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SOME REFLECTIONS ON GEOBOTANY AND VEGETATION MAPPING

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In honour of my master Oriol de BOLÒS, *who has so greatly contributed to the development of Landscape Science and Vegetation Cartography.*

ABSTRACT

The work of mapping Catalonia's vegetation has led the Geobotany and Vegetation Cartography Group at the University of Barcelona to consider the theoretical interpretation of landscape. This paper synthesizes our approaches and proposals on this subject.

After a brief review of the precedents, the author sets out his ideas on relationships among plant communities and landscape interpretation. Communities linked dynamically and those not belonging to the same potential domain are treated separately. Well-established terms are used when possible, in an attempt to restore their original meaning; but new definitions or terms are also proposed if necessary. Tables 1-4 schematize the concepts put forward in the text. In the last section practical aspects of vegetation mapping are discussed and a shortened example of their result in cartographic legends is provided. Besides the English scientific terms, the corresponding French forms are given in the text. Moreover there is, at the end, a glossary including the equivalent Spanish and Catalan terms.

Key words: landscape analysis, succession, series, complexes, zonation, catena, mosaics, phytocoenose, tessella, geocomplexes, potential vegetation, vegetation maps...

RÉSUMÉ

Quelques reflexions sur la Géobotanique et la cartographie de la végétation

Les travaux de cartographie entrepris ces dernières années par le Groupe de Géobotanique et de Cartographie de la Végétation de l'Université de Barcelone nous ont amené à réfléchir sur l'interprétation théorique du paysage végétal. Ce travail veut offrir une synthèse de nos conceptions et de nos propositions sur ce sujet. Après une brève révision des précédents, l'auteur expose ses idées concernant l'interprétation du paysage et les relations entre diverses communautés végétales. Il considère séparément les groupements végétaux appartenant à une même série de succession et ceux non liés entre eux du point de vue dynamique. Il utilise, autant que

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possible, les termes scientifiques largement établis, tout en tâchant de leur attribuer leur sens original; mais il propose, quand c'est nécessaire, de nouvelles définitions et de nouveaux termes. Les tableaux 1-4 schématisent les concepts commentés dans le texte. La dernière partie du travail présente des aspects pratiques de la cartographie végétale et montre, en utilisant un exemple partiel, comment ils se traduisent dans la légende d'une carte de végétation. Dans le texte il donne, en plus du vocabulaire scientifique anglaise, les termes français correspondants; et tout à la fin, il y a ajouté un glossaire rassemblant aussi les formes espagnoles et catalanes des mots scientifiques les plus importants..

Introduction

This paper, devoted to analysing some theoretical aspects of Geobotany and its practical applications, is an indirect the result of the work on vegetation mapping carried on by the Geobotany and Vegetation Cartography Group of the University of Barcelona. This is the development of the paper presented, as a poster, to the 39 IAVS Symposium (Vegetation Science and Landscape Ecology), held in Lancaster in September 1996.[2]

In recent years, the team has been working on the mapping of Catalonia's vegetation at the scale 1:50,000. The Pyrenean area (c. 8,000 km^2) is the first phase of the project. Understanding and mapping the landscape has led us to grapple with a number of cartographic methods and to reflect on and work out concepts referring to basic landscape science. This paper synthesises our approaches and proposals on these questions.

General questions on vegetation and landscape

Since the beginning of the development of Geobotany, many authors have defined a great many concepts and an even larger terminology. Frequently, translation, semantic misunderstanding or re-definition of terms has led to distorted use of concepts, producing some confusion in scientific communication; in relation to this, see the comments of BOLÒS (1995). The following considerations and schemes set out, though only briefly, our way of understanding vegetation phenomena and states.

Apart from a few older precedents, scientific interpretation of plant landscape did not begin until this century. Some clear concepts referring to plant community distribution and landscape can be found, for example, in BRAUN-BLANQUET (1928) or in DU RIETZ (1930). Since then, assays on vegetation and landscape have greatly increased, so that Landscape Science has become a well defined doctrine. We would like to mention, as one of the first accurate landscape analysts, SCHMITHÜSEN (1959). And, among the south European geobotanists, we believe that O. de BOLÒS holds an outstanding position in this field. This au-

[2] The title of this poster was "Vegetation mapping and landscape analysis"and the authors were, apart from the author of this paper J. CARRERAS, E. CARRILLO, A. FERRÉ, X. FONT, J.M. NINOT & I. SORIANO.

thor first gave his ideas on landscape in his work on the vegetation of the Barcelona region (1962), which were later developed in a methodical and consistent manner in his assay on Botany and Geography (1963). The importance of this work for the establishment of the bases of geographical Botany, remarked long ago by ourselves (VIGO, 1964), has not been more generally recognised until recent years (see for example THEURILLAT, 1992b, ALCARAZ, 1996 or ASENSI, 1996). After this first study, the author reconsidered his proposals (BOLÒS, 1976, 1984a, 1984b), specifying some concepts and redefining several terms.

As a special branch of Landscape Science, we must name Synphytocoenology, mainly developed by GÉHU (1976, 1979,...) and RIVAS-MARTÍNEZ (1976, 1987,...) from the ideas of TÜXEN (1973, 1978, 1979,...); the first two authors have together presented a synthetic approach (GÉHU & RIVAS-MARTÍNEZ, 1981). Inspired by the sigmatist methods for plant community analysis, this doctrine uses similar practices for the study of landscape. It is based on making relevés of association complexes, establishes basic classification units (sigmassociation, sigmetum, synassociation) and proposes a hierarchic typological scheme (not much used to date; see, however, GÉHU 1976, GÉHU & GÉHU-FRANCK 1989,...) and a particular corresponding nomenclature. Some authors (see BOLÒS, 1984b) are sceptical about the appropriateness of such a typological system, and many others (mainly among ecologists), who even find the phytocoenological nomenclature too complicated, are reluctant to accept the proliferation of heavy and probably dispensable names. In accordance with this opinion, we consider that it would be better not to turn to Latinisms, which are difficult to introduce in wide scientific circles, for naming landscape units. THEURILLAT (1992a, 1992b) published a well-documented and exhaustive analysis on the different interpretations of plant landscape and introduced a new scheme which we consider very valuable, although some proposals and nomenclature aspects do not apear to be very appropriate to us. BÉGUIN et al. (1994) basically accept THEURILLAT's analysis, proposing, however, several changes to nomenclature.

The following reflections are essentially based on the ideas of BOLÒS and the above-mentioned approaches of THEURILLAT, taking into account, of course, the opinions and works of other authors. We must remark that our intention is not to present an exhaustive analysis but simply to present basic consistent schemes and to establish the meaning of some terms, according to our own point of view.

We make use of established terminology when possible. However, we have attempted to give back the original meaning to widely used terms, to limit the sense of ambiguous ones and, if necessary, to propose new definitions or to suggest new terms. The need for clear concepts and a good scientific communication requires every word to be used with just one meaning. If new conceptual load is added, this must clarify or enrich it, but never distort or deviate its meaning. It is well-known that both in common and scientific language different interpretations of a word lead to unfortunate misunderstanding and confusion which could easily be avoided by agreement on the meaning of the specific terms.

In some cases we propose formal changes either to adapt the spelling of words to a correct norm or to avoid neologisms constructed without considering derivation rules or the meaning of the original Latin and Greek terms. Nomenclature, although less important than concept, is not secondary.

Besides the English terms, the text and the schemes include (in italics and, when necessary, in brackets) the corresponding French forms. At the end of the text we give a glossary also including the Catalan and Spanish forms of main terms. The terms liable to misunderstanding, newly delimited or newly proposed, are clearly, though briefly, defined.

Relationships among plant communities

Tables 1 and 2 outline the relationships among plant communities, according to our own views, and select or propose the naming of the corresponding phenomena and empirical observations. Abstract concepts (theoretical phenomena) and concrete facts (concrete expressions) have been differentiated. Table 1, which refers to dynamically linked communities, moreover distinguishes between time and space dimensions. Table 2 refers to communities not themselves linked dynamically. We considered it necessary to present these two tables separately in spite of there being some coincidences at least in the formal aspect.

Table 1. Relationships –and their expression– among communities linked dynamically among themselves.
Relations, dans le temps et dans l'espace, –et leur expression– entre des communautés liées entre elles du point de vue dynamique.

	in time	in space
theoretical phenomenon *phénomène théorique*	**Succession** *Succession*	**Arrangement** *Arrangement*
concrete expression *fait concret*	**Series** *Série*	**Complex (eucomplex)** *Complexe (eucomplexe)*

The concepts **succession** and **series** (see table 1) offer little doubts since they are used here with their usual sense in Ecology and Geobotanics. We must stress, however, that the term **series** should be restricted to its original time dimension which it still keeps in Ecology, i.e. to the sequence of communities replacing each other in the same place, the real expression of succession. CLEMENTS (1928; see for example SHIMWELL, 1971) adopted the term sere as the sequence of communities from the parent rock to the climacic vegetation. This term was later used by many authors (DAUBENMIRE, 1968; COLINVAUX, 1986,...), though not always with such a specific sense. The word series has a more generic connotation, so it is used here to refer to any kind of time sequence, with no condition.

In order to generically name (see tables 1 and 2) the placement in space of communities establishing contact we propose the term **arrangement**, little connotated, but neither strange nor unexpressive (to our knowledge there is no equivalent term), and we define it as

layout of plant communities in any geographical area.

Giving a specific sense to common terms is not negative, it is in fact a usual process in scientific language; in this same field, we could name for example community, association, succession, series, ...

The term **complex** (see tables 1 and 2) has been used since long ago and, with no adjective determining its sense, it means an ensemble of plant communities which share a given area.

This was its original sense (DU RIETZ, 1917, see THEURILLAT, 1992b; 1930, "phytocoenose-complexes",...; BRAUN-BLANQUET, 1928, "Gesellschaftskomplexe",...; BRAUN-BLANQUET & PAVILLARD, 1928, "complexes de groupements") and has been kept by most of the authors (TÜXEN, 1956,...; BOLÒS, 1962,...; RIVAS-MARTÍNEZ, 1976, "complejos de comunidades; LEMÉE, 1978; BÉGUIN et al., 1979; etc.). But with this term having such a broad meaning, it can be used in different cases, which often brings the need to add an adjective (or some kind of reference) in order to especify the kind of complex referred to. Thus, there are formation complexes (DU RIETZ, see THEURILLAT, 1992b), zonation complexes (DU RIETZ, 1930), tessellar and pluritessellar complexes (BOLÒS, 1963), climacic complexes (BRAUN-BLANQUET, 1928), composite complexes (ISACHENKO, see ALEKSANDROVA, in WHITTAKER 1973), "complexes within a relatively homogeneous part of the landscape" (SCHWABE, 1989), sigmassociation complexes (TÜXEN, 1977), geosigmetum complexes (GÉHU, 1991), and so on. In landscape description and vegetation cartography, we must distinguish on the one hand complexes formed by communities linked to each other through dynamic relationships (i.e. corresponding to the same series), and on the other hand those formed by communities belonging to different dynamic series; BOLÒS (1962, 1963, 1984) had already made this distinction, naming them tessellar (or unitessellar) complexes and pluritessellar complexes respectively. In order to avoid composite names, we propose to use the terms **eucomplex** (or simply **complex**) for complexes of communities belonging to the same series, and **geocomplex** for complexes with communities corresponding to several dynamic series.

Limiting the term complex to the first case (spatial ensemble of communities belonging to a single series) is not anomalous. Even BRAUN-BLANQUET (1964) used complex with this meaning, when talking for example about the *Querco-Lithospermetum-Bromion* complex of the south-facing slopes of central Europe. And TÜXEN (1979), when defining the sigmetum as a group of associations in space with a single plant potentiality, names a sigmatistic unit corresponding to this particular kind of complex. Also POTT (1996) seems to confer this specific sense to vegetation complexes.

We must remark that south-west European schools have tended to use tessellar complex (eucomplex) and series as synonymous, while they are in fact only correspondent, and this has led to the utilization of series with an inappropriate territorial sense. This was the case of GAUSSEN & REY (1947,...) in vegetation maps, and it is still carried on by French (OZENDA, 1964,...) and Spanish (RIVAS-MARTÍNEZ, 1976,...) schools. This kind of semantic deviations is not rare, even in scientific language, but does not appear to be suitable if one wants to preserve conceptual rigour.

Table 2. Relationships –and their expression– among plant communities not linked themselves dynamically.
Relations –et leur expression– entre des communautés végétales non liées entre elles du point de vue dynamique.

theoretical phenomenon: *phénomène théorique*	**Arrangement** *Arrangement*	**Zonation** *Zonation* **Combination** *Combinaison*
concrete expression: *fait concret*	**Complex (geocomplex)** *Complexe (géocomplexe)*	**Catena** *Catène* **Mosaic** *Mosaïque*

As can be seen in Table 2, and as said before, we also use the term **arrangement** for communities which do not belong to the same series. We do not consider to be necessary to propose two different terms, since the phenomenon is mainly the same. However, in this case, we must distinguish two situations existing inside arrangement: zonation and combination. **Zonation** is understood in the usual way: arrangement of communities (or of vegetation in general) on more or less parallel bands as a result of any given ecological gradient. We use the term **combination** to refer to a non-zonal arrangement, meaning

layout –not random– of plant communities (or vegetation in general) in any geographical area not affected by any dominant ecological gradient.

MUELLER-DOMBOIS & ELLENBERG (1974) give a similar specific sense to the common term combination when they speak about habitat combination. However, ISACHENKO (see ALEKSANDROVA, 1973) uses this term to refer to any kind of complex of communities, both simple and composed.

Zonation and combination, as understood here, are not terms with antagonistic concepts. In fact, in some cases, a combination can also be the result of a net of different ecological gradients.

Geocomplex, catena and mosaic refer to specific cases. The term **catena** (from the latin "catena", chain) was introduced by MILNE in 1936 (see THEURILLAT, 1992a) to designate a regular chaining of soil types, as a result of a zonation phenomenon; and this is the sense always used by ecologists (e.g. DUVIGNEAUD, 1974; COLINVAUX, 1986; FRONTIER & PICHOD-VIALE, 1991) sometimes being extended to vegetation chaining. In order to refer to habitat chaining, conditioning the community catena, some ecologists have used the expression *ecological series*. The term was already used specifically for vegetation by SCHMITHÜSEN (1959) and was later used by BOLÒS (1962,...). It corresponds to the "Zonationskomplexe"of BRAUN-BLANQUET (1964). Due to both its etymology and its original meaning, this term can be defined as

well-arranged ensemble of plant communities (or in general vegetation units) linked among themselves in a geographical area, which is the real expression of a zonation. It can also be called zonation complex.

The original sense of the term has however been deviated to the territorial area. GÉHU & RIVAS-MARTÍNEZ (1981), like other authors (e.g. ALCARAZ, 1996) use the term to mean a group of neighbouring tessellas which constitute the spatial frame of a geosigmetum. THEURILLAT (1992a, 1992b) uses the term mainly to refer to a territorial frame, but he also admits that it corresponds to a "toposequence de la végétation", and makes use of it indistinctly with these two meanings, which brings a troublesome confusion. However, GILLET & GALLANDAT (1996) define catena in its proper sense, mentioning BOLÒS and THEURILLAT as references. And RIVAS-MARTÍNEZ (e.g. 1996) keeps the original definition of catena, but uses the adjective "catenal"when referring to a territory. GÉHU (1991) also uses catenal as synonymous for phytotopographic; an among the examples of "catenal phytosociology"given by him there are typical catenas, compound catenas and mere vegetation transects not corresponding to any zonation phenomenon. We must remark that confusing catenas and transects is a mistake made by many authors.

We believe the term catena should retake its original and unique sense.

When communities are arranged in a space without following a dominant ecological gradient, i.e. when they correspond to what is here called a combination, we use the term **mosaic**. No previous name unambiguously expressing this concept has been found.

The term mosaic has an informal general use, as a common word, and has hardly ever been explicity defined as a scientific term. We propose here to establish its meaning as

any ensemble of plant communities (or in general vegetation units), belonging to different dynamical series, which share a given area.

PFEIFFER (1958) used the expression "Mosaik Komplexe" when referring to complexes determined by the heterogeneity of ecological factors. BRAUN-BLANQUET (1964) unspecifically mentions "*mosaïque de groupements*", but also uses the expression "*groupements en mosaïque*" as opposed to "*groupements en ceinture*" (zonally arranged). RIVAS-MARTÍNEZ (1976) refers to *mosaics of com-*

munities which belong to different synassociations (i.e., complexes). GÉHU and RIVAS-MARTÍNEZ (1981), when defining *geosigmetum*, speak about a *tessellas mosaic*; and BIONDI (1996) refers to mosaics of ecosystems. The concept of these last meanings is nearly identical to that given to mosaic by us, without an adjective. BOLÒS (1962, 1963, 1984b) used the even vaguer expression *communities group* (meaning ensemble of communities non-zonally arranged) with a nearly identical sense. This expression had already been used by VON POST (see PFEIFFER, 1958). BOLÒS (1963, 1984b) used *local mosaic* to name a territorial unit which, according to the examples given, can include both tessellar and pluritessellar ensembles; but he also defines *mosaic* (1976), with no adjective, as "landscape formed by several communities... (or soil types) sharing the territory..., usually not in zones or parallel bands...", a meaning which is very close to the one proposed here. NAVEH & LIEBERMAN (1984) give a similar sense to complex and mosaic when stating that "plant communities representing these three groups (zonal, azonal and extrazonal vegetation) thus form complex mosaics in each landscape".

Landscape interpretation

If we apply this basic network of relationships among communities to landscape interpretation, we need to establish a system to order the different kinds of ecological places and the corresponding vegetation units. This kind of systems had already been constructed –explicitly or implicitly– long ago. Considering the above exposed ideas and taking as basic models those previously proposed by several authors (SCHMITHÜSEN, TÜXEN, GÉHU, RIVAS-MARTÍNEZ,...), and especially BOLÒS (1963) and THEURILLAT (1992a), we have constructed the schemes shown in Tables 3 and 4.

Table 3 specifically considers the actual vegetation, which is the main study point when interpreting landscape and its components. The kinds of habitats are classified in the left column and vegetation units in the other three columns. Of these three columns, the first one establishes the units deriving from simple vegetation analysis and is in fact the basic axis determining or presupposing the rest of the scheme. The other two refer to the typological system mainly based on the sygmatistic method and classification.

We must stress that in this scheme, the only noticeable variation line is, from the top downwards, increasing complexity. At first we do not consider to be appropriate to introduce the territorial dimension as well, as THEURILLAT (1992a, 1992b) and others do. We believe these schemes to be more coherent when made only from two variables. This does not mean that new phytogeographical classification systems can not be devised from the proposals stated here, as this has in fact already been tried by several authors (SCHMITHÜSEN, 1959; BOLÒS, 1963, 1984b; GÉHU & RIVAS-MARTÍNEZ, 1981; RIVAS-MARTÍNEZ, 1987a; THEURILLAT, 1992a, 1992b).

Table 3. Levels and concepts with regard to actual vegetation.
Niveaux et concepts relatifs à la végétation actuelle.

ecological places	vegetation units		
	analytic units	generic systematical units	basic categories
Equihabitat *Equihabitat*	**Synusia** *Synusie*	**Synon** *Synon*	**Union** *Union*
Coenotope (biotope) *Coenotope (biotope)*	**Plant community, Phytocoenose** *Phytocoenose*	**Syntaxon** *Syntaxon*	**Association** *Association*
Tessella *Tessèlle*	**Eucomplex (complex)** *Eucomplexe (Complexe)*	**Sigmataxon** *Sigmataxon*	**Sigmassociation** *Sigmassociation*
Pluritessella *Pluritessèlle*	**Geocomplex** *Géocomplexe*	**Geosigmataxon** *Géosigmataxon*	**Geosigmassociation** *Géosigmassociation*

In relation to the terms used in Table 3, we will start with those referring to the analytical units.

The **synusia** concept does not appear to be disputable now. We can start with the initial definition of GAMS (1918, see SCHIMWELL, 1971) as a "unit composed of species of similar life forms with similar ecological requirements" or with that stated by GILLET & GALLANDAT (1996) as an "elementary one-layered floristically, physiognomically and ecologically homogeneous vegetation unit". Many other authors (CAIN, 1930; DU RIETZ, 1930; BARKMAN, 1973, etc.) give similar interpretations. From these definitions it is possible to see that, as stressed by BRAUN-BLANQUET (1928), synusia can correspond to a unistrate phytocoenose or to one of the strata composing a pluristrate phytocoenose. We must clarify here that we take this term in its proper sense but not in its abstract sense as defended by GAMS and BARKMAN (1973). In relation to this, see THEURILLAT's (1992b) discussion.

To name the kind of habitat corresponding to a synusia we propose the term **equihabitat**. If the synusia corresponds to a unistrata phytocenose, the equihabitat is practically equivalent to the biotope (coenotope). If the synusia is a particular stratum of a phytocenose, the equihabitat is the integral (physical and biotic) environment in which it develops. Some authors (see, for example, FRONTIER & PICHOT-VIALE, 1991) refer to this particular case as *microclimate*, or *microha-*

bitat (BARKMAN, 1973), but we believe that this term has a more diffuse sense, sometimes more generic, and sometimes more restricted.

The term **synon** has a systematic value and was proposed by THEURILLAT & GEISSLER (in THEURILLAT, 1992a) as a generic name referring to any unit within the synusial classification (therefore with a meaning equivalent to taxon in the organism systematics). **Union** corresponds to the basic category in this classification system.

Phytocoenose and the parallel terms **sintaxon** and **association** need no explanation, since here they have their usual sense in Geobotanics and Ecology; phytocoenose, however, being treated as a specific concept. On the other hand, **biotope** has been defined in different ways. In general, it corresponds to the habitat where a biocoenose develops (LEMÉE, 1978; FRONTIER & PICHOT-VIALE, 1991) or to a physical environment coexisting with a biocoenose (MARGALEF, 1974). But it also corresponds to the site where a given plant community grows (WALTER, 1976) or to the "type of sites characterized by specific phytocoenoses of the potential natural vegetation" (KÜCHLER, 1967), and in this latter case it is nearly equivalent to tessella (see below). We would like to take it here to mean the space occupied by a phytocoenose (or a biocoenose, in general), with the corresponding ecological parameters, a sense which has also been given to it in several other cases. However, since this meaning goes beyond the purely ecological sense mainly given to this term, we propose the new term **coenotope** to name both the geographical and the ecological space.

The value given here to the term **eucomplex** (or, simply, **complex**) has been discussed above. It covers

the ensemble of plant communitites belonging to the same succession series which share a given area. It is defined by both the set of plant communities and by the dominant one.

Accepting the restrictive sense that THEURILLAT (1992b) gives to the word site, the corresponding complex would be called in English *site-complex*; but we believe it is not operative to accept this conceptual restriction.

Complexes corresponding to the zonal, extrazonal or zonal vegetation have sometimes been differentiated (in accordance with ELLENBERG; see, for example, WALTER, 1976; NAVEH & LIEBERMAN, 1984). BOLÒS (1984a) names the first ones **normal complexes**, a quite appropriate name; extrazonal complexes could be named **topoclimatic** or **topogenic complexes**, and azonal ones, **edaphic** or **edaphogenic complexes**. In a more general way, complexes mainly conditioned by climatic factors –i.e., normal and topoclimatic complexes– could be named **climatogenic complexes**. RIVAS-MARTÍNEZ (1987a, 1987b, 1996) and GÉHU (1991) use in a less appropriate way the terms *climatophilous* and *edaphophilous* referring to complexes ("series") with a similar sense to that given here as climatogenic and edaphogenic.

Tessella is the term proposed by BOLÒS (1963), and accepted later by many authors, to mean any geographical area ecologically uniform enough to support the same potential community.

It corresponds to either what SCHMITHÜSEN (1959) gives the German name *"Fliese"*, semantically equivalent; although some authors (for instance SCHWABE, 1990) consider it is not completely synonymous. It is also related to the Italian word *"piastrella"* (PIGNATTI, see THEURILLAT, 1992b). Tessella is not unambiguously equivalent to *ecotope*, as BOLÒS (1963) affirmed. This last term initially referred (see SCHMITHÜSEN, 1948, 1959) to a holistic land unit, composed of communities and environment; at other times it has been used "to define niche or niche space as a function of habitat" (COLINVAUX, 1986), and even as synonymous for "Fliese". On the other hand tessella cannot refer unambiguously to site, a word often used as synonymous for habitat, and at other times mean the smallest holistic land unit (NAVEH & LIEBERMAN, 1984); it has even been used as synonymous for tessella as remarked by THEURILLAT (1992b). *Tessera* cannot be equivalent to tessella either, but rather to ecotope in its original holistic sense (see NAVEH & LIEBERMAN, 1984). Although ANSSEAU & GRANDTNER (1990) state that tessera is the English form corresponding to tessella, it is not incoherent to mantain this last spelling; in Geometry and Cartography the form tessellation exists (with ll, not with r) to indicate any repeatable pattern of a regular polygon or polygohedron (see FRASER TAYLOR, 1991). We may add that GÉHU (1991) also refers to tessellas as isopotential areas.

The terms **sigmataxon** and **sigmassociation** –the latter initially adopted by BÉGUIN & HEGG (1975)– are taken here with a sense very close to that given originally by TÜXEN (1977; see also BÉGUIN et al., 1979; GÉHU, 1977, 1979; THEURILLAT, 1992b). They refer to complexes studied and defined by means of sigmatistic methodology. Remember that TÜXEN (1978) used the term *sigmetum* with the same value as sigmassociation. A sigmassociation consists of a complex of associations. The term sygmataxon refers in a generic way to any unit within the syntaxonomical classification.

We must stress that, at least in our view, a sigmassociation must correspond to a space with a unique potentiality, but it does not necessarily occupy a whole tessella; in other words, a tessella can have several sigmassociations, each with a complex of different associations and/or a dominant association.

The term **geocomplex**, last line of table 3, already used by other authors with a similar meaning (see THEURILLAT, 1992b), has already been commented on above. We define this term as

any ensemble of communities (or in general vegetation units) corresponding to different tessellas –i.e. belonging to different successional series– which are related in a given area.

This coincides with the *pluritessellar complex* of BOLÒS (1963), also called *landscape cell* by the same author (1984a, 1984b). A geocomplex corresponds either to a *mosaic*, the most general case, or to a *catena*, all concepts commented on above. The casual identity between geocomplex ("géosigmetum") and catena has already been pointed out by GÉHU (1991). On the other hand, this author stresses that any geocomplex ("géosigmetum" or "géosérie") must be enclosed in a geomorphologically and biogeographically homogeneous space, a valid condition in order to delimit this kind of unit.

BOLÒS (1962, 1963,...) considers that to describe landscape, in middling-latitudes, it is interesting to bear in mind the zonal arrangement of vegetation in a valley east-west orientated, and he names the corresponding vegetation transects as *double catena* or *main catena*. The disadvantage of this latter term is that it suggests a simple zonal arrangement. He also analyzes, in his descriptive works (1962,...), *local catenas* and *groups of associations*, the latter corresponding to what we name here mosaics, as stressed above. The same author (BOLÒS, 1962, 1963, 1984b) proposes to use the adjectives *orogenous* or *orogenic, edaphic* or *edaphogenic*,... to discuss which basic factors determine pluritessellar complexes.

Pluritessella is the name we propose to designate the space corresponding to a geocomplex, and can be defined as

any geographical area (geomorphic unit) supporting diverse ecological conditions, including several tessellas.

Pluritessella is practically equivalent to the "*Fliesengefüge*" of SCHMITHÜSEN (1948). According to THEURILLAT (1992b), it corresponds to the English term *site-pattern*, but this would mean, as mentioned above, taking the site term in a very restrictive sense.

In the sigmatistic classification of geocomplexes, **geosygmataxon** refers to any classification unit; and **geosigmassociation** (equivalent to *geosigmetum*, originally proposed by TÜXEN, 1978) corresponds to the basic category in the system. We take these terms in their general sense (see THEURILLAT, 1992b). A geosigmassociation is formed by associations belonging to different succession series and occupying, therefore, a pluritessella.

On the other hand, we would like to remark that THEURILLAT (1992a, 1992b) proposes a hierarchic classification of geosigmassociations, based on the territorial extension criteria and linking vegetation typology with phytochorological analysis.

In this paper we deliberately leave to one side topics referring to territorial divisions and to phytogeography in the strict sense, which many other authors have considered (see above). We would like to stress, however, that phytogeographical classifications do not strictly imply an increase in complexity in relation to landscape interpreting systems, such as the one shown here, althoug they do extend them, but rather they consist of differentiation levels within areas in a particular hierarchic system. In this field there were also some conceptual deviations and important changes to the interpretation bases. From the original idea that phytogeographical classifications must only be based on distribution of taxonomic units (SCHMITHÜSEN, 1959), several authors have gone on to consider vegetation as well (a criterion which seems logical enough) and even to consider as fundamental some different elements from flora and vegetation cover, such as geomorphology, bioclimate, etc. HUGUET DEL VILLAR (1929) remarked that the distinction of phytogeographical units must have flora and vegetation as bases, not other external characters; and BRAUN-BLANQUET (1964) states that the best natural and real criteria to determine large bioclimatic units and the best method to represent them graphically are, without doubt, the plant communities themselves. TAKHTAJAN (1986) insists that "neither geomorphology and climate nor soil and fauna nor even vegetation can serve as the sole basis for floristic division or classification" although later on remarks: "we should always consider the plant formations of a given area". For this and other aspects of botanical geography, see BOLÒS (1989).

We will also leave to one side the sigmatistic nomenclature usually used for the phytotopographical units to which we have already referred in the general questions on vegetation and landscape. We would like to remark, however, that TÜXEN (1978) proposed distinguishing between *primary* (only formed by natural communities), *secondary* (also including substitution communities), and *terciary* (typical of artificially created environments) sigmatistic units. This distinction can be extended to any kind of complexes.

In order to complete this section on landscape interpretation, we still need to look at potential vegetation. The interest we give to the dynamic aspect in vegetation analysis is explicit enough in the preceding comments. We agree with BOLÒS (1984a) and ASENSI (1996) in that the study of a landscape requires an analysis of relationships between communities, both spatial and temporal.

If we are referring to potential vegetation, the former scheme (table 3) can be simplified as table 4 shows. This table can easily be interpreted by comparing it with table 3 and taking into account the considerations made. The sense given here to **potential vegetation** is the usual one, adding the adjective natural, i.e. stable (permanent) natural vegetation. For a practical conception of climacic vegetation we follow BOLÒS (1962, 1963,...), who defines it as the existing stable vegetation (or which could exist at present) in the areas under normal conditions; this concept mostly coincides with what WALTER (1976) names *zonal vegetation*, i.e. the natural vegetation of *euclimatops*. Climacic vegetation is included, therefore, as a particular case, in potential vegetation; but this one also includes the different permanent communities, linked to stable special environments.

We call **holotessella**

the whole territory (frequently an ensemble of tessellas) which would support the same potential community.

This term is practically equivalent to *potential domain*. In its primary state, it only includes the potential community; in landscapes affected by humans, it will also (even only) include the communities of the corresponding regressive series (see, for example, BOLÒS, 1984a). THEURILLAT (1992b) proposes the name *macrotessella*, which does not appear to be very appropriate to us since it includes a reference to the territorial dimensions, an aspect we believe, as stressed above, not to be essential.

Following BOLÒS (1963, 1984b), we will speak of *climax domain* to designate the territory where a determinated community acts as a climax, i.e. "the area within which tessellas under normal environmental conditions sustain a single climax

Table 4. Levels and concepts with regard to potential vegetation.
Niveaux et concepts relatifs à la végétation potentielle.

ecological places	analytic units	generic systematical units	basic categories
Biotope *Biotope*	**Potential community** *Communauté potentielle*	**Syntaxon** *Syntaxon*	**Potential association (or subass.)** *Association (ou sous-ass.) potentielle*
Holotessella, Potential domain *Holotessèlle, Domaine potential*	**Holocomplex** *Holocomplexe*	**Holosigmataxon** *Holosigmataxon*	**Synassociation (or synsubassoc.) Holosigmassociation** *Synassociation (ou synsousass.), Holosigmassociation*

association (or a single group of localized climax associations)". We must bear in mind that in a given climacic domain, several potential domains can (or usually do) exist.

To designate the ensemble of all the communities possible within a holotessella, i.e. belonging to a particular succession series, we use the term **holocomplex**. This corresponds to the *macrotessellar complex* of THEURILLAT (1992b), suggesting a dimensional component which is not justified.

The name *potential complex*, used by ourselves in some cases, does not appear to be equivalent to holocomplex; it could refer both to the complex (eucomplex) and to the holocomplex, since both unit types are included in a uniform space in relation to potential vegetation. However, the term *climax-complex* has been used in a clear and uniform way to refer to all communities existing in a climacic domain (BRAUN-BLANQUET, 1928; SCHMITHÜSEN, 1959,...).

In the landscape sigmatistic typology, the term **holosygmataxon** (*macrosygmataxon* according to THEURILLAT, 1992b) would correspond to any generic unit within the system; and, through linguistic coherence, the basic category should be named *holosigmassociation* (*macrosigmassociation* according to THEURILLAT's, 1992b, proposal). But because the term **synassociation** (often alternating with sigmetum) has already been widely used in the same sense (RIVAS-MARTÍNEZ, 1976; GÉHU & RIVAS-MARTÍNEZ, 1981), it seems logical to give it preference. A synassociation can be defined, according to these authors, as a

basic potential unit which includes all the plant communities of the same series (and corresponds, in fact, to a holotessella).

Aspects of vegetation mapping

In this last section we comment on the application of the above mentioned vegetation cartography criteria. We must remember, however, that the gestation process of this paper was inverse; i.e., our cartography work and the need to establish coherent and practical critera for vegetation representation has driven us to consider more general theoretical aspects.

Taking into account SANTANACH's (1996) considerations on geological maps, we would like to remark first of all that a map does not only consist in representing the sum of the observations made on the vegetation of a given territory, but is both more and less. It is more because there is an interpretation and a synthesis of data and geobotanical knowledge. It is less because it requires a selection of the accumulated information; in a cartographic document, irrelevant facts must be minimized and the most important elements must be emphasized. A good map must involve an exhaustive collection of data and must show a coherent theoretical interpretation. If not based on numerous direct data, it will be the representation of an idea; if no interpretation has been made, it will become an unexpressive photograph of the landscape (see also BOLÒS, 1962).

We must also take into account that cartography representation methods and the units recognised in a map are mainly dependent upon its scale. We refer here to medium-scale maps (1:25,000, 1:50,000), which are those most usually used by us.

For the application of the theoretical schemes commented on above to medium-scale mapping of vegetation, potential vegetation and actual vegetation should be taken into account.

Potential vegetation, i.e. the potential or climacic domains (the corresponding holotessellas and synassociations), shows the territory's vocation, helps to understand the actual landscape, and is very valuable information when planning actions such as those related to land management.

As pointed out by many authors, in landscapes highly transformed by man, in which there are hardly any remains of final communities, it may be difficult to determine the potential vegetation of a given area. These situations can be shown on a map using some special kind of convention and can be commented on in the expanded legend.

If potential vegetation is known, its cartographic representation offers no problem when dealing with subsimple or complexid units. However, in mosaics and hypermosaics more or less ingenious conventions are needed (see below).

In relation to the **actual vegetation**, at the scales employed, the cartographic units represented can only correspond to three cases: simple communities (when occupying a quite extensive area), complexes (tessellar) and mosaics. Catenas do not need be graphically represented as units. They are either separated by zones or included in more extensive units (mainly mosaics). Accepting this, and considering that in practice we hardly find pure communities or complexes without including some plots of other kinds of vegetation, which cannot be represented, we have established four cartographic units:

N.s. units = nearly simple units (*unités subsimples*): Made up almost entirely by a sole association (or in general by a sole community). In practice they almost always include some plots of other communities (belonging to the same succession series or not) of low cartographic significance or too small to be represented. For example, an extensive stand of a Sub-Alpine pine wood integrating, in addition to the forest, some small patches of heaths, edges and glade communities, verges of nitrophilous vegetation along the paths,...

Complexids (*complexides*): Basically made up of an ensemble of communities belonging to the same complex (i.e. to the same succession series). Each complexid is defined by both the actual set of communities making it up and the dominant community (or communities). It is understood that a complexid may include some non-representative vegetation plots of other succession series, i.e. small tessellas impossible to be represented at the map's scale. For example, an area in the potential domain of Sub-Mediterranean oakwood, formed by dominant box scrubs, spots of mesophilous pastures, some forest patches,... although including some rocky areas (representing another tessella) too small to be considered.

Mosaics, cartographic mosaics (*mosaïques, mosaïques cartographiques*): Basically made up of a low or medium number of communities belonging to several complexes (or series). For example, a mosaic of pastures, some calcicolous and others acidophilous, forming irregular patches showing the different nature of the geological substratum.

Hypermosaics (*hypermosaïques*): Made up of a large number of communities belonging to several complexes. This is the case of very steep slopes where rupicolous vegetation, small scree, pasture spots, scrubwood pieces,... appear entangled. Some highly humanized areas can also often be referred as hypermosaics.

The distinction between mosaics and hypermosaics does not come from theoretical considerations, but from the practical opportunity to distinguish, at least, two levels of diversity in geocomplexes.

We have already mentioned that mosaics and hypermosaics bring problems when potential territories must be delimited, since the spaces corresponding to these units have a higher or lower number of small potential areas which cannot be directly represented. This problem was also remarked by THEURILLAT (1992b) when commenting on what he names *hypogeocomplexes* and *hypogeosigmassociations*. For these two cases of habitat fragmentation RIVAS-MARTÍNEZ (1994) uses the terms *microtessellas, microsigmassociations* and *synassociations fragments*, and he strongly states that it is neither necessary nor interesting to know its potential vegetation.

We adopt two different solutions, according to what is necessary. One is to define potentiality as a mosaic of communities; this is the case for example of many areas of the Alpine belt for which we give a mosaic of pastures as potential vegetation. The other one is graphically to ascribe to them the potential vegetation that would occupy more space; this is the case of many rocky and steep areas defined as hypermosaics and appearing on the map as potential territory of some kind of rocky vegetation. In this manner, the solution is comparable to that of n.s. units, with the only difference that in the latter the potential community is more dominant. With these conventions and with the intention of extending the information on the map's report, we believe that the problem of the graphical representation of potentiality in these cases is solved.

In relation to the way of naming each of these cartographic units, although based on sigmatistic methodology for the study of communities, we try to avoid too complicated names. We prefer, whenever possible, to first use a physiognomical-ecological definition (usually completed by assigning the unit to a more general category of the legend), and then to give in detail the asssociation names (or other syntaxa) which make it up.

For the graphical representation, we always limit each unit in a precise way –eliminating, therefore, the transition zones or the diffused limits– and we use four kinds of semiotical resorts: background colours, patterns, numbers and symbols.

Potential vegetation is represented on the map by means of background colours. We simply define it in the legend with the corresponding plant community name. Actual vegetation units have identification numbers. Subsimple units are indicated, on the apropriate potential vegetation background, with the corresponding number and are defined by the community, unique or absolutely dominant, which constitutes them.

Complexids also have an identification number and are defined, in the simplified legend, by the dominant community, although the other communities present are often indicated, in second place.

Mosaics and hypermosaics, with their own number, are explained when possible by an ecological formula, and in second place, or in any case, as mixtures of the different kinds of vegetation which they include.

BOLÒS's (1962, 1984a) proposal of quantifying the relative extension of each community inside each complex (or mosaic) by means of a four-term scale is efficaceous and interesting; it was used in the map of the Barcelona area (BOLÒS & VIGO, 1962). We do not use it in 1:50,000 maps because it would mean multiplying the number of cartographic units, since those composed units similar in content but different in the proportions of the forming communities should be subdivided.

Apart from colours and numbers, we use –as already mentioned– other graphical means. Forest masses are indicated by symbols, corresponding to the dominant tree species. Patterns are used to distinguish three other physiognomic units: shrublands, pastures, and crops and hay meadows. Very interesting vegetation plots, although not extensive enough to be drawn as well-delimited areas, are sometimes indicated using special symbols (triangles, squares,...).

The combination of graphic elements gives three basic levels of reading to the cartographic document: vegetation physiognomy (forest map), potential domains and actual vegetation. On the other hand, in these last two cases, the definition of cartographic units in the legend includes two approximation levels, one based on the physiognomic and ecological traits of vegetation, and the other explained by means of the corresponding phytocoenological units.

Because our intention is not to make an extensive analysis of these cartographic documents, we guide the interested readers to other publications (BOLÒS et al., 1990; CARRERAS et al., 1991, 1994, 1996; CARRERAS & VIGO, 1994). However, we offer here two pieces of the summarized legend corresponding to the "Mapa de vegetació de Catalunya 1:50.000, Puigcerdà 217 (36-10)"(CARRERAS et al., 1996), which can be useful as an example.

POTENTIAL VEGETATION

- * Montane acidophilous and xerophilous pine forests (*Veronico-Pinetum sylvestris*)
- * Calcicolous and mesophilous Pinus uncinata woods (*Pulsatillo-Pinetum uncinatae*)
- * High mountain vegetation on schistaceous scree (*Senecion leucophylli, Iberidion spathulatae*)

PRESENT VEGETATION

PASTURES OF SUB-MONTANE AND MONTANE BELTS

34. Mesophilous pastures on limestone ground: *Euphrasio-Plantaginetum mediae*
37. Complexid of Montane pastures of winged broom: *Genistello-Agrostidenion* (pastures) + acidophilous scrubs (*Sarothamnion scoparii, Violo-Callunetum*) +...
38. Mosaic of acidophilous pastures (*Genistello-Agrostidenion*), hay meadows (*Arrhenatheretalia*), acidophilous fens (*Caricion fuscae*),...

Glossary

We give here a list of terms in alphabetical order according to the English form, and we indicate their equivalents in French (fr.), Spanish (esp.) and Catalan (cat.).

Arrangement; fr. arrangement; esp. ordenación; cat. arranjament
Association; fr. association; esp. asociación; cat. associació
Biotope; fr. biotope; esp. biótopo; cat. biòtop
Catena; fr. caténe; esp. catena; cat. catena
Climatogenic; fr. climatogénique; esp. climatogénico; cat. climatogènic
Coenotope; fr. coenotope; esp. cenótopo; cenòtop
Combination; fr. combinaison; esp. combinación; cat. combinació
Complex, eucomplex; fr. complexe, eucomplexe; esp. complejo, eucomplejo; cat. complex, eucomplex
Complexid; fr. complexide; esp. compléjida; cat. complèxida
Community group; fr. groupe de communautés; esp. grupo de comunidades; cat. grup de comunitats
Edaphogenic; fr. édaphogénique; esp. edafogénico; cat. edafogènic
Equihabitat; fr. équihabitat; esp. equihábitat; cat. equihàbitat
Eucomplex. See complex

Geocomplex; fr. géocomplexe; esp. geocomplejo; cat. geocomplex
Geosigmassociation; fr. géosigmassociation; esp. geosigmasociación; cat. geosigmassociació
Geosigmataxon; fr. géosigmataxon; esp. geosigmataxon; cat. geosigmatàxon
Holocomplex; fr. holocomplexe; esp. holocomplejo; cat. holocomplex
Holosigmassociation; fr. holosigmassociation; esp. holosigmasociación; cat. holosigmassociació
Holosigmataxon; fr. holosigmataxon; esp. holosigmataxon; cat. holosigmatàxon
Holotessella; fr. holotessèlle; esp. holotesela; cat. holotessel·la
Hypermosaic; fr. hypermosaïque; esp. hipermosaico; cat. hipermosaic
Mosaic; fr. mosaïque; esp. mosaico; cat. mosaic
Normal complex; fr. complexe normal; esp. complejo normal; cat. complex normal
N. s. unit (near simple unit); fr. unité subsimple; esp. unidad subsimple; cat. unitat subsimple
Phytocoenose; fr. phytocoenose; esp. fitocenosis; cat. fitocenosi
Pluritessella; fr. pluritessèlle; esp. pluritesela; cat. pluritessel·la
Potential domain; fr. domaine potentiel; esp. dominio potencial; cat. domini potencial
Series; fr. série; esp. serie; cat. sèrie
Sigmassociation; fr. sigmassociation; esp. sigmasociación; cat. sigmassociació
Sigmataxon; fr. sigmataxon; esp. sigmataxon; cat. sigmatàxon
Succession; fr. succession; esp. sucesión; cat. successió
Synassociation; fr. synassociation; esp. sinasociación; cat. sinassociació
Synon; fr. synon; esp. sinon; cat. sínon
Syntaxon; fr. syntaxon; esp. sintaxon; cat. sintàxon
Synusia; fr. synusie; esp. sinusia; cat. sinúsia
Tessella; fr. tessèlle; esp. tesela; cat. tessel·la
Tessellar complex; fr. complexe tessellaire; esp. complejo teselar; cat. complex tessel·lar
Topoclimatic; fr. topoclimatique; esp. topoclimático; cat. topoclimàtic
Topogenic; fr. topogénique; esp. topogénico; cat. topogènic
Union; fr. union; esp. unión; cat. unió
Zonation; fr. zonation; esp. zonación; cat. zonació

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