

# GIS utilization in determining the limits between low morphological units

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## Abstract

The limit between low morphological units is quite difficult to be established due to the fact that the lithological, elevation and/or structure differences are hardly visible. Thus, the contact between piedmont and plain units is represented, in many cases, by areas where limits are hard to be drawn. In order to establish the way geographic information system (GIS) may contribute to the determination of the aforementioned limits, we used the situation of the limit between the Getic Piedmont and the Romanian plain and compared the obtained results to examples from other areas with different formation and evolution conditions. Presently, the Getic Piedmont undergoes a modelling process as valleys widen, torrential enlargements laterally advance, and slope denudation develop, which make difficult to establish a clear southern limit. The fan texture of the valleys, their age, the flowing direction, as well as the differences of altitude, lithology, and structure disposal represent the main elements when establishing limits even in the case of GIS analysis. The drawing of thematic layers rendering elements such as hydrographic system, hypsometry, DEM on a traditional cartographic support, orthophotoplans, satellite images, for a better interpretation of the geomorphologic aspects allow a more objective attempt of reconstructing the morphological limits.

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## Introduction

Geomorphology enabled the introduction of the piedmont or pediment term in geography. By the end of the 19<sup>th</sup> century, scientists used the notion of pediment aiming at those greatly eroded surfaces, located in areas with arid tropical climates, as well as for the contact region between mountain and plain. Fragmentation, together with climate and rock were considered essential factors for the genesis and further evolution of a pediment. Thus, W. Mac Gee (1897), quoted by Nichols *et. al.* (2005) stated that an erosion pediment located towards the foot of a mountain always has a correspondent accumulation pediment at the contact with the plain.

When analysing the piedmont area of the Appalachian mountains, Davis (1930) considered the contact/transition region as a hilly region resulted from the development of a new erosion cycle towards the extremity of the mountains, which had been transformed into a peneplain in a previous cycle. The accumulation piedmont, which was initially considered proluvial plain at the foot of

a mountain, was mainly generated by the conditions of an arid climate, on highly inclined slopes, where the intermittent torrential flow amplified the accumulation of sediments. These geomorphologic units do not have a long existence as they were subjected to further folding that led to their transformation in hilly regions or even low altitude mountains.

The term of piedmont acquired two main meanings, a morphological and a genetic one. The first meaning refers to any kind of flat or slowly inclined surface, no matter its genesis, but located at the foot of a mountain. From the genetic point of view, there are three morphological categories – accumulation piedmont, erosion piedmont and tectonic piedmont (Posea and Popescu, 1973).

The piedmont regions, in terms of position, are no longer considered piedmont-like when the alluvial cover is completely destroyed. This situation is also noticed in the case of the area used as an example in the present paper – the Getic Piedmont. It was initially considered as a single morphologic unit between the Southern

Carpathians and the plain area, which, at the foot of the mountains, was made up of an association of high hills, depressions, and alluvial fans. However, later on, the piedmont term applied only to the relict part of the former Villafranchian alluvial plain, located 15–30 km southwards, because the northern part was subjected to folding, which led to the formation of a distinct unit, the Getic subcarpathians.

Consequently, the Getic plateau represent a transition unit located between the Getic subcarpathians and the Romanian plain, while from east to west, it develops between the Dambovită and the Danube rivers (Fig. 1). This unit overlaps two distinct structural units, separated by the Peri-Carpathian fault. In the north, it is the Getic depression with a background of Carpathian origin, as well as a platform unit made up of crystalline rocks and granites. In the south, it is the Wallachian platform made up of schists with granite intrusions. The subunits and morphological features of the Getic Piedmont are rendered in Fig. 2.

- Strehaia plateau is made up of Pliocene and Quaternary deposits with monocline structure. The altitude varies between 350 m in the north-west and 200 m in the south-east (Boengiu, 2004, 2008). In the northern half there appears a hilly unit with large interfluvies, east-west directed cuestas, and consequent valley; in the south, its morphology is dominated by interfluvial plateaus (Enciu, 2001).
- Jiu's hillocks, made up of Romanian Villafranchian deposits, have the aspect of prolonged hills that decrease from 400 m in the north to 300 m in the south.
- Oltet Piedmont displays a typical monocline structure; in the north interfluvies were transformed into hilly summits, while in the south it gets enlarged and acquires the aspect of plateaus (Aur, 1996).
- Cotmena Piedmont developed among the valleys of the Olt, the Topolog and the Argeș rivers. There predominate plateau interfluvies that get larger southwards and highly inclined slopes that are affected by landslides and gully erosion.
- Argeș hills are framed by the Argeș and the Argeșel valleys; they represent a series of summits made up of Pliocene rocks and valleys developed parallel from west to east. The maximum altitudes reach about 600–700 m in the north and 300 m in the south.
- Căndesti plateau, located among the Argeș, the Argeșel, and the Dambovită rivers, appears as an assembly of summits with 0.5–3 km wide tops and altitudes that decrease from 700 m in the north to 300 m in the south.

The Getic piedmont is about 200 km long and displays an average width of 90 km. It represents the most extended piedmont, molasse, fluvial-lacustrine, Pliocene-Villafranchian unit from Romania. It also individualizes itself through its extra-mountain position, at the periphery of the subcarpathians, altitude that gradually decreases from north to south and from north-east to south-west, lithology (Căndesti layers prevail), great development of the inner fluvial

plains, with floodplains and terraces within convergence areas (Mihailescu, 1966).

### Materials and Methods

For establishing low geomorphologic limits, we have generally started from the study of the geomorphologic aspects characterizing contact areas between the piedmont and the plain, in the case of the Getic piedmont, as well as from the comparison of this region with other regions displaying similar features. These features helped us to find the best way GIS may be used in defining the aforementioned limits on the base of lithological, pedological, hydrographical, hypsometrical data, which represent thematic layers on a 20 km wide strip (10 km within the piedmont area and 10 km within the plain area). We chose these dimensions of the aforementioned strip because the altitudinal difference between the plain and piedmont units can no longer be used as a delimitation criterion. Consequently, we analysed the other mentioned aspects in order to establish a more precise delimitation of the two studied units. Moreover, this wide limit is frequently used in the Romanian literature in the field, as there have been registered numerous difficulties in the case of a more precise determination so far.

Thus, the studied geographical unit corresponds to the geological unit of the Getic depression, formed after the sinking of the area located in front of the Carpathians and the penetration of water during the Upper Cretaceous. Its formation is the result of a long evolution of the respective basin. If we study the Dacian deposits, it is easy to notice that almost the entire Getic basin is a shallow one, marked by successive withdrawals and rising of the lake water level. It was a basin characterized by a hydrological and climatic regime that favoured the development of rich vegetation and the formation of many coal horizons. The steady sedimentation regime also lasted in the Levantine, but the coarser sand and gravel deposits indicate the beginning of certain tectonic movements and a change in the activity of the river system. Gradually the movement increased in intensity, as well as the erosion within the Carpathian area, which was subject to rising and great accumulation of materials towards its periphery, within the Getic depression region the subsequent character of which stimulated accumulation (Boengiu and Curcan, 2001).

The end of the Pliocene corresponded with the phase of fragmentation of Gornovița erosion surface, due to the strong denudation of the mountain region. The resulted materials were carried by the river system towards the periphery of the mountains, corresponding to the final sedimentation and emergence of the Getic Piedmont. This relief unit resulted from a complex process of lacustrine, alluvial, and proluvial accumulation, which lasted within certain sectors even after the end of the Upper Villafranchian (Fig. 3). Thus, even if the Getic Piedmont is considered a homogenous unit, it does not mean that its formation and emergence were achieved uniformly. During the Villafranchian, neither the tectonic conditions nor the clogging process of the Getic lake were uniform within the entire area. Consequently, the unit developed in successive stages

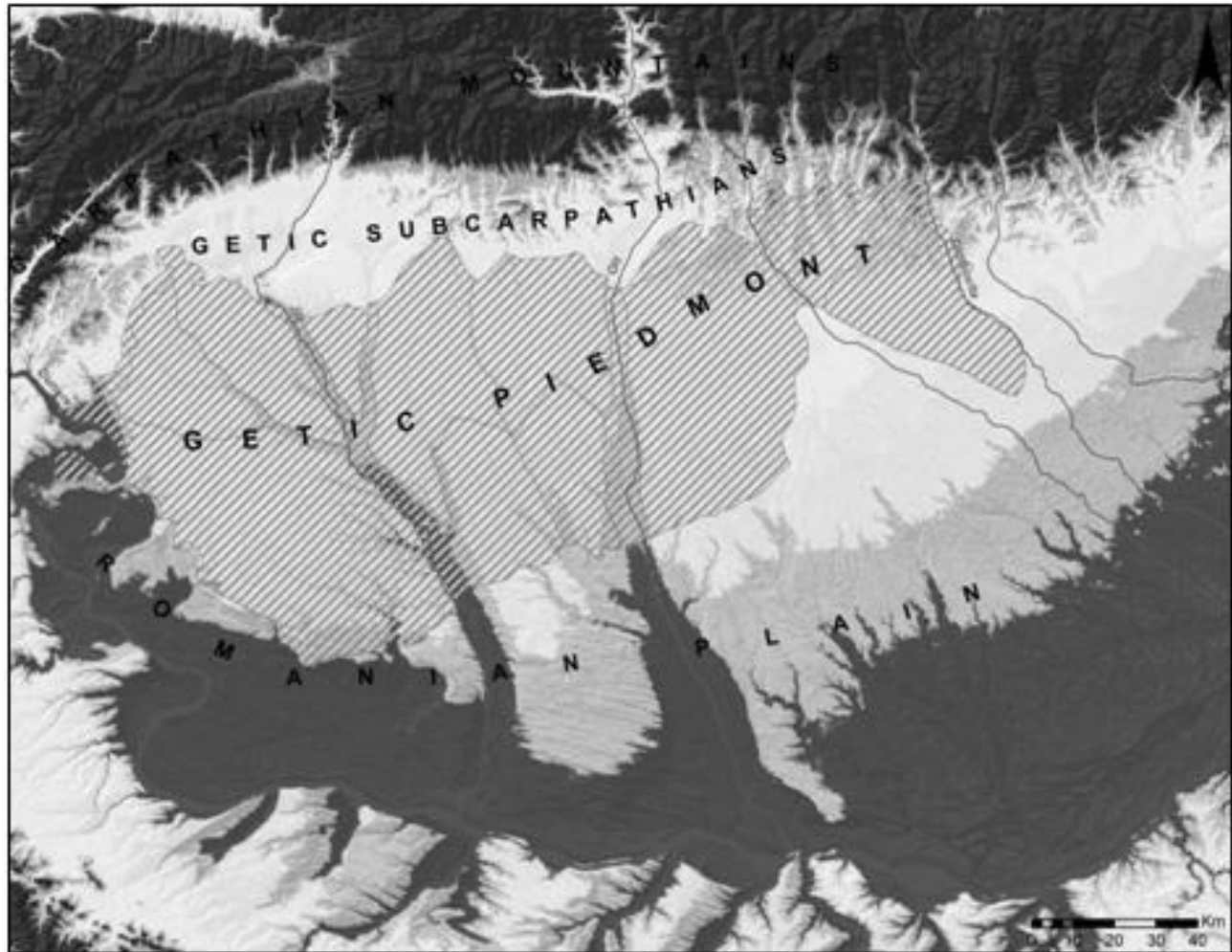


Fig. 1: Geographical location of the Getic Piedmont

and zones, from north-west to south-east, differentiated in their turn in compartments due to the influence of neotectonic movements.

The future morphological evolution of the piedmont that would bring to ever greater differences between the two mentioned relief units – the Getic subcarpathians and Piedmont is induced by their different features – lithology, structure, fragmentation, intensity of present processes. Thus, the prevailing characteristic is the presence of prolonged summits, directed from north to south, resulted from the fragmentation of the initial piedmont surface by the almost parallel river system, which had also contributed to the formation of the piedmont cover, but during other phase and at another level. The remaining parts of the initial surface are narrow in the north, but they gradually enlarge southwards and remain partially undisturbed by further modelling. At the southern periphery of the piedmont, the surface becomes so smooth that it was considered a high plain, the passage towards the proper plain unit being hard to notice on certain sectors (between the Jiu and the Arges river); however, in other sectors, it is marked by erosion escarpments (between the Danube and the Jiu rivers or east of the Arges river).

Lithology (sands, argillaceous sands, marls, gravels) favoured the rapid evolution of slopes and the starting of geomorphologic processes the intensity and frequency of which decreased as the interfluvies got larger and lower. If lithology was highly favourable to denudation processes that occurred in a great variety of forms, it did not allow the maintenance of the shallow aquifers. Certain parts of the Getic Piedmont (Cotmena, Căndeati, and Oltes Piedmonts) are well known for the lack of small depth aquifers and for numerous difficulties fresh water supply has to deal with (Boengiu and Enache, 2002).

It is well known that the entire area located in front of the Carpathians was characterized by great mobility during Quaternary period, which was a direct consequence of high intensity and varied tectonic activity. The Getic sedimentary area was subjected to general rising movement, which was proven by accelerated erosion, appearance of structures, and destruction of the piedmont cover. On the background of this rising, there occurred, regionally or locally, either movements that amplified the general rising, through axial convexities or development of anticlines, or subsidence or





- The 3<sup>rd</sup> type is that of the piedmont experiencing the fragmentation stage, where complex landforms mask the contact with the mountain.
- The 4<sup>th</sup> case is that of the regions where contact cannot be established; it is the case of the so-called false piedmonts, where the sedimentation of the lower basins, sometimes isolated one from another, replaces the piedmont.

We retain the four cases of the limit between the piedmont and foot of the mountains specific for the areas where sediments did not undergo a folding process as it is the case of Pre-Alps or Subcarpathians. In case there is interposed a folded area, the delimitation would go along the alignment where structure differences are noticed.

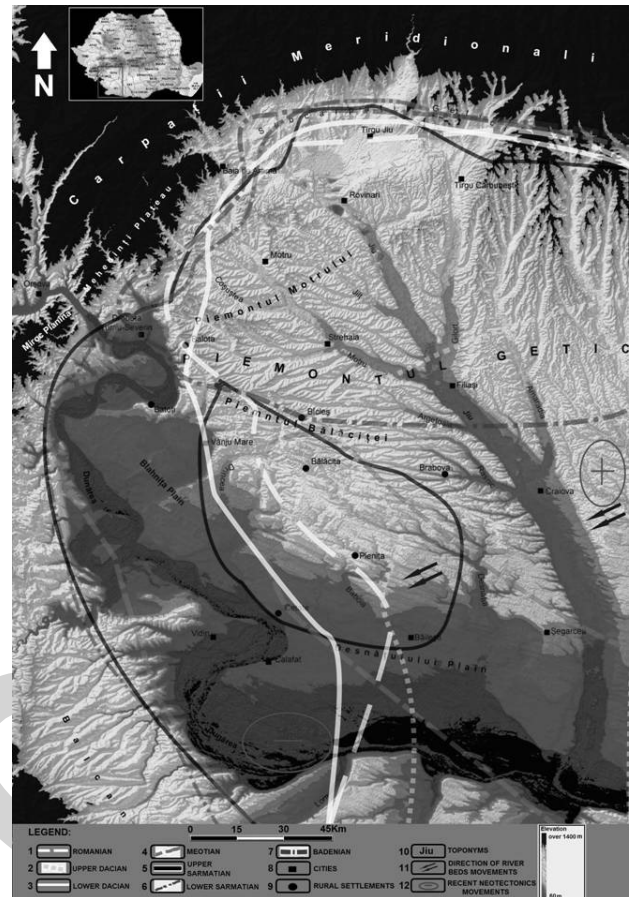
Coming back to the limit between piedmont and plain, we also mention the case of Ganga plain, India, which is part of the Indo-Gangetic foreland. It is considered that the Piedmont surface formed during the Late Pleistocene - Holocene (Shukla and Bora, 2003) and it incorporates sandy areas and beach pebbles disposed in a monocline structure covering a 10-50 km wide surface, in alluviation compartments (Fig. 4). In this case, for establishing the limits, there were used different methods – direction of paleocurrents, drillings, and geomorphologic proofs, but we think the geomorphologic ones are quite obvious as there appears a terrace ( $T_2$ ) along the main collector, which brings a discontinuity that might be considered the piedmont limit. The altitude criterion is also important as well as the chain of lakes that developed within hydrographic convergence areas.

We used the following cartographic products – geological maps at a scale of 1: 50,000 and 1:200,000, pedological maps 1:200,000, topographical maps 1:50,000, hydrographical maps 1:50,000. Thus, we extracted all the information necessary for the delimitation between the plain and the piedmont units. The GIS analysis permitted the loading of quantitative, qualitative and spatial data on thematic layers (Fig. 5 a,b,c) that allowed their correlation in a constructive manner for a better interpretation of the limit. By means of ArcGis 9.3 we could visualize the thematic maps and notice the details that might represent good elements in determining the limits between low geomorphologic units. By using the created layers, on the base of the aforementioned criteria, we established the limit as a strip on each different layer. By interpolating all these strips that appear on different layers we reduced the initial distance limit mentioned in literature in the field oscillated before.

### Results and Discussion

Through GIS analysis and interpretation of bibliographical data (Burrough, 1986), as well as of the data obtained during our field observations, especially at the contact between the Oltes and Cotmeana subunits and the plain, there came out the following aspects regarding the studied limits.

The limit with the Oltenia plain, in the south, from Drobeta Turnu-Severin to Radovan is marked by a 100 m high steep



**Fig. 3:** Shore evolution and neotectonic movements in the Western part of the Getic Piedmont (source Boengiu and Avram, 2009)

escarpment between the sedimentary surface of the piedmont and the plain unit (the terraces of the Danube) (Cotet, 1957). In this region, the geomorphologic and lithological difference can be easily followed along a line that is quite visible on the topographical maps, as well as in the field. The situation changes at Radovan eastwards to Slatina because of the altitude difference, which is the essential element that usually separate neighbouring relief units, disappears. The Danube, along the previous sector had a lateral evolution eroding the piedmont material and led to the formation of the terraces which are presently part of the plain, did not have the same development eastwards. The initial surface appears as low piedmont accumulations within the plain; low hills advance along the interfluvies with a reduced altitude difference so that establishing the limit becomes quite difficult.

If to Radovan, as we have already mentioned, the limit is quite visible, eastwards we notice a different situation. Thus, along Radovan – Podari sector, the southern limit is mainly stratigraphic and secondly geomorphologic. The geomorphologic element (escarpment) does no longer impose the dominant feature of the landscape, but it becomes part of the geographical and geological complex by means of which we can explain the southern limit of the piedmont along the Desnăsui – the Olt sector. The limit maintains

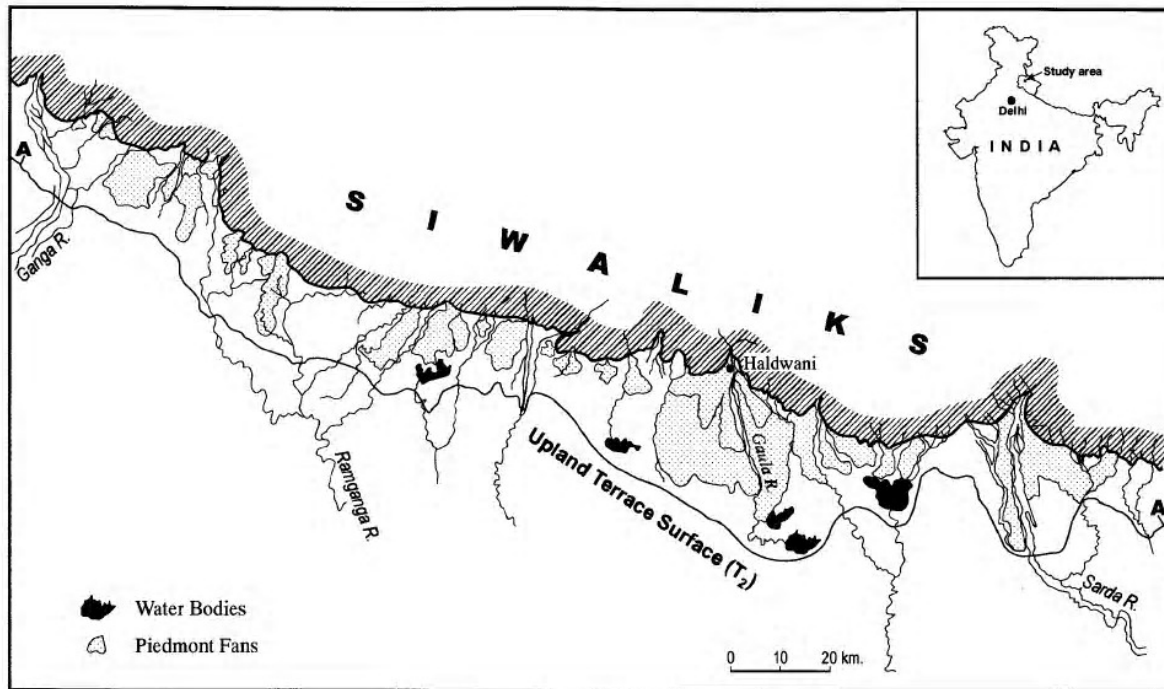


Fig. 4: Location of Ganga plain (source Shukla and Bora, 2003)

along the line of the two contrary deviations, that of the Desnățui river from northwest-southeast to north-south and that of the Oltet river from north-south to northwest-southeast, in the area of Bals. Within the plain region, there appears a new element – the field resulted from the initial surface as its structure and formation manner have nothing in common with the Quaternary Danube. In the sector Desnățui – the Jiu, the northern limit of Danube valley can be noticed on the direction Robul hill – Segarcea – Grănicioara hill, the altitude of which oscillates between 119 and 117 m, while southern limit of the piedmont is considered a conventional alignment that starts at Radovan, passes north of obsequent valley of the Radovan and through Sălcuța – Calopăr – Florica hill and Bucovicioru hill and ends near Podari commune, on the right bank of the Jiu river. When establishing this limit, we took into account the following elements:

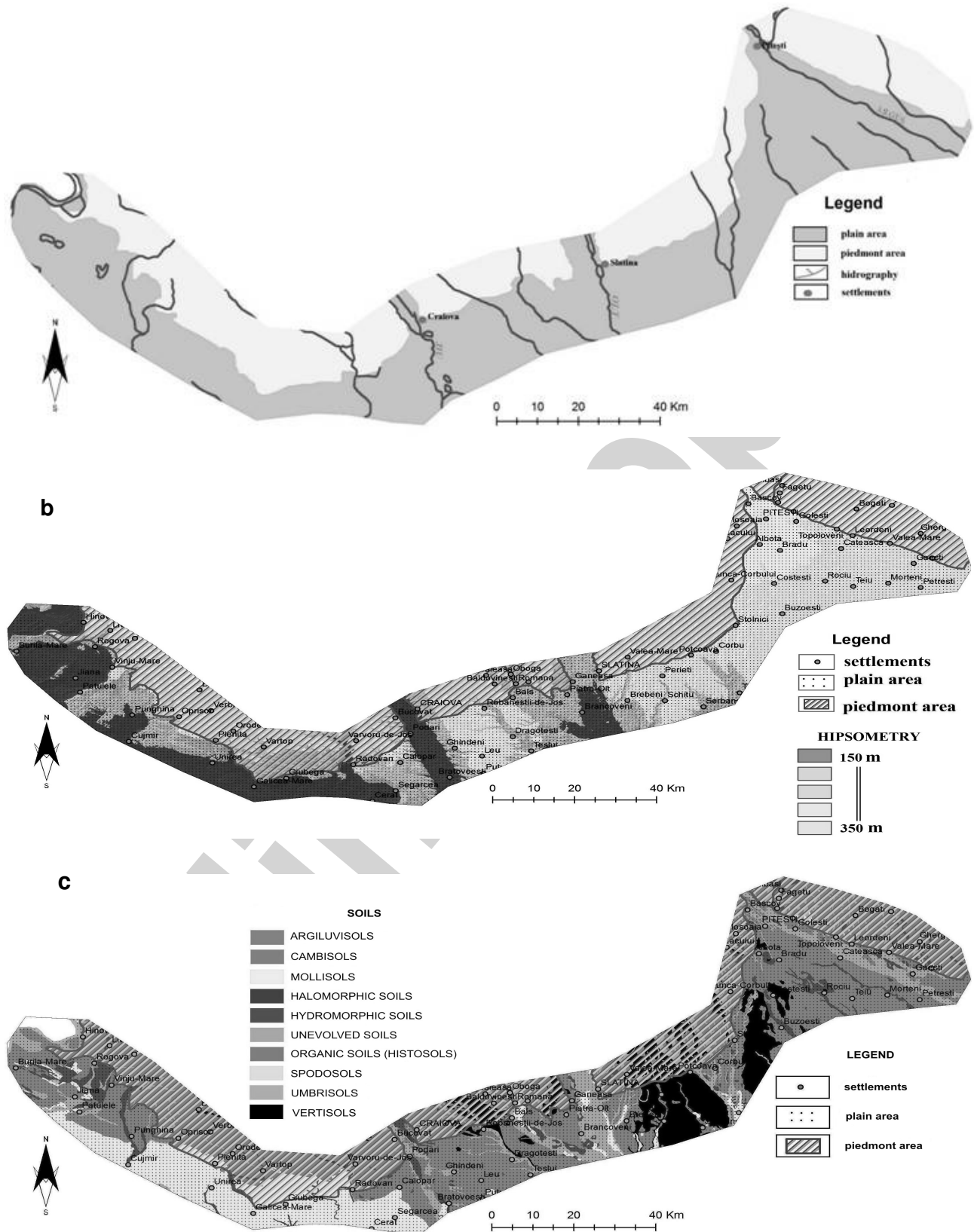
- The Levantine deposits are no longer present at the surface along this alignment.
- The saucers that appears within the perimeter of Sălcuța – Calopăr Piedmont field, disappear north of the above-mentioned limit and here formed a series of lakes that represent one more proof of the Levantine clay presence.
- Within Sălcuța – Calopăr field, the physiognomy of the settlements is the classical one for plain units as localities are not located only along river valleys for ensuring water supply.
- As altitude, the plain between the Desnățui and the Jiu rivers is lower than 160 m, all areas of the altitude which exceeds this value being automatically included in the piedmont region.

The sector Podari – Slatina represents the most difficult area for establishing the southern limit of piedmont. Besides

complexity imposed by the presence of piedmont fields and their penetration as outliers within plain region, the Jiu and the Olt rivers, through their terraces and impact upon geomorphologic processes, modify the geomorphologic features of traditional limit one more time. Taking into account the fluvial plains made up by the aforementioned rivers, we could establish the northern limit at Filiasi and respectively Drăgășani, where they penetrates the piedmont as gulfs. Thus, when establishing the limit along this sector we had to take into consideration the following elements:

- Lithological, as the Levantine deposits disappear on interfluvies.
- Hydrographical, as at the contact between the piedmont and plain, the Teslui river undergoes a modification of flowing direction and, from this point further, it also has terraces on the right; another proof is the convergence of rivers in Bals area.
- Topographical, an altitude difference of about 40 m between Sarul hill and Oltet river.
- Geomorphologic, due to the different drainage density and relief intensity, namely the valleys are denser and deeper within piedmont, while fragmentation is more reduced and less deeper within the plain.
- Physiognomy of settlements, which is linear, along the valleys within the piedmont, while in the plain region, there predominate large human settlement.

Due to complexity of this sector, the limit of piedmont is not just a line, but a 10 km wide strip that goes along the alignment of the settlements of Craiova- Bals - Slatina and the altitude of which varies between 188 and 175 m. Cotmeana platform borders Pitesti plain. The limit of these two neighbouring geographical units is also



**Fig. 5:** Means by which GIS helps the determination of the limit between low morphological units: (a) hydrographical, (b) hypsometrical and (c) pedological maps

difficult to establish because this pre-hilly plain was built as a continuation of Villafranchian piedmont platform on the base of gravels removed from the first. The limit goes along the settlements of Pitesti, Smeura, Cerbu, Lunca Corbului, Optasi, Slatina. Starting from this alignment, interfluvies get larger southwards, relief intensity decreases from more than 200 m to less than 50 m.

Cândești Piedmont displays a clear limit southwards along the Argeș river floodplain of which is 2-3 km wide between Pitesti and Găești. The morphological and landscape contrast can be easily noticed due to almost 150 m altitude difference between the floodplain of river and the piedmont interfluvie. The only area that raises certain problems is the south-eastern one, where the piedmont gets in contact with the fan-like disposed terraces of Dâmbovită river.

GIS utilization for the determination of low geomorphologic limits is useful and it supports the classical analysis of these contact areas. It allows the visualization of thematic layers that enable precise interpretation of changes characterizing the features of relief units. In case the limit is emphasized by noticeable altitude differences, the hypsometrical map or a DTM model allows strict delimitation. This type of contact appears in the area between Drobeta Turnu-Severin and Radovan, where the piedmont surface directly borders the terraces of Danube, as well as that between Cândești Piedmont and Pitesti plain, also characterized by major declivity.

If the altitude difference is not significant, drawing of hydrographical maps (enabling us to notice the points where streams change direction, the presence of lakes), lithological maps (in the case of the Getic Piedmont the limit is rendered by the disappearance of the Levantine horizon southwards), pedological maps (different features of soils according to declivity and parental rock), as well as maps rendering the density, distribution and form of settlements, may represent useful means when it comes to accurately determine the limit.

The limits of Getic Piedmont displays features described in the present paper being characterized by a great complexity on certain sectors. The altitude of plain located south of the piedmont does not exceed 170-180 m, drainage density and relief intensity display higher values north of limit, the valleys from piedmont region are older than the valleys from plain region. In terms of lithology, the plain is entirely made up of Quaternary deposits, mainly represented by sands, fluvial gravels, aeolian deposits and reddish deluvial clays, while the piedmont displays old, Pleistocene or even older deposits.

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