arouses anthropological interest because it is a quilombola region: in the historical-spatial context of the Boqueirão community, its village is a remnant of the mocambos that accumulated along the valley corridor during the period of Brazilian slavery, by blacks who took refuge in the mountains of the complex, according to Lima (2023).

• **Serra da Pedra Redonda** – this is the last subunit of Serra do Rela considered, it forms the tip of the mountain range in the west-northwest direction and is essentially made up of a series of branches. It exhibits remarkable rocky outcrops, from which it derives its name, as Santos (2017) clarifies.

• **Guaratuba Creek** – this is a river course that emerges in the mountainous region, crosses the region of the Guaratuba farm and enters the Bahian territory of Coronel João Sá. In agreement with Lima (2020), its amount is the nicknamed Riacho do Meio, which converges with other tributary river courses and supplies the Gasparino Reservoir, whose flow is accentuated during rainy periods and flows into the Vaza-Barris River.

Serra da Guia

Serra da Guia is a mountainous portion located in the northeast region of the mountain range, in the southwest of the territory, which marks the belonging of the municipality of Poço Redondo – SE. Topographically, this geological formation comprises the area that is higher in altitude than all immediately adjacent points (containing 762 meters); and represents the culmination of the Sergipe territory, according to Santos and Nunes (2004).

Emerged in the region that receives the historical-spatial name of Guia, this part of the Serra Negra comprises an area of approximately 1,650.70 hectaresof remaining forest (Santos Júnior *et al*, 2017). Where the typical vegetation of the Caatinga predominates. According to Lima (2020), its geomorphological qualities added to the climate factor lead to milder climatic conditions at the top that, respectively, sustain high-altitude swamps composed of wetter forests that help in the recharge of water sources in the Jacaré River sub-basin.

It stands out for its ecotourism potential and dominates territorial elements that also assume a geosymbolic representation for the quilombolas who reside in the local settlements, strengthening them in the preservation of their identity. Notable for their contributions within the historical-spatial context of Guia are the environments:

• **Guia Cemetery** – this is a set of burials in a region of relict forest at the summit of Serra da Conceição, settled at latitude 9°58'54.0" south and longitude 37°52'06.9" west. It presents itself as a site of anthropological interest because it was a space exclusively intended for the burial of blacks who had taken refuge in mocambos at the top of the mountain since the period of slavery, as Costa (2016) clarifies.

• **Serra da Conceição** – this is the main prominence of the Serra da Guia formation, is part of the same geological structure and represents the highest altitude stretch of the set of adjacent elevations. Emerging at the interstate limit, it reaches an altitude of 762 meters and makes this mountain range recognized as the highest point of the State of Sergipe.

• **Jacaré River Sub-basin** – is the drainage basin formed by the extension of the flow of the Jacaré River and its tributaries that capture surface water from precipitation or the natural exudation of the subsoil by the suspended aquifers that outcrop in the depressions between the foothills of the mountains, mostly in the mountainous portion of the Serra da Guia.

Serra Grande

The Serra Grande (or **Serra de Prata)** is a mountainous segment emerged in the northwest region of the mountain range and located on the route that determines the Sergipe-Bahia interstate limit, where it acts as a natural border. Topographically, this geological portion covers the area that is second higher in altitude than all the readily adjacent points of the complex, whose measurements give it an altimetric value of 680 meters.

It happens as an extension of the mountainous relief that constitutes the Serra da Guia, being part of the same geological structure and continuing the slope from which the plain of the Boqueirão Valley proceeds. However, its relief curves and resumes continuity in the opposite direction, changing orientation in such a way that it acquires the figure of a hook. Although its culmination is located outside the territory of Sergipe, the adjacent area of Sergipe also sustains an equivalent altimetric value near the interstate limit.

It stands out for providing an optical effect that converts the mountain into the aforementioned "Serra de Prata" after the rainfalls. Such a phenomenon happens when sunlight falls on water droplets left on the plants and rocks of their slopes after rain or fog. These droplets act as tiny lenses, scattering sunlight in various directions. Therefore, when viewed from the angle of Boqueirão, the scattered light creates a silver or white glow on the mountainous slopes, giving the impression that Serra Grande is silvery.

• **3-pointed massifs** – these are rocky outcrops that make up the mountain's relief. They were presumably originated by the same geochemical masses that formed these mountain ranges. They are located in a region of latitude 9°57'07.4" south and longitude 37°54'04.0" west and remain partially exposed, due to the insufficient presence of vegetation cover.

• **Serra do Ponto Fino** – this is the last subunit of the Serra Grande considered here, which added to the Serra da Barra constitute the mountainous portion that would be its extremity accompanied by the foothills. It works as a watershed and, respectively, isolates the drainage network of the Boqueirão Creek from the Jacaré River Sub-basin that is on the Sergipe side. It arouses ecotourism interest for the species preserved in its stronghold, as Santos (2017) clarifies.

2. Results

Serra Negra is what is called a continuous system of mountains that constitute a small mountain range, inserted in the Structural Province of Borborema, containing a mixture of different characteristics, such as highlands, valleys and rugged

terrain, with unevenness. Its mountains are geologically related and align in a continuous formation caused, certainly, by the same tectonic processes. For more detailed authors, a more accurate scientific term for its characterization would be a rocky mass, provided with several plutonic bodies, as presented in Carvalho (2022).

Thus, the Serra Negra would be a large mass of intrusive igneous rock, with transverse folds in its area,resulting from the process of cooling magma at great depth in the crust and consisting of intermediate rocks, with granodioritic to quartz-monzonitic compositions, which were later exposed due to erosion following the tectonic upheaval, in a transcurrent context of the plates (**figure 5**).

Figure 05: Rocky outcrop in Serra da Guia showing a probable suspended magmatic intrusion. **Source:** Courtesy of Leane Santos (2018) to the author.

Although there is still no precise age on the formation of the mountainous relief, laboratory experiments and theoretical work of the latter have indicated that large volumes of granitoids are due to a substantial production of magma during periods of orogenesis on the timescale of about 952–933 million years ago (**table 1**).

The isotopic composition of minerals that are part of the rocks of the Serra Negra Granite indicates that this process, which would be active in an environment dominated by transcurrence, where the plates slid laterally in relation to each other, dates back approximately 951 million years, according to the methods originally published by Carvalho (2005) which more recently were brought up in the studies by Oliveira *et al*. (2017). Considering the numbers repeated by the studies listed in **table 1**, it is assumed here that its geological formation began after these tectonic processes, about 952 million years ago.

The transition between the two tectonic environments mentioned above is an important point of discussion. A better understanding of this context dominated by the occurrence may provide valuable insights into the geological processes that shaped this region during the Cariris Velhos cycle and determine the precise age of the Serra Negra mountains.

In line with the updating of the interstate dividing lines made official by the federated units, a new configuration is also in force for the territorial domain of the mountain complex, in which the belonging of the two neighboring municipalities is punctuated. After the cartographic adjustments were made by the SEI/BA report (2019), which were subsequently approved by the entities, some information offered by the bibliographic materials about the belonging of areas of the complex began to conflict.

Table 1: Geochronology by radiometric dating.

Data source	Rock sample	Radiological method	Age
SILVA FILHO *et al.* (1979)	Granito Serra Negra	Rb-Sr	870 Ma
CARVALHO (2005)	Granito Serra Negra	Pb-Pb	961 ± 38 Ma
CARVALHO (2005)	Granito Serra Negra	U-Pb	952 ± 2 Ma
OLIVEIRA *et al.* (2006)	Granito Serra Negra	U-Pb	952 ± 2 Ma
OLIVEIRA *et al.* (2010)	Granito Serra Negra	U-Pb	952 ± 1 Ma
OLIVEIRA *et al.* (2017)	Granito Serra Negra	U-Pb	952 ± 1 Ma
LIMA *et al.* (2017)	Granito Serra Negra	U-Pb	933 ± 7 Ma

Therefore, the spirit of this work is based on the need to update the theoretical bases with this new cartographic configuration. It was understood here that, from then on, it would be important to present the names of the artificial components created by the residents in the elaboration of a more integrated description of the mountainous portions. However, it is considered that the present study may not have exhausted all references regarding physiographic attributes and that future studies may present more information.

Lima (2020) assessed, in a scientific work, that this mountain range was mostly located in the Sergipe territory (holding 55% of its area; 2,850 hectares), with its smallest part inserted in the Bahian territory (45% of the area; 2,379 hectares). This division, elaborated based on cartographic inputs prior to the modification, attributed both the Boqueirão valley and its community to the state of Sergipe. In this line, with the new demarcation mark between the states, the data become partially discordant for the ownership of hectares of land presented in the study in question (**figure 6**).

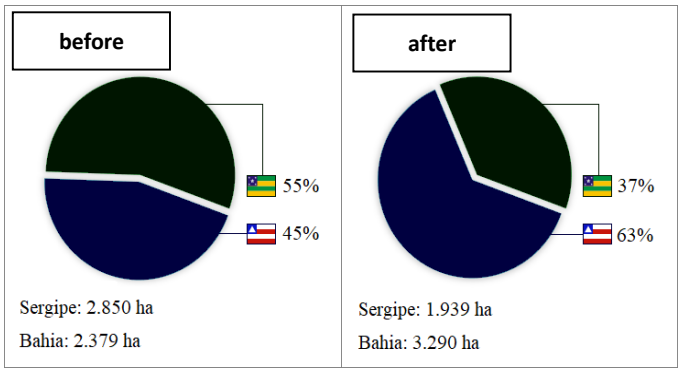

Figure 06: Detention of Serra Negra before and after the renewal of the interstate border route. **Source:** Author's work based on information from Lima (2020).

Taking into account the changes made, approximately 37% of the mountainous area was now located in the territory

of Poço Redondo, which corresponds to 1,939 hectares, while the other 63% was inserted in the territory of Pedro Alexandre, equivalent to 3,290 hectares. These numbers were obtained here by measuring with the help of ArcGIS considering the surface area encompassed by the mountain range, which totals **5,229** hectares. It is concluded that these modifications in the bordering strip that crosses the Serra Negra were significant enough to invert the proportions of its administrative jurisdiction.

To understand the impact of this, a future anthropological report aimed at describing, gauging and documenting the cultural, social and behavioral aspects of the peoples of the Boqueirão strip, especially in relation to legal issues, such as an imaginable official recognition of the quilombola territory, will now depend on the interests of Bahia.

Regarding its altimetry, Serra Negra is an imposing set of granite elevations whose altitude reaches **762** meters above sea level in Serra da Guia, the highest point of the entire mountain range. Both the analysis of the accessible literature on subdivisions of the complex and the content of this compendium make it possible to document the names that help to identify and characterize its different units, including ordering them by altimetry, although the accurate measurement of altitudes is extremely difficult (**Table 2**).

Table 2: Region Peaks. Values collected in the ArcGIS, Esri, NASA, NGA, and USGS (2024).

Training	Domain	Geographic coordinates	UF	M
Serra da Guia	Serra Negra Complex	9°58'53.0"S and 37°52'06.6"W	SE	762
Serra do Rela	Serra Negra Complex	9°58'47.9"S and 37°53'59.7"W	BA	716
Serra da Voturuna	Serra Negra Complex	9°58'56.0"S and 37°53'07.7"W	BA	712
Serra Grande	Serra Negra Complex	9°57'52.4"S and 37°53'08.3"W	SE	680
Serra do São Clemente	Serra Negra Complex	9°59'18.9"S and 37°51'05.6"W	SE	667
Serra de Itabaiana	Itabaiana Dome	10°44'18.2"S and 37°21'42.2"W	SE	653

As a result of the results of table 2, it is verified that Serra Negra contains the three highest mountain blocks in the state of Sergipe – considering the possibility that the stretch of Serra da Guia that is nicknamed **Serra do São Clemente** is also a mountain range in this complex. There are still other sections that are less pronounced, but which still contribute to the grandeur of the mountain set, which are elements of the disputed mountain ranges, which were named by the adjacent communities in their own way.

Thus, the criticisms in relation to this division of the mountain range by names may highlight that the mountainous portions do not have formalized names, making the nature of this material unprecedented. However, based on the assumption that the population residing in the mediations of the mountains commonly identifies elements of the landscapes with proper names (SEI/BA, 2019), this work respects the denominations widely used by the peoples and represents a formalization of concepts that do not yet exist in the literature.

Concluding this study, the prospective critical review made here on the principles that governed the origin, on geolocation and on the components of the Serra Negra Complex gathered relevant information, and could contribute a little more to the framework of knowledge pertinent to the series of mountains – which are important not only from a scientific point of view, but also ecological, economic and cultural.

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