THE INVENTORY AND EVALUATION OF GLACIAL AND PERIGLACIAL GEOMORPHOSITES. STUDY CASE – RETEZAT MOUNTAINS (SOUTHERN CARPATHIANS, ROMANIA)

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ABSTRACT

The primary purpose of this paper is the inventory and evaluation (by our method) of the most important glacial and periglacial geomorphosites in the Retezat Massif. Thus, 30 geomorphosites were analyzed, for which inventory sheets were drawn up and subsequently evaluated: scientific value – 20 points (paleogeographical interest, representativeness, rarity, integrity, degree of scientific knowledge, use in educational purposes, ecological value, diversity), aesthetic value -20 points (visibility, space structuring, color contrast, level difference, landscape framing), cultural value -20 points (cultural characteristics, historical characteristics, religious characteristics, iconographic/ literary representations, cultural manifestations, symbolic value), economic value – 20 points (accessibility, infrastructure, yearly number of visitors, number of types and forms of use, economic potential/income), management and use – 20 points (preservation degree, protected sites, vulnerability / natural risks, the intensity of use, the use of aesthetic, cultural and economic value, relationship with planning policies). The total weight is calculated as the sum of the geomorphosites values divided by 100 in order to be able to compare it with other existing methods in the specialized literature. The obtained values vary between 0.36 (Grohotiș scree) and 0.78 (Bucura glacial cirque), and 0.77 (Zănoaga glacial cirque).

Keywords: inventory, evaluation, geomorphosites, glacial, periglacial, Retezat, Southern Carpathians, Romania

INTRODUCTION

Geomorphosites are landforms that, thanks to human perception, receive a value that can be scientific, aesthetic, cultural and economic [11]. The study of geomorphosites dates back to the beginning of the 2000s, among the main objectives of the scientific community being: the realization of the theoretical design, the establishment of inventory, evaluation and mapping methodologies and ways of valorization.

The inventory consists in the identification of all geomorphosites in a particular area and their classification. There is no unanimously accepted methodology in the specialized literature. Thus, several geomorphosite inventory sheets were created; the most well-known belong to Pralong, 2005 [8] and Reynard, 2007 [10]. In the present study, for the selected geomorphosites, the inventory sheet from the work of [8] (with modifications) was used, a sheet that includes both qualitative and quantitative elements.

Since 2000, the evaluation of geomorphosites has been constantly at the attention of researchers, and numerous evaluation methods have been developed. These are different

from one geomorphological school to another, depending on the value assessed primarily (especially scientific), the targeted area and the purpose of the approach.
[9], [2], [3], [5] summarize the existing methods in the specialized literature, with each of them establishing strengths and weaknesses as well as the possibilities of use.
On the world level, two important period can be outlined in terms of evaluation methods: 2000-2009 (numerous methods appeared that generally targeted all geomorphosite values, applied for different geographical spaces) and 2009 - present (a lower number of methods appeared, more refined and which combine the quantitative and the qualitative side, including the management/use of geomorphosites).
In 2012, we proposed a new evaluation method, which was initially applied for the Ponoare protected natural area (all evaluated geomorphosites are karst landforms), and later, for the upper basin of the Argeș River (the evaluated geomorphosites having different origins: glacial, periglacial, karst, fluvial, tectonic etc.) [1], [4].
The own method used in these two studies has the main purpose of increasing the degree of objectivity of the evaluation, by introducing numerous different parameters (with clear scores and subscores) adapted to the Romanian Carpathian area [4].
To validate it, it is necessary to apply it in different geographical contexts where there are geomorphosites with varied typology and value. In order to achieve this approach, the present study is a continuation of the previous ones (2012, 2020) [1], [4]. Its general objective consists of evaluating the geomorphosites in an alpine area (the Retezat massif), where typical glacial and periglacial geomorphosites are located, some of them of great value at the national level.

STUDY CASE

The Retezat massif is located in the northwest of the Southern Carpathians (Romania), part of the Retezat-Godeanu Group, between Jiu, Strei and Danube (Figure 1). It is connected to the Godeanu Mountains, in the southwestern (via the Tulișa ridge) and to the Șureanu Mountains in the eastern and northeastern. They are bordered by depression areas with low altitudes (Hațeg at 300-400 m and Petroșani at 700-800 m), which they dominate through steep slopes.
Considering the variety and diversity of the geomorphological and hydrological landscapes, the complexity of the glacial and periglacial relief, the value of the elements of flora and fauna (over 1200 species, many of which are endemic), in 1935, it was declared the first national park on the territory of Romania, currently being a biosphere reserve. When it was established, the Retezat National Park had an area of 13,000 ha. Today, the site is 38,138 ha, and it is mainly located within the basins of Lăpușnicu Mare, Nucşoara and the right tributaries of the Râului Mare. Within the park, the scientific reserve (Zlata - Dobrun basin) stands out, with an area of 1,500 ha, where access is strictly limited [5], [7], [13].
In the Retezat National Park, there are 50 peaks over 2000 m, the highest being Peleaga – 2509 m, Păpușa – 2508 m and Retezat – 2482 m (with a unique aesthetic value due to its cut shape, which makes it visible and recognizable from a long distance) [13].
According to [6], the petrographic composition is represented by lithological formations belonging to the Danubian Autochthon and the Getic Nappes. The Danubian autochthon consists of granitoid eruptive massifs in the central part (such as Buta and Retezat), meso-metamorphic schists (quartzitic, mica schist, graphitic) located on the periphery and sedimentary deposits (in the southeast and north) containing limestone, conglomerates, sandstones. Getic Nappes has a relatively small extent and consists of ophiolites and

meso-metamorphic crystalline schists. All these rocks determine distinct geomorphological landscapes (on crystalline, the relief is massive, rough, heavy, and rounded; on the granite, sharp interfluves appear, with talus; on limestone, a relief develops with steep slopes and specific landforms), with important differences in terms of the morphology of glacial and periglacial landforms [5].

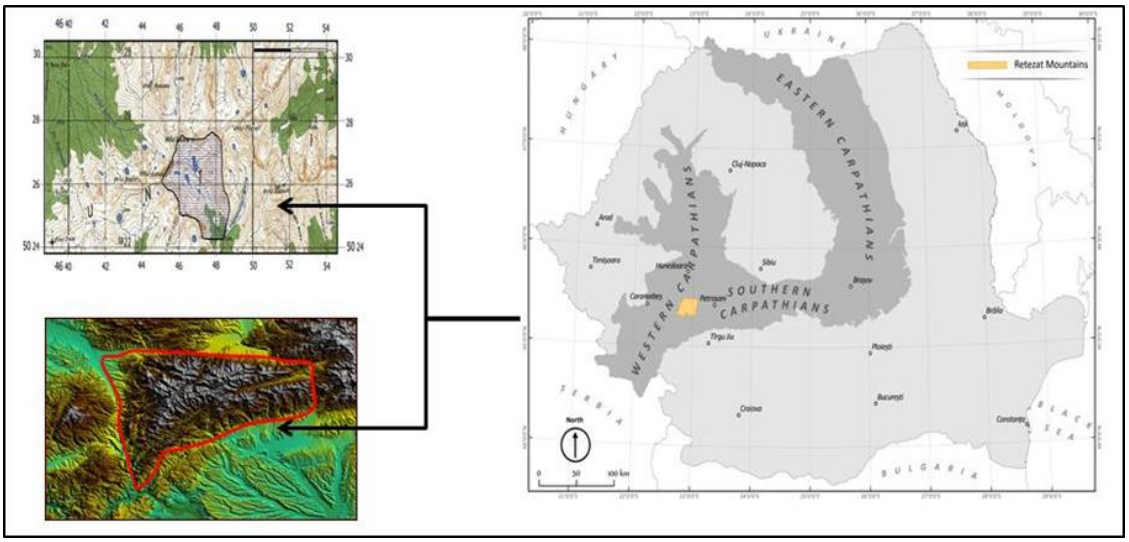

Figure 1. The geographic position of Retezat Mts in Romania

Its specificity is given by the presence of the most complex and representative glacial and periglacial geomorphosites in Romania. Next, we shall exemplify the most important types of geomorphosites from the previously listed categories [5] with modifications and additions [7, 12].

Glacial geomorphosites (Figure 2):

- glacial and glacio-nival cirques with different morphologies such as: Aradeşu I, II, Berbecilor, Buta, Bârlogul Ursului, Bârlea, Căldarea Pietroasă, Cioaca Radeșului, Ciumfu, Custura, Dobrunu, Fereastra Custurii, Galeşu, Groapele, Gemenele, Lia, La Clince, Judele, Obârşia Nucşoarei, Pustnicu, Pilugu, Pietrele, Peleaga, Peleguța, Păpușa, Radeşu, Răsucit, Slăveiu, Şesele, Stânişoara, Ștevia, Știrbu, Țapului, Turcel, Tăul Negru, Văsiel, Valea Rea, Zănoaga, Zănoguța;
- glacial valleys with lengths measured in km, with a transverse U-shaped profile, and as examples we mention Aradeşu, Buta Mică, Buta, Cârligu, Dobrunu, Lăpușnicul Mare (developed by Judele, Bucura, Peleaga and Paltina valleys), Nucşoara (developed by Beagu, Galeşu, Valea Rea, Pietrele, Stânişoara valleys), Paroşu Mare, Peleaga, Radeşu Mic, Radeșul Mare, Râu Alb, Râul Bărbat (developed by Custura, Ciumfu, Gruniu, Lazăru, Văcarea valleys), Şesele, Ștevia, Zlătuia (developd by Scoaba Retezatului, Rovine, Tăului Negru, Ştirbu valleys);

Figure 2. The most important geomorphosites in the Retezat Mountains
(A- Zănoaga glacial cirque; B- Bucura glacial cirque; C- Galeșu glacial cirque;
D- Țapului glacial cirque; E- Peleaga Needles; F- Peleaga Peak)

- alignments of peaks and ridges/karlings (with lengths of more than 1 km) such as Retezat, Păpușa, Bucura, Zlata-Zănoaga, Slăveiu (contemporary, affected by periglacial system)
- the moraines of the valleys: Râul Mare, Râul Bărbat, Nucşoara, Pietrele, Judele, Ștevia;
- the glacial step with glacial knobs and striae, different in morphology depending on the rocks on which they were formed;

- the glacial saddles formed between cirques Galeşu and Valea Rea, Valea Rea and Peleaga, Valea Rea and Pietrele, Pietrele and Bucura, Pietrele and Stânişoara, Stânişoara and Ştevia, Ştirbu and Bucura;
- Periglacial geomorphosites (Figure 2):
- sharp peaks and ridges of different shapes, with steep slopes and different types of scree (needles or fangs: Pelegei Needles, Slăveiul Mare; towers: Porții Tower);
- corridors of avalanches with V profile and lengths in meters;
- micro depressions and snow niches;
- cones and talus, torrents of stones, masses of gelifracts;
- pronival rampart and glacier stone (in the valleys Judele, Știrbu, Pietrele, Valea Rea, Pietricele, Ana);
- cryoplanation surfaces;
- solifluction terraces and mounds;
- thufurs;
- stone pavements;
- block fields and stone circles;

METHODOLOGY

The proposed methodology aims to inventory, classify and evaluate the geomorphosites that have been selected based on the criteria of importance and representativeness. It starts from the selection from specialized literature and the field trip, in which geomorphosites will be located on the cartographic materials [1, 4].

Their inventory will be made based on the sheet used in the specialized literature (8), with modifications related to the area where it will be applied, later they will be classified according to several criteria: time, type, origin and importance.

The evaluation is carried out based on the criteria in table 1, and for the calculation of the total value the formula is applied: Vtot = (Vsci +Vsce +Vcult +Veco+Mg)/100 [1,4] where Vsci - the scientific value, Vsce - the aesthetic value, V cult - cultural value, V eco - economic value, Mg - management and use. For each sub-criterion, a score is given between 0 and the maximum value that can be given according to table 1.

For the scientific value, the evaluated sub-criteria are: paleogeographical interest (the existence of fossils/elements of value to show the evolution of the area), representativeness (the importance for the analyzed area), rarity (at the level of the analysis scale), integrity (affecting the geomorphosite by the current geomorphological processes), the degree of scientific knowledge (the presence of the landform / geomorphological process in the specialized literature, in different categories of papers), the use in educational purposes (the possibility or even the use as an example for pupils and students in practical field applications), the ecological value (existence of rare or protected species, other ecological characteristics) and diversity (for both geodiversity and biodiversity, if any) [1].

As part of the aesthetic value, the following are evaluated: visibility (the number of belvedere points towards the geomorphosites and the panorama it offers), the space structuring, the color contrast (the greater contrast means the higher value), the level difference (larger level differences increase the aesthetic value) and landscape framing (the mode of structure into the landscape) [1].

The cultural value is given by the following sub-criteria: cultural characteristics, historical characteristics, religious characteristics, iconographic representations (in literary works,

works of art, etc.), festivals /cultural manifestations (their importance and frequency are taken into account), symbolic value [1].
The economic value consists of: accessibility (how access is achieved and the distance from it), infrastructure (type of roads, paths, cable infrastructure, proximity to other types of facilities), the number of yearly visitors, number of types and forms of tourism (use in tourist activities through different types and forms of use), economic potential (if it is possible to calculate actual incomes) [1].
The management and use evaluates the following sub-criteria: preservation degree (how the geomorphosite suffers as a result of aggressive human activities), protected sites (natural protected areas), vulnerability / natural risk (natural and anthropogenic risks), the intensity of use (way, period and intensity of use), the use of the aesthetic, cultural or economic value (if there are forms of tourism or other activities of this type), relationship with the planning policies (the existence of strategies, projects, programs in which the geomorphosites are included) [1].

Table 1. The criteria and scores proposed for evaluating geomorphosites [1, 4]

Scientific value – 20 points	**Aesthetic value - 20 points**	**Cultural value - 20 points**	**Economic value - 20 points**	**Management and use - 20 points**
paleogeographic interest -3p	visibility – 4p	cultural characteristics -4p	accessibility -4p	preservation degree -4p
representativeness-2p	space structuring – 4p	historical characteristics -4p	infrastructure-4p	protected sites -3p
rareness – 2p	colour contrast - 4p	religious characteristics - 4p	yearly visitors number -4p	vulnerability/ natural risks - 3p
integrity -2p	level difference- 4p	iconographic/ literary representations -2p	number of types and forms of use (inclusively touristic) -4p	the intensity of use - 4p
degree of scientific knowledge -3p	landscape framing-4p	festivals/ cultural manifestations -2p	economic potential (incomes) -4p	the use of aesthetic, cultural and economic value -3p
use in educational purposes - 3p		symbolic value -4p		relationship with planning policies-3p
ecologic value-3p				
diversity-2p				

To ensure comparability with other methods, division by 100 is performed, so the total value will be between 0 and 1 (as with most other methods). To ensure an objective evaluation, all criteria have the same weight (20 points), with no reason for one of the values to receive higher total scores [1, 4].

RESULTS AND DISCUSSION

Following the application of the methodology described above, aimed at the selection, inventory, classification and evaluation of geomorphosites, a series of results summarized in tables 2, 3 and 4 were obtained. Thus, of the total of 30 selected geomorphosites, 56.67% are glacial and 43.33 % are periglacial. The weights are identical to those for the functionality criterion: 56.67% are passive (glacial geomorphosites formed during previous glacial phases, today they are modeled in the periglacial system), and 43.33% are active (periglacial geomorphosites resulting from the action of freeze-thaw processes,

eolization, nivation, the action of rainwater, etc.). Regarding the spatial distribution of geomorphosites, their weight is 60% for areal ones (glacial cirques/complexes), 20% for linear ones (glacial valleys, ridges, etc.) and 20% for punctual ones (peaks and witnesses of erosion).

Table 2. – The glacial and periglacial selected geomorphosites from the Retezat Mts- classification and inventory

Name	**Code**	**Origin**	**Type**	**Functionality**
Zănoaga glacial cirque	HDgla01	glacial	area	passive
Bucura glacial cirque	HDgla02	glacial	area	passive
Tăul Negru glacial cirque	HDgla03	glacial	area	passive
Gemenele glacial cirque	HDgla04	glacial	area	passive
Pietrele glacial cirque	HDgla05	glacial	area	passive
Peleaga glacial cirque	HDgla06	glacial	area	passive
Galeșu glacial cirque	HDgla07	glacial	area	passive
Țapului glacial cirque	HDgla08	glacial	area	passive
Dobrunu glacial valley	HDgla09	glacial	linear	passive
Judele glacial complex	HDgla10	glacial	area	passive
Lăpușnicul Mare glacial complex	HDgla11	glacial	area	passive
Nucșoara glacial complex	HDgla12	glacial	area	passive
Bucura karling	HDgla13	glacial	linear	passive
Retezat saddle	HDgla14	glacial	area	passive
Lolaia saddle	HDgla15	glacial	area	passive
Peleaga saddle	HDgla16	glacial	area	passive
Judele saddle	HDgla17	glacial	area	passive
Grohotiș scree	HDper01	periglacial	area	active
Drăgșanului ridge	HDper02	periglacial	linear	active
Piciorul Peleaga ridge	HDper03	periglacial	linear	active
Peleaga needles	HDper04	periglacial	linear	active
Slăveiul Mare needles	HDper05	periglacial	linear	active
Peleaga peak	HDper06	periglacial	punctual	active
Custura peak	HDper07	periglacial	punctual	active
Bucura peak	HDper08	periglacial	punctual	active
Păpușa peak	HDper09	periglacial	punctual	active
Retezat peak	HDper10	periglacial	punctual	active
Rock glacier at Valea Rea	HDper11	periglacial	area	active
Rock glacier at Pietrele Valley	HDper12	periglacial	area	active
Porții Tower	HDper13	periglacial	punctual	active

Table 3. The sample structure of glacial and periglacial selected geomorphosites

		Absolute frequency	Relative frequency
Origin	Glacial	17	56.67
	Periglacial	13	43.33
Type	Area	18	60.00
	Linear	6	20.00
	Punctual	6	20.00
Functionality	Passive	17	56.67
	Active	13	43.33

The total value of the geomorphosites varies between 0.78- Bucura glacial cirque, 0.77- Zănoaga glacial cirque, respectively, 0.36 for the scree – Grohotiș (Table 4). The first geomorphosites are known nationally, within them, there are glacial lakes that hold national superlatives (the deepest – Zănoaga, respectively, the most extensive – Bucura) and present the most significant flows of tourists from this massif. The Grohotiș

geomorphosite has the lowest value (the scientific importance is high, but the other values are low) and is poorly used from a tourist point of view.

Table 4. The assessment of glacial and periglacial selected geomorphosites

Name	Scientific value	Aesthetic value	Cultural value	Economic value	Management and use	Total value
Zănoaga glacial cirque	20	20	2	17	18	77/ 0.77
Bucura glacial cirque	20	20	2	18	18	78/ 0.78
Tăul Negru glacial cirque	18	18	0	10	14	60/ 0.60
Gemenele glacial cirque	19	20	1	10	14	64/ 0.64
Pietrele glacial cirque	19	19	0	10	12	60/0.60
Peleaga glacial cirque	20	20	0	14	15	69/0.69
Galeșu glacial cirque	19	20	0	12	17	68/0.68
Țapului glacial cirque	19	19	0	9	14	61/0.61
Dobrunu glacial valley	18	19	0	10	13	60/0.60
Judele glacial complex	20	19	0	12	15	66/0.66
Lăpușnicul Mare glacial complex	20	20	1	14	15	70/0.70
Nucșoara glacial complex	19	20	0	12	14	65/0.65
Bucura karling	19	20	1	12	12	64/0.64
Retezat saddle	18	18	0	9	11	56/0.56
Lolaia saddle	17	16	0	9	10	52/0.52
Peleaga saddle	18	18	0	8	11	55/0.55
Judele saddle	17	17	0	8	10	52/0.52
Grohotiș scree	13	9	0	7	7	36/0.36
Drăgșanului ridge	14	14	0	11	9	48/0.48
Piciorul Peleaga ridge	14	14	0	11	10	49/0.49
Peleaga needles	17	18	0	10	12	57/0.57
Slăveiul Mare needles	16	18	0	10	12	56/0.56
Peleaga peak	17	20	1	12	13	63/0.63
Custura peak	17	19	0	10	11	57/0.57
Bucura peak	16	20	1	11	12	60/0.60
Păpușa peak	17	18	1	11	12	59/0.59
Retezat peak	17	20	2	12	13	64/0.64
Rock glacier at Valea Rea	15	9	0	7	7	38/0.38
Rock glacier at Pietrele Valley	15	9	0	7	7	38/0.38
Porții Tower	16	16	1	10	10	53/ 0.53

The scientific value of the selected geomorphosites is very high. They are located in the first protected natural area of Romania - the Retezat National Park, where the most typical and complex glacial and periglacial geomorphosites are considered to be located. They also have a significant didactic value, being present in school textbooks and university courses or in some field applications in geography study programs. Thus, the maximum

value (20p) was given to the following geomorphosites: Zănoaga glacial cirque, Bucura glacial cirque, Peleaga glacial cirque, Judele glacial complex, Lăpușnicul Mare glacial complex, and the one with the lowest value (13p) was evaluated to be Grohotiș scree (Table 4).
The aesthetic value is also high, being included between 20 points (Zănoaga glacial cirque, Bucura glacial cirque, Peleaga glacial cirque, Lăpușnicul Mare glacial complex, Nucșoara glacial complex, Bucura karling, Peleaga peak, Bucura peak, Retezat peak) and 9 points (Grohotiș scree, Rock glacier at Valea Rea, Rock glacier at Pietrele Valley). High values are recorded either by glacial complexes impressed with numerous landforms or lake units, by ridges with a special morphology that also have a panoramic function, or by peaks that are important belvedere points or have a special shape (such as the Retezat peak) (Table 4).
The cultural value was evaluated with reduced scores between 0 and 2 points (Zănoaga glacial cirque, Bucura glacial cirque, Retezat peak), there being no elements of cultural, historical, religious or symbolic importance related to this area (Table 4).
The economic value presents the average importance at the national level, the assessment is carried out with considerable difficulty due to the lack of clear data related to the number of tourists/year or the income obtained from tourist activities. The points awarded to these sub-criteria are standardized for the entire area. Also, accessibility is relatively difficult for all geomorphosites, only the different categories of marked paths are able to reach them. According to this criterion, the points awarded vary between 18 (Bucura glacial cirque) and 7 (Grohotiș scree, Rock glacier at Valea Rea, Rock glacier at Pietrele Valley) (Table 4).
For management and use, the points awarded are between 18 (Bucura glacial cirque, Zănoaga glacial cirque) and 7 (Grohotiș scree, Rock glacier at Valea Rea, Rock glacier at Pietrele Valley). These values are related to the presence of the Retezat National Park, the degree of high protection of many areas but also of the existence of natural risks (avalanches, rock falls, etc.) Apart from the Retezat National Park management plan, there are no projects/policies related to territorial planning and local development (Table 4).

CONCLUSION

This method was applied for three case studies, namely: the Ponoare natural area (Mehedinți Plateau), the upper basin of the Argeș River (Southern Carpathians) and the alpine sector of the Retezat massif (Southern Carpathians).
For the first case study, karst geomorphosites were selected, and their total value varied between 0.75 (Ponoare Natural Bridge) and 0.35 (Ponoare Sinkhole Field) [1].
In the research related to the upper basin of the Argeș River, the chosen geomorphosites are varied in origin (glacial, periglacial, fluvial, tectonic, etc.) their values varying between 0.75 (Vânatorea lui Buteanu Peak) and 0.51 (Izvorul Moldoveanu Valley) [4].
In the present study, the geomorphosites selected are glacial and periglacial, and their total values vary between 0.78 (Bucura glacial cirque), 0.77 (Zănoaga glacial cirque), respectively 0.36 (Grohotiș scree).
It can be seen that the obtained values contribute to the validation of the method, the differences being relatively small and reflecting the specificity of the analyzed area. Thus, in the first case, the reduced values are due to the difficult access to the area, the lack of adequate infrastructure and promotion. In the second case, the higher scientific value is noted, to which is also added the accessibility achieved through cable transport or the

Transfăgărașan national road, as well as the high degree of knowledge the population has about them and from the specialized literature.
In the present work, geomorphosites have a great value in terms of the aesthetic and scientific point of view. The economic value, management and use are average compared to the other case studies, but the cultural value is the lowest. These data are highlighted by the average of the points awarded by value categories for the 30 geomorphosites, obtaining: scientific value - 17.46, aesthetic value - 17.56, cultural value - 0.43, economic value -10.76; management and use value - 12.26.
In the future, it is necessary to choose some areas from the Carpathian with varied lithology, structure and tectonics, as well as with other types of relief such as: volcanic, fluvial and petrographic..

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