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## **An ‘alphabet’ to describe the spatio-temporal dynamics of settlement systems: a relevant representation of time?**

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### **Abstract:**

This paper presents a work in progress within the ANR project Archaedyn, which concerns the development of an ‘alphabet’ designed to characterize and compare the evolution of the settlement pattern in several French microregions during the Roman period.

The ‘alphabet’ is a composite indicator, built from 3 criteria relating to the quantitative, hierarchical and spatial evolution of the settlement pattern. The different combinations of these criteria form the characters of the ‘alphabet’. The evolution of the settlement system of each microregion between two periods can thus be written as a chain of characters. It is then possible to compare these ‘signatures’ of the different microregions through time.

This indicator has a strong temporal dimension as it is designed in terms of stability/instability with the previous situation. Synthesising the evolutions of the settlement pattern on the long term, it is an efficient tool to identify major types of dynamics.

### **Keywords:**

Settlement dynamics; hierarchy; spatial structure; composite indicator; time formalisation.

### **Introduction:**

Within the Archaedyn project<sup>1</sup>, the workgroup 2 ‘Settlement patterns and territories’ aims to analyse the organisation, intensity and stability of rural settlement from 800 BC to 800 AD in ten microregions of Southern and Central France. The data come from field surveys and only include remains of settlements as defined by the geographer R. Brunet: ‘The settlement (‘l’habitat’) is the grouping and the layout of dwellings in a given space; it can include annexes for livestock and storage, as well as workshops and other buildings for professional use’ (Brunet et al., 1992: 229). Diachronic and interregional comparisons required to use common indicators to describe the settlement patterns in each area. Several indicators were developed to characterise the intensity, hierarchical organisation and spatial structure of the settlement, each of them describing the situation of the settlement pattern in an area at one century (Gandini et al., 2008, Bertoncello et al, 2012a, Bertoncello et al., 2012b). In order to describe the dynamics between these states, three of these individual indicators were used to create a composite indicator resuming the evolution of the settlement patterns in terms of intensity, hierarchical and spatial structures. This paper presents the building of the composite indicator and discusses the time formalisation it induces. It has been applied to four French microregions: the Yonne valley in Burgundy (Yonne), the eastern part of the Languedoc (Hérault, Gard), the Argens valley and Maures massif (Var), and the Préalpes of Grasse (Alpes-Maritimes).

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<sup>1</sup> ‘Spatial dynamics of territories from Neolithic to Middle Ages’: ACI ‘Spaces and Territories’, French Ministry for Research and New Technologies, contract ET28 2005-2008; Program of the French National Agency of Research, contract ANR-08-BLAN-0157-01, 2009-2012, coordinated by F. Favory and L. Nuninger (UMR 6249- USR 3124, Besancon, France).

## 1. The individual indicators:

### 1.1 Quantitative dynamic of the settlement

The dynamics underlying the evolution of the number of settlements through time can be assessed by calculating the rate of pre-existing, created and deserted settlement on the total number of occupied settlements per century in each microregion. For example, in the case of the Languedoc area (fig.1), the curve of the number of occupied settlements peaks on the 1<sup>st</sup> c. AD and on the 4<sup>th</sup> c. AD. Although the number of settlements increases regularly from the 2<sup>nd</sup> c. BC to the 1<sup>st</sup> c. AD, the relative proportions of pre-existing, created and abandoned settlements during this period show a strong instability: at each century, a lot of settlements disappear while new ones are created. On the 4<sup>th</sup> century, the settlements inherited from the 3<sup>rd</sup> century play a more important role in the increase of the number of occupations.

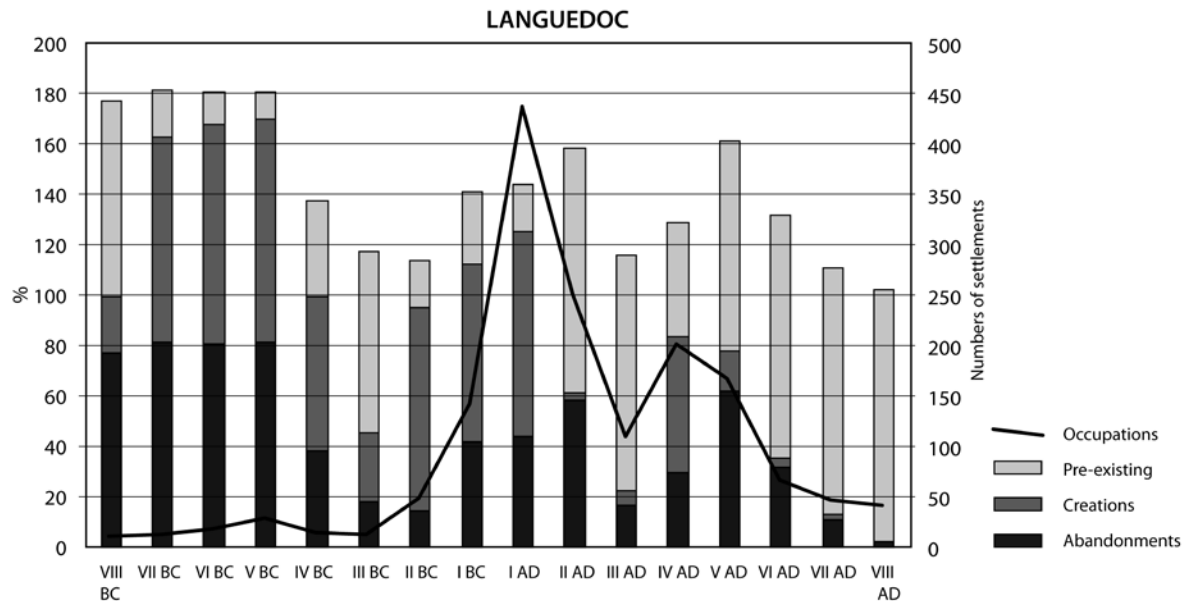


Figure 1: Quantitative indicator of the settlement dynamic in the Languedoc area.

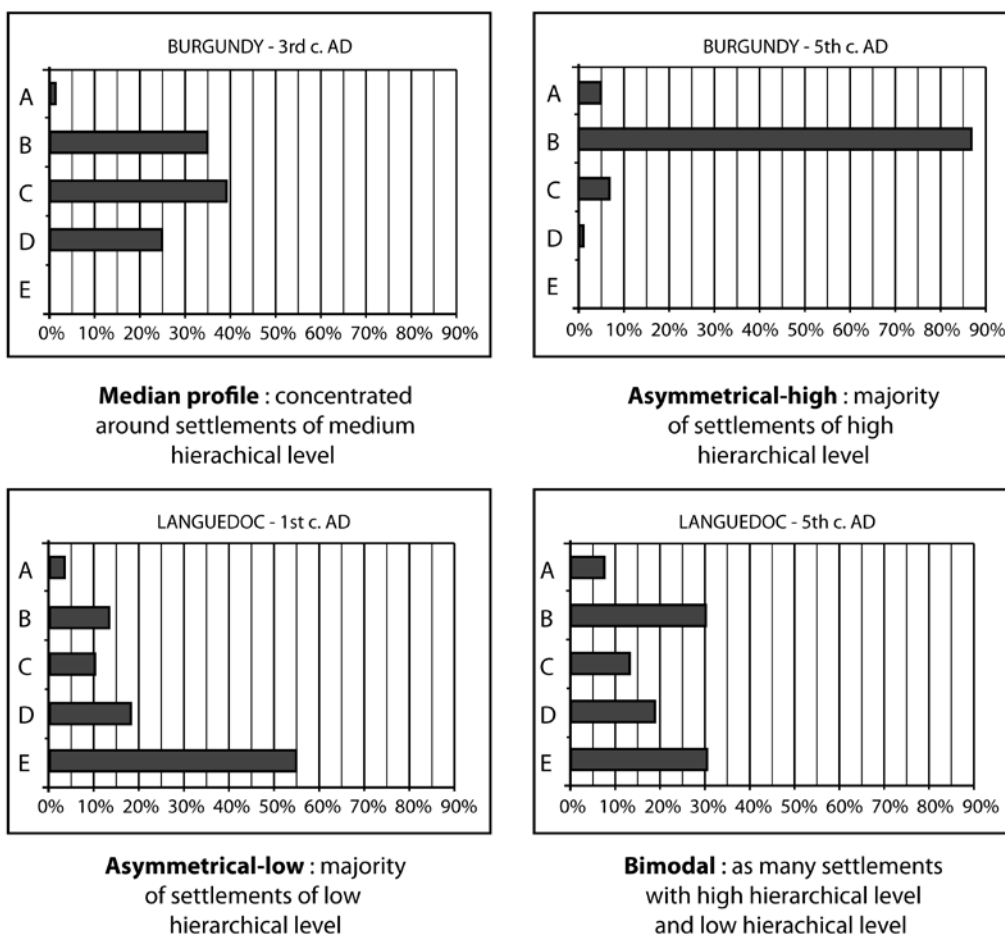
### 1.2 Hierarchical profile of the settlement.

In a systemic approach, the structure and the evolution of the system depend on the interactions between the system's components. In the case of the settlement systems, the relative hierarchical position of the settlements determines the nature of their interactions (Durand-Dastès et al., 1998). We assume that the hierarchical range of the settlements can be inferred from the field survey data (surface area, building materials, duration, function: Gandini et al., 2008). The classification (Factor Analysis and Agglomerative Hierarchical Clustering) of 1491 settlements from the ten microregions according to these four criteria defined five classes of settlements, which we interpreted as five hierarchical levels (tab. 1).

Classes	% of settlements	Surface area	Length of occupation	Building materials	Function	Interpretation
A	4%	> 2 ha or 1 to 2 ha	> 5 centuries	Elaborated (mosaics, marble, sculpted elements) or only stones	political and/or religious and/or symbolic function	High hierarchical level
B	21%	1 to 2 ha or > 2 ha	> 5 centuries	Elaborated (mosaics, marble, sculpted elements) or more ordinary (stones and tiles)	agricultural or craft activity or no known function	↓
C	19%	0,5 to 1 ha	3 to 5 centuries	tiles and/or stones, or more elaborated (tubuli, hypocaust bricks, painted coatings)	agricultural or craft activity or no known function	
D	28%	0,1 to 0,3 ha, or 0,3 to 0,5 ha	1 to 3 centuries	tiles, or tiles and stones	agricultural or craft activity or no known function	
E	27%	< 0,1 ha	< 1 century	tiles and stones or perishable materials or absence of materials	agricultural or craft activity or no known function	Low hierarchical level

Table 1: Hierarchical classification of the settlements.

The distribution of the settlements per class defines the hierarchical profile of each area at each century. The regional histograms show four types of distributions, which correspond to different hierarchical structure of the settlement (fig. 2).

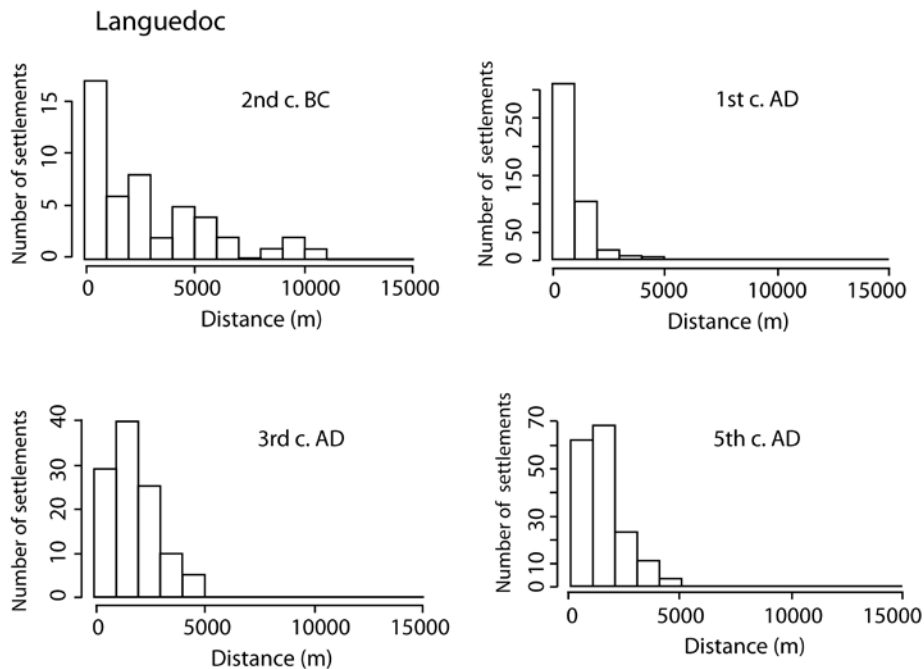


© ANR Archæodyn 2008-2012, archeological data: F. Favory, E. Fovet, P. Nouvel, L. Nuninger, M.-J. Ouriachi, C. Raynaud ; data analysis: F. Bertoncello, H. Mathian et E. Fovet.

Figure 2: The four types of hierarchical profile.

### 1.3 Spatial structure of the settlement.

Several indicators were used to characterise the spatial structure of the settlement. Amongst them, we selected the local spacing to build the composite indicator: in each microregion, the average distance from each settlement to its five nearest neighbours is calculated per century. The resulting histograms show the level of concentration / dispersion of the settlement pattern (fig. 3).



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Figure 3: Local spacing indicator: the example of the Languedoc area.

## 2. Elaboration of a composite indicator.

The individual indicators mentioned above describe the settlement pattern in an area at one century. Thus they refer to a state of the settlement system. These indicators were calculated for four centuries (2<sup>nd</sup> c. BC, 1<sup>st</sup> c. AD, 3<sup>rd</sup> c. AD and 5<sup>th</sup> c. AD), which correspond to key steps in the quantitative evolution of the settlement.

The composite indicator conversely aims to describe the change between these four states: is the settlement pattern stable or instable? What is the significance of the changes?

Two approaches were possible to create the composite indicator: starting from the analysis of the observed regional situations ('data driven') or identifying all the possible theoretical situations ('concept driven'). In this particular case, we combined and went back and forth between these two approaches.

More specifically, the composite indicator results from the combination of the various modalities of the three selected individual indicators: the modalities form the signs of the 'alphabet'. The building of the 'alphabet' had to be parsimonious in order to avoid too many signs. This is why we limited the number of modalities by defining only the main types of evolution for each indicator.

Concerning the quantitative indicator, seven modalities were identified (tab. 2): they result from the combination of three levels of instability (high, medium, low) and of their impact on the number of settlements (increase, decrease or stagnation). The level of instability depends on the rates of deserted settlements during the previous century, of pre-existing settlements that are still occupied during the current century, and of new settlements. For example (tab. 2), a strong rate of desertions during the previous century would lead to a low rate of pre-existing settlements during the century under review. If this is combined to a strong rate of creations during the current century, then it shows a strong

instability of the settlement pattern. However, as creations can balance the desertions, this would not necessarily change the number of settlements. Concerning situations of settlement pattern's stability, we decided to group the three possible quantitative impacts in one modality in order to limit the number of signs.

Rate of created settlements during the current century	Rate of deserted settlements during the previous century	Rate of pre-existing settlements	Number of settlements	Instability			Quantitative dynamic (instability + number of settlements)	Characters
				Low	Medium	High		
high	high	low	stagnation			X	Strong instability =	Fi =
high	medium	medium	increase			X	Strong instability +	Fi +
medium	high	low	decrease			X	Strong instability -	Fi -
medium	medium	medium	stagnation		X		Medium instability =	Im =
high	low	high	increase		X		Medium instability +	Im +
low	high	low	decrease		X		Medium instability -	Im -
low	medium	medium	decrease	X			Stability -	
medium	low	high	increase	X			Stability +	S
low	low	high	stagnation	X			Stability =	

→ **7 characters**

- Fi= Strong instability and stagnation of the number of settlements
- Fi- Strong instability and decrease of the number of settlements
- Fi+ Strong instability and increase of the number of settlements
- Im= Medium instability and stagnation of the number of settlements
- Im- Medium instability and decrease of the number of settlements
- Im+ Medium instability and increase of the number of settlements
- S= Stability and stagnation of the number of settlements
- S- Stability and decrease of the number of settlements
- S+ Stability and increase of the number of settlements

} **S : stability**

Table 2: Modalities of the quantitative indicator.

The evolution of the hierarchical structure is evaluated through the comparison between the hierarchical profiles of the settlement at two different centuries. The sixteen possible combinations of the four types of profile (fig. 2) are interpreted in terms of stagnation, strengthening or reduction of the hierarchy (tab. 3). The profiles of the Burgundy study area (fig. 2) show a reduction of the hierarchy: the settlements distributed between three classes of medium hierarchical level during the 3<sup>rd</sup> c. AD (median type profile), concentrate during the 5<sup>th</sup> c. AD on one class (B), which corresponds to a high hierarchical level (asymmetrical-high profile).

HIERARCHICAL PROFILE - PERIOD 1	HIERARCHICAL PROFILE - PERIOD 2	Period 1	Period 2	TENDENCY TO HIERARCHY	Characters
Asymmetrical profile with a majority of settlements of low hierarchical level	Asymmetrical profile with a majority of settlements of low hierarchical level	Asym-	Asym-	Stagnation	H=
Asymmetrical profile with a majority of settlements of high hierarchical level	Asymmetrical profile with a majority of settlements of high hierarchical level	Asym+	Asym+	Stagnation	
Median profile: concentrated around settlements of medium hierarchical level	Median profile: concentrated around settlements of medium hierarchical level	Med	Med	Stagnation	
Bimodal profile: as many settlements with high hierarchical level and low hierarchical level	Bimodal profile: as many settlements with high hierarchical level and low hierarchical level	Bim	Bim	Stagnation	
Median profile: concentrated around settlements of medium hierarchical level	Asymmetrical profile with a majority of settlements of low hierarchical level	Med	Asym-	Strengthening of the hierarchy	H+
Bimodal profile: as many settlements with high hierarchical level and low hierarchical level	Asymmetrical profile with a majority of settlements of low hierarchical level	Bim	Asym-	Strengthening of the hierarchy	
Median profile: concentrated around settlements of medium hierarchical level	Asymmetrical profile with a majority of settlements of high hierarchical level	Med	Asym+	Reduction of the hierarchy	H-
Bimodal profile: as many settlements with high hierarchical level and low hierarchical level	Asymmetrical profile with a majority of settlements of high hierarchical level	Bim	Asym+	Reduction of the hierarchy	
Median profile: concentrated around settlements of medium hierarchical level	Bimodal profile: as many settlements with high hierarchical level and low hierarchical level	Med	Bim	Strengthening of the hierarchy	H+
Asymmetrical profile with a majority of settlements of low hierarchical level	Median profile: concentrated around settlements of medium hierarchical level	Asym-	Med	Reduction of the hierarchy	H-
Asymmetrical profile with a majority of settlements of high hierarchical level	Median profile: concentrated around settlements of medium hierarchical level	Asym+	Med	Strengthening of the hierarchy	H+
Bimodal profile: as many settlements with high hierarchical level and low hierarchical level	Median profile: concentrated around settlements of medium hierarchical level	Bim	Med	Reduction of the hierarchy	H-
Asymmetrical profile with a majority of settlements of low hierarchical level	Bimodal profile: as many settlements with high hierarchical level and low hierarchical level	Asym-	Bim	Reduction of the hierarchy	
Asymmetrical profile with a majority of settlements of high hierarchical level	Bimodal profile: as many settlements with high hierarchical level and low hierarchical level	Asym+	Bim	Strengthening of the hierarchy	H+
Asymmetrical profile with a majority of settlements of high hierarchical level	Asymmetrical profile with a majority of settlements of low hierarchical level	Asym+	Asym-	Strengthening of the hierarchy	
Asymmetrical profile with a majority of settlements of low hierarchical level	Asymmetrical profile with a majority of settlements of high hierarchical level	Asym-	Asym+	Reduction of the hierarchy	H-

→ { H= : Stability of the hierarchical profile  
H+ : Strengthening of the hierarchy  
H- : Reduction of the hierarchy

Table 3: Modalities of the hierarchical indicator.

Regarding the spatial indicator, the stagnation, increase or decrease of the average distance from each settlement to its five nearest neighbours respectively shows the stability or a tendency to dispersion or concentration of the settlement pattern (tab. 4). For instance, the settlement pattern in the Languedoc area undergoes a strong concentration between the 2<sup>nd</sup> c. BC and the 1<sup>st</sup> c. AD, whereas it disperses slightly during the next period (fig. 3).

Spacing (average distance from each settlement of its five nearest neighbours)	Concentration / dispersion	Instability	Characters
Strong increase	Strong dispersion	X	C-
Moderate increase	Moderate dispersion	X	C-
Small increase	Small dispersion		C=
Strong decrease	Strong concentration	X	C+
Moderate decrease	Moderate concentration	X	C+
Small decrease	Small concentration		C=
Stagnation	Stagnation		C=

→ { C+ : Concentration of the settlement  
C- : Dispersion of the settlement  
C= : stagnation of the spacing

Table 4: Modalities of the spatial indicator.

The addition of the modalities of these three indicators composes a thirteen characters ‘alphabet’ (seven for the quantitative indicator, three for the hierarchy and three for the spatial dynamic). The association of each of the modalities from each of the three indicators produces sixty-three possible combinations or ‘trigrams’. As these ‘trigrams’ integrate the different indicators we retained to describe the settlement’s dynamic, we call them the ‘signatures’ of the evolution of the settlement pattern in each area within a period of three centuries (tab. 5).

For example, the signatures of the areas Argens, Languedoc and Burgundy areas are similar between the 2<sup>nd</sup> c. BC and the 1<sup>st</sup> c. AD: 'Fi+C+H+', which means that the settlement dynamic is characterized by a strong instability with an increase of the number of settlements, leading a more concentrated pattern and a stronger hierarchy. The Préalpes area shows the same evolution except for the hierarchical profile (H=), which does not change between the 2<sup>nd</sup> c. BC and the 1<sup>st</sup> c. AD (tab. 5).

	Quantitative dynamic			Spacing			Hierarchical profile			Signature		
	2BC-1AD	1AD-3AD	3AD-5AD	2BC-1AD	1AD-3AD	3AD-5AD	2BC-1AD	1AD-3AD	3AD-5AD	2BC-1AD	1AD-3AD	3AD-5AD
Argens	Fi+	Im-	Im=	C+	C-	C=	H+	H-	H=	Fi+C+H+	Im-C-H-	Im=C=H=
Languedoc	Fi+	Im-	Im+	C+	C-	C=	H+	H-	H+	Fi+C+H+	Im-C-H-	Im+C+H+
Burgundy	Fi+	S	Im-	C+	C=	C-	H+	H=	H-	Fi+C+H+	SC=H=	Im-C-H-
Préalpes	Fi+	Im-	Im=	C+	C-	C+	H=	H-	H=	Fi+C+H=	Im-C-H-	Im=C+H=

Table 5: 'Signatures' of the four study areas between the 2<sup>nd</sup> c. BC and the 5<sup>th</sup> c. AD.

To make the 'trigrams' more explicit, we translated them into 'ideograms': a sign or a grey scale represents each modality of the indicators. In this new representation, a distinction is made between the number of settlements and the settlements dynamics, defined in terms of stability or instability (fig. 4).

	Stability	Instability	
Number of settlements		 Decrease of the number of settlements	 Increase of the number of settlements
Spacing		 Concentration of the settlement	 Dispersion of the settlement
Hierarchy		 Reduction of the hierarchy	 Strengthening of the hierarchy
Settlement's dynamics		 Medium instability (low rates of created/ deserted settlements)	 Strong instability (high rates of created/ deserted settlements)

Figure 4: Symbol table of the 'ideograms'.

The application of these 'ideograms' to four microregions shows the interest of this representation to visualise the evolution of the settlement pattern in each area through time and to compare the microregional dynamics (fig. 5). At a microregional scale, the variety of the 'ideograms' shows the diversity of the evolutions from one period to another. On an interregional level, the 'ideograms' highlight the singularity of the Burgundy area between the 1<sup>st</sup> and the 3<sup>rd</sup> c. AD: whereas all the areas experience a medium instability characterised by the decrease of the number of occupations, a more dispersed settlement pattern and a reduction of the hierarchy, the situation remains very stable in Burgundy during this period. Indeed this type of evolution is delayed to the next period in Burgundy (3<sup>rd</sup> c. AD – 5<sup>th</sup> c. AD). It is also interesting to note the diversity of the microregional dynamics during this last period, as shown by the wide range of 'ideograms'.



	2nd c. BC - 1st c. AD	1st c. AD - 3rd c. AD	3rd c. AD - 5th c. AD
ARGENS			
LANGUEDOC			
BURGUNDY			
PREALPES			

Figure 5: Representation of the microregional dynamics of the settlement using the 'ideograms'.

### 3. Time formalisation in the 'alphabet' / 'ideograms'

Allowing to go from the description of states to that of the settlement dynamics, the 'alphabet' and the 'ideograms' are two ways of formalising spatio-temporal processes. Both of them include different levels of perception of the dynamics (fig. 6).

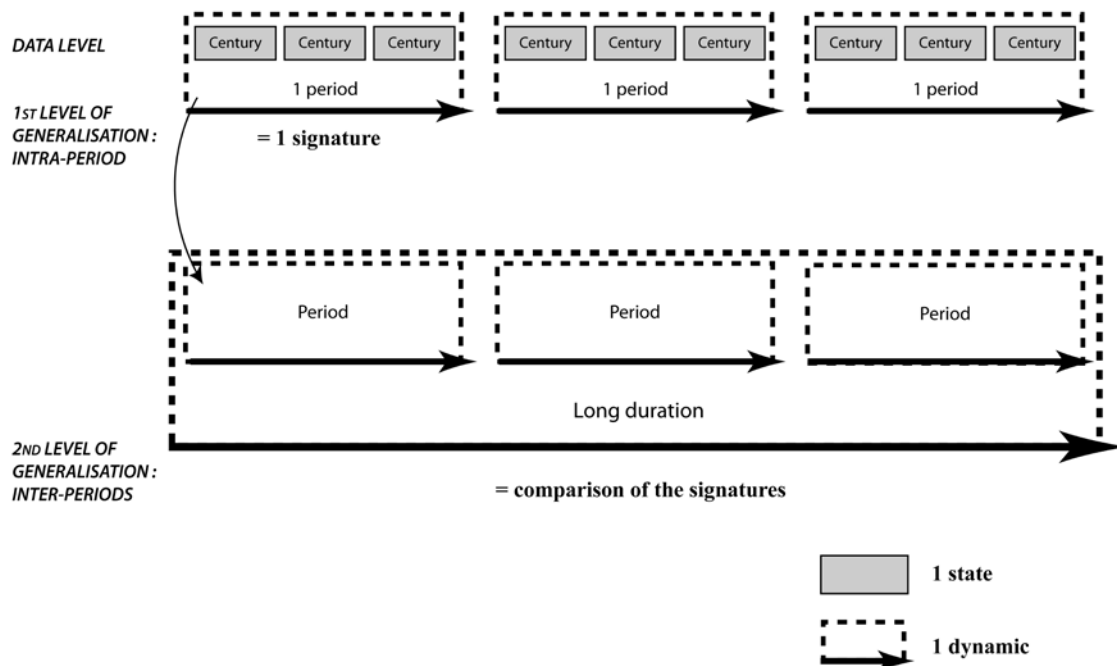


Figure 6: Levels of perception of the dynamics in the 'alphabet' / 'ideograms'.

At the data level (the settlements), the century is the minimum object due to the smallest available chronological resolution of the remains in the various microregions. This time granularity implies to consider each century as one state, fixing the settlement pattern in a stable situation, although it necessarily undergoes transformations during these hundred years. We are aware of the possible impacts of this time discretisation on our perception of the settlement dynamics and it would be interesting to test the robustness of our model by reducing the time granularity when possible.

In our model, the 'ideograms' synthesise the settlement dynamic within a period of three centuries: each microregional signature thus corresponds to a first level of generalisation, i.e. intra-periodic. The comparison of the microregional signatures through time is a second level of generalisation (inter-periodic). At the first level, the dynamic results from the comparison of states (the centuries), whereas it results from the comparison of dynamics (signatures) at the second level (fig. 6). As an example, the settlement dynamic in the Argens area between the 2<sup>nd</sup> c. BC and the 5<sup>th</sup> c. AD can be described as follow (fig. 5): after a phase (2<sup>nd</sup> c. BC – 1<sup>st</sup> c. AD) of intense restructuration of the settlement pattern (strong instability due to high rates of desertions and creations, which leads to an increase of the number of occupations, the concentration of the settlement pattern and the strengthening of the hierarchy), the second period (1<sup>st</sup> c. AD – 3<sup>rd</sup> c. AD) corresponds to a phase of skimming (medium instability characterised by a lot of desertions with very few creations, which leads to a decrease of the number of settlements, a more dispersed pattern and a reduction of the hierarchy towards the higher hierarchical levels). The last period (3<sup>rd</sup> c. AD – 5<sup>th</sup> c. AD) shows the stabilisation of this settlement structure (medium instability due to persisting desertions compensated by some creations, stagnation of the number, spacing and hierarchical range of the settlements).

In such a formalisation, the long duration (i.e. the settlement dynamic during seven centuries) is perceived through the addition of short durations (i.e. three phases of three centuries). This is thus a discontinuous approach, which does not necessarily reflect the possible different temporalities and overlaps of the various phenomena implied in the evolution of the settlement pattern. For instance, the temporality of the process of settlement creation is much shorter than that of hierarchical structuration. Nevertheless, this discontinuity is balanced by the focus put on the dynamics: as each signature is compared to the previous one in order to qualify the change, this formalisation forces to link the different stages of the settlement system.

### **Conclusion:**

The 'alphabet' and the derived 'ideograms' respond to the purpose to describe the spatio-temporal dynamics of the settlement system rather than its successive states. Synthesising various indicators, this tool allows to characterise the dynamics by integrating their multiple components instead of deducing them from the juxtaposed descriptions of the individual indicators. This mode of visualisation of the dynamics greatly facilitates the comparisons through time and space, both at interregional and intraregional scales and in a diachronic or synchronic perspective.

Concerning time, the 'alphabet'/'ideograms' articulate several durations, from the century to the 'canonical' period i.e. the Antiquity (2<sup>nd</sup> c. BC – 5<sup>th</sup> c. AD). The dynamics are first perceived within sequences of three centuries (the 'signatures') but the necessity to articulate and link them to compare the signatures counterbalances this discontinuous approach. Allowing to synthetically represent the evolutions of the settlement pattern on the long term, the 'alphabet' and 'ideograms' appear to be efficient tools to identify generic types of dynamics. It is thus a first step towards the identification of 'stylised facts' of the settlement dynamic (Sanders, 2006: 154).

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