

CONSIDERATIONS AND PROPOSALS ON MORPHO-PEDO-LITHOSTRATIGRAPHIC UNITS IN QUATERNARY STUDIES^(*)

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ABSTRACT - *Considerations and proposals on morpho-pedo-lithostratigraphic units in Quaternary studies* - *Il Quaternario*, 2, n. 1, 1989, p. 3-9 - After the analysis of the definition of morpho- and pedo-stratigraphic units as proposed by various authors, some considerations are made about their acceptability and use in studies on Quaternary. In particular, deficiencies in the proposed definitions are emphasized as due to the fact that the conceptual bounds proper of stratigraphy have been overstepped by introducing morphological and pedological elements which are variously external to it. Finally, it is proposed and commented a type of definition which is based upon a strict mutual parallelism and independence of stratigraphy to morphology and pedology.

RIASSUNTO - *Considerazioni e proposte sull'unità morfo-pedo-litostratigrafiche per lo studio del Quaternario*. *Il Quaternario*, 2, n. 1, 1989, p. 3-9 - Dopo aver analizzato le definizioni proposte da vari autori per le unità morfo- e pedo-stratigrafiche, si riportano alcune considerazioni sulla loro accettabilità ed utilizzazione nello studio del Quaternario; in particolare si mette in evidenza alcune carenze derivanti, sostanzialmente, dal fatto che tutte le definizioni proposte hanno, di fatto, forzato in varia misura i limiti concettuali della stratigrafia, tentando di introdurre in essa elementi morfologici e pedologici che le sono in varia misura estranei. Viene infine proposta e commentata una procedura di definizione basata su una stretta parità di rango fra stratigrafia, morfologia e pedologia.

Key-words: Methodology, geomorphology, stratigraphy

Parole chiave: Metodologia, geomorfologia, stratigrafia

1. INTRODUCTION

The application of the usual and coded stratigraphic methods to the study of Quaternary causes problems which are considerably different from those we are faced with in the study of other geological periods.

As Richmond (1959) observed, the difference comes mainly from the possibility of making very fine and subtle distinctions in the stratigraphy of quaternary deposits⁽¹⁾ as a consequence of the facility of defining in detail the genetic features of sediments, and of applying the actualistic criterion. However, unfavourable conditions such as horizontal and vertical variability of facies; presence of identical facies in deposits of different age; general absence of indicative fossils; and presence of frequent stratigraphic discontinuities make the possibility of fine and precise discriminations difficult to realize.

To overcome this difficulty it is necessary to complete bare stratigraphic data with geomorphological

and pedological data, as all those interested in studies on Quaternary know very well. Especially if a cartographic description of the obtained data is required, such operation implies the availability of reference categories into which information extracted from different disciplines can be introduced.

Within this topic, the aim of this article is to point out synthetically the current situation and to make some suggestions.

2. CURRENT SITUATION

The necessity of having particular stratigraphic categories which may be used for the study of Quaternary emerged at the end of the '50s on the occasion of the compilation of the "*Code of Stratigraphical Nomenclature*" edited by the American Commission of Stratigraphical Nomenclature.

At that time, some authors proposed the "pedo-stratigraphic units" and the "morphostratigraphic units". The former units as proposed by Richmond and Frye (1957)⁽²⁾ were accepted and used in the *Code of Stratigraphical Nomenclature* in spite of the objections raised by some authors such as Merrill's comments

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⁽¹⁾ On this regard, it is sufficient to remind how inadequate is the concept of "formation" as given in all stratigraphical codes when Quaternary sequences are studied. In fact, if the definition given in the codes is rigorously applied, it would be impossible to distinguish the different moraines of a single glacial complex from one another, or the various alluvial terraces of a same terraced sequence, in all the cases when the lithology of deposits cannot be differentiated in the field.

⁽²⁾ A "soil stratigraphic unit" is defined in the code as a "a soil with physical features and stratigraphic relations that permit its consistent recognition and mapping as a stratigraphic unit. Soil stratigraphic units are distinct from both rock stratigraphic and pedologic units".

(1958) whose purpose was to demonstrate that the proposed units were not substantially different from the usual "lithostratigraphic units", or Orombelli's opinion (1971) regarding the possibility of defining in an univocal way the lower limit of such units.

The "morphostratigraphic units" as proposed by Frye and Willmann (1962)⁽³⁾ were not accepted in the code mostly because of the objections by Richmond (1962). Essentially, these are based on the fact that a stratigraphic unit is always, by definition, a rocky body tridimensionally-defined; whereas "morphology provides a clue only to surficial extent; it can not serve to define a rock body, for it gives no suggestion as to extent in depth". Thus, the lower limit of a morphostratigraphic unit cannot be defined and, consequently, it is impossible to distinguish a given morphostratigraphic unit from the ones beneath or above it.

More recently and in a more specific context, the resort to "morphostratigraphic units" in the study of continental Quaternary was advanced by Carraro and Ferrarino (1981). These two authors would define with this word a morphological unit corresponding to a "landscape element related to a single modelling agent and episode"⁽⁴⁾. From the definition and its explaining notes, we can infer that the adjective "stratigraphic" as used in the term "morphostratigraphic" by Carraro and Ferrarino (*op.cit.*) has a different meaning from that as used by Frye and Willmann (*op.cit.*). As a matter of fact it does not originate from the idea of adding the term "morphostratigraphic unit" to the already coded stratigraphical nomenclature. Instead, it would reflect the strict analogy between the general evolutionary sequence of morphogenetic processes -- such as developing into subsequent "morphostratigraphic units" -- and that of petrogenetic processes which lithostratigraphic units belong to.

Castiglioni (1982) commented upon Carraro and Ferrarino's attempt that the "proposed enunciations lead to a new definition in stratigraphic terms of concepts which stratigraphy itself cannot include and are clearer if usual geomorphologic nomenclature is applied". Yet, according to Castiglioni, morphostratigraphic maps (as based on the aforesaid units) would not differentiate substantially from "geomorphologic maps with a morphochronologic approach".

Another more recent attempt for more suitable

(3) According to the proposed definition "a morphostratigraphic unit is defined as comprising a body of rock that is identified primarily from the surface form it displays; it may or may not be distinctive lithologically from contiguous units; it may or may not transgress time throughout its extent".

(4) In a still unpublished recent work Carraro gives a new definition of this unit by stating that it is an erosional element corresponding to "a portion of the topographic surface closely associated genetically with a definite modelling episode".

categories to Quaternary studies in the coded stratigraphic system is the introduction of "allostratigraphic unit". This is defined by the *North American Stratigraphic Code* (1983) as a "mappable stratiform body of sedimentary rock that is defined and identified on the basis of its bounding discontinuity". This definition -- which was explained by notes and drawings in the above mentioned code -- shows that the introduction of such units aims at:

- 1) dividing stratigraphically a lithologically homogeneous sedimentary body (i.e., a body belonging to a single lithostratigraphic unit) into units that are limited vertically and/or horizontally by discontinuities (i.e., morphologic surfaces and soil levels)⁽⁵⁾;
- 2) ascribing to the same unit sedimentary bodies which, though geographically separated, can be related to one another on the basis of even not strictly lithological elements⁽⁶⁾

This is particularly interesting because it grants to make allowance also for elements such as erosional surfaces and soil levels in the definition of stratigraphic units. However, it is worth noting that such elements that are often fundamental in a detailed reconstruction of the geological evolution of an area, are considered only as a *discontinuity*, disregarding at all their characterizing function of the allostratigraphic units they delimit. The role these elements play in the classification logic is thus notably reduced such as it is, consequently, in the adherence of the units so defined to the requirements of Quaternary detailed studies⁽⁷⁾.

Although allostratigraphic units represent a progress made from previous stratigraphic codes, they seem not to satisfy at the best what is needed in studying Quaternary. On the other hand, the effort in including them in the stratigraphic code system is probably very near the maximum that the logic constraints on which the system is based may bear.

This fact that is evident, as a paradox, also in the etymology of the used term (allostratigraphic = other than stratigraphic), comes out also from the consideration that the criterion of the strict mutual independence of stratigraphic units of one another (which is one of the basic criteria in all stratigraphic codes) is somehow not

(5) E.g., to distinguish bodies originated by single depositional phases in a gravel sequence sedimented in a lacustrine basin during several sedimentary cycles separated from one another by erosive phases (which may be joined up with the development of soils).

(6) For instance, to distinguish several units, each of them corresponding to the same order of terraces in a set of isolated edges of lithologically homogeneous fluvial terraces.

(7) It may be important to distinguish the areas within a terrace where its summit plain corresponds to an erosional surface or to distinguish several units characterized by various soils within an alluvial cover.

valid for these new units. As a matter of fact, an allostratigraphic unit may correspond either to a multiple or a submultiple part of a lithostratigraphic unit in most cases. This would somehow be the consequence of the fact that the elements used in defining the unit ("delimiting discontinuities" -- i.e., *outside* the sedimentary body) are different -- strictly speaking -- from the other stratigraphic elements ("lithology"; "fauna"; "time"; which all are elements *inside* the sedimentary body).

The reported considerations about morphostratigraphic, pedostratigraphic and allostratigraphic units show clearly the "impasse" one has to face. On one hand it is undoubtedly necessary to refer to more complex entities than those typical of stratigraphy; on the other the new units are not completely satisfactory from the logical point of view and/or from that of their correspondence to the needs of Quaternary studies. This latter is a particularly serious question as the units we tried to define correspond to actual entities of the physical reality and geological jargon; even if not introduced in a nomenclature code system, terms such as "terrace", "moraine" and "alluvial fan" are real geologic entities generally accepted as a combination between lithology and shape.

3. CONSIDERATIONS AND A PROPOSAL

The scarce effectiveness of the stratigraphic-morphological-pedological reference categories so far proposed seems to be due in fact to the attempt to introduce into a code as proposed for a given discipline -- namely, stratigraphy -- elements belonging to other disciplines such as geomorphology and pedology. As a matter of fact, we are trying to mix markedly dishomogeneous characteristics such as "shape" and "pedologic profile" together with elements proper of stratigraphy (e.g., lithology, faunal assemblage, geologic time, etc) by introducing them into a relatively simple and logic system which divides the whole set of "strata" forming the Earth's crust superficial portion into subsets that are homogeneous for independent-of-one another-specific features.

This forcing does not seem caused by logical needs, rather by historical reasons because stratigraphy has always played an important role in the Earth Sciences. Furthermore, the need to take into account morphological and pedological elements emerged clearly when coded stratigraphical nomenclature had already been in use and, eventually, we cannot skip over the fact that, in the common language, the word "stratigraphy" often has a wider meaning than the one of the homony-

mous discipline⁽⁸⁾.

Such considerations led us to face the matter without forcing the conceptual limits of stratigraphy while starting, on the contrary, from the assumption of the total mutual parallelism and independence of stratigraphy, geomorphology and pedology. In this way, the complex units we have to define (stratigraphic-morphological, stratigraphic-pedological, etc) would correspond to superpositions or intersections of simple units, everyone being defined independently of the other within the field of each of the three disciplines⁽⁹⁾.

Obviously the developing of such proceeding in a systematic and complete way requires to have at disposal three separate code systems logically consistent with one another. So far these are not available because there are no coded systems in pedology or geomorphology similar to that for stratigraphy.

This impasse can be got over if we consider that we are not looking at elaborating a complete reference system including the three mentioned disciplines but that our aim is to give a logically acceptable definition of units actually usable in studying Quaternary.

Thus, with keeping this in mind we can proceed in this way:

- a) To individualize the contexts within the geomorphology and pedology fields which are structurally analogous to that covered by the stratigraphic field;
- b) To identify, within the above mentioned contexts, units which can be integrated with a main lithostratigraphic unit (i.e., a "Formation")⁽¹⁰⁾;
- c) To define with appropriate terms the entities resulting from combinations of the units obtained as in item b).

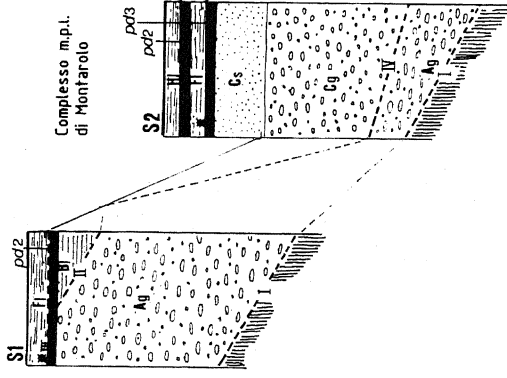
As to item a), it may be assumed that the spotted contexts are represented by *chronologically arranged sequences of forms and soils, both outcropping or buried, present on the surface or beneath it*. Soil and form sequences might be indicated with synthetic terms such as *pedosequence* and *morphosequence*, res-

(8) This extension of the meaning of the term "stratigraphy" is actually present in the word "morphostratigraphy" as it was used by Carraro and Ferrarino (1981).

(9) It is worth noting that this procedure allows the respect of methodological and conceptual specific aspects of the three disciplines from an intimately interdisciplinary viewpoint taking *stratigraphical, morphological* and *pedological* facts as evidence of the same sequence of *geological* events.

(10) Strictly speaking, we should refer more to an "allostratigraphic unit" ("allo-formation") rather than to a "lithostratigraphic unit" as the former is more suitable to be used in Quaternary studies.

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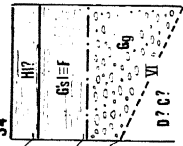


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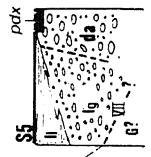
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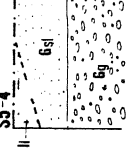
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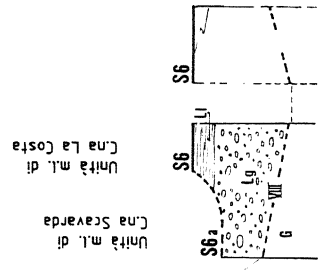
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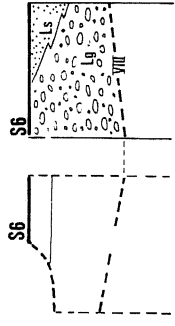
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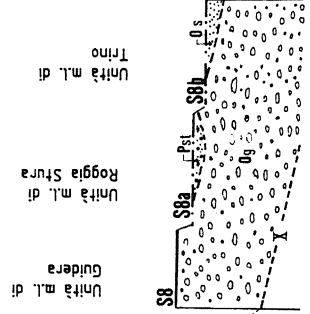
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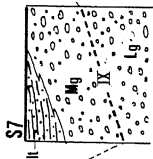
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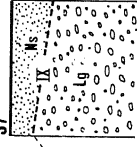
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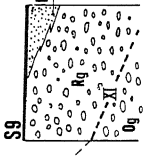
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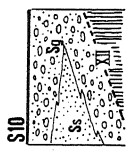


Fig. 1 - Morpho-pedo-lithostratigraphic sections of the terraced sequence of the southern sector of Piedmontese plain (from Bosi et al., in press).

Legend : 1 = accumulation surface, either exposed or buried; 2 = erosional surface, either exposed or buried 3 = surface of mixed or uncertain origin; 4 = name of terraces; 5 = name of the main erosional surfaces; 6 = name of lithostratigraphic unit (A, B) and their prevalent lithological composition (g = gravel; s = sand; l = silt; t = peat); 7 = gravel of Darola; 8 = pre-Quaternary formations; 9 = pedologic units (pd1 = soil of the "ferretto" type; pd2 = buried soil of paleo-dalf type; pd3 = buried soil of haploboroll type; pdx = deeply evolved soil above the gravel of Darola); 10 = Early Palaeolithic findings. (N.B. - m.p.l. = morpho-pedo-lithostratigraphic; m.l. = morpho-lithostratigraphic).

Schemi morfo-pedo-litostigrafici per la successione terrazzata della pianura piemontese occidentale. (da Bosi et al., in stampa)

Legenda: 1 = superficie di accumulo, affiorante o sepolta; 2 = superficie d'erosione, affiorante o sepolta; 3 = superficie di genesi mista o incerta; 4 = denominazione delle superfici terrazzate; 5 = denominazione delle principali superfici d'erosione; 6 = unità pedologiche (pd1 = suolo sepolto tipo "ferretto"; pd2 = suolo sepolto tipo paleodalf; pd3 = suolo sepolto tipo haploboroll; pdx = suolo evoluto sulle ghiaie di Darola); 7 = denominazione delle unità litostigrafiche (A, B ...) e loro litologia prevalente (g = ghiaie; s = sabbie; l = limi; t = torbe), in bianco unità di litologia non conosciuta; 8 = ghiaie di Darola; 9 = formazioni pre-Quaternarie; 10 = reperti del Paleolitico inferiore (N.B. m.p.l. = morfo-pedo-litostigrafico; m.l. = morfo-litostigrafico).

pectively⁽¹¹⁾. The structural analogies between these two sequences and the stratigraphical context (i.e., the strata forming the most superficial portions of the Earth's crust) seem to be sufficient for the attainment of our goal, although we must remember that these analogies are not very strict because of the difference between *chronological sequence* (as to geomorphology and pedology) and *spatial sequence* (as to lithostratigraphy) at least.

As to item b), it should be sufficient to define the "form" as the fundamental unit of a morphosequence. The "form" is to be considered as "a morphological entity whose origin is the consequence of a single morphogenetic event"⁽¹²⁾. As to the pedosequence, the corresponding unit might be represented by the "soil", as it was defined by Orombelli (1971, p. 271)⁽¹³⁾.

Obviously, there are various ways to realise what is proposed in item c).

Tentatively, the following list of terms can be

(11) To resort to such not fully satisfactory terms is necessary because in both geomorphology and pedology there are not words with a meaning analogous to that of the word "strata" when used in the word "stratigraphy". Moreover, it is also opportune not to utilize terms which can be used with other meanings such as, e.g., "morphochronology" actually referring to "age" which lies outside of the concept of a "chronologically ordered sequence".

(12) This definition sounds rather similar to the one used by Carraro for morphostratigraphic units (see footnote 4).

(13) "Tridimensional material entity formed for chemical, physical and biogenic weathering of pre-existing rocks and sediments, in which a pedological profile can be recognized".

outlined:

- "Morpho-lithostratigraphic unit" = 1 formation + 1 form;
- "Morpho-lithostratigraphic complex" = a sequence of several formations separated from one another or delimited between each other by one or more forms;
- "Morpho-lithostratigraphic set" = set of several morpho-lithostratigraphic units and/or complexes;
- "Pedo-lithostratigraphic unit" = 1 formation + 1 soil;
- "Pedo-lithostratigraphic complex" = sequence of several formations and one or more soils;
- "Pedo-lithostratigraphic set" = set of several pedo-lithostratigraphic units and/or complexes;
- "Pedo-morpho-sequential unit" = 1 form + 1 soil;
- "Pedo-morpho-sequential complex" = sequence of several forms with one or more soils;
- "Pedo-morpho-sequential set" = set of several pedo-morpho-sequential units and/or complexes;
- "Morpho-pedo-lithostratigraphic unit" = 1 formation + 1 form + 1 soil;
- "Morpho-pedo-lithostratigraphic complex" = sequence of several formations separated from one another or delimited between each other by one or more forms with one or more soils;
- "Morpho-pedo-lithostratigraphic set" = set of several morpho-pedo-lithostratigraphic units and/or complexes.

With reference to denomination and meaning of the proposed terms, the following explanations are to be given:

- 1) The prefixes "morpho" and "pedo" used in the words "morpho-lithostratigraphic" and "pedo-lithostratigraphic" must be regarded as abbreviation of "morphosequential" and "pedosequential" (which derive directly from "morphosequenc" and "pedosequenc")⁽¹⁴⁾. They do not come from "morphostratigraphic" and "pedostratigraphic" in that these terms cannot be accepted in the proposed categorial scheme;
- 2) As to the forms associated with formations in units, complexes and sets, either erosional or accumulation forms delimiting above the most superficial formation have also to be taken into account;
- 3) Obviously, the name given to a formation should be respectful of the coded stratigraphical use. A "form" could be defined as an "erosional or accumulation or composite surface of..." followed by a geographical indication. A similar procedure could be adopted for the definition of a "soil", or it could be used a denomination expressing the character of the soil (e.g. soil

(14) It is a simple resource to avoid the awkwardness of these terms.

of fersiallitic type);

- 4) The sets (morpho-lithostratigraphic, pedo-lithostratigraphic, etc) were introduced in the scheme as inclusive categories. They can be useful in the cartographic field when "units" and "complexes", even though were appropriately determinable, cannot be delimited exactly because of the scale or for other reasons.

4. REMARKS ON THE APPLICATION OF THE PROPOSED SCHEME

The proposed classification was used for a study on Quaternary in a part of the Piedmontese plain characterised by the presence of twelve orders of terraces referable to a time interval between the upper part of Early Pleistocene and Present (Bosi et al., in press).

The terraces are formed by more or less complex sequences of lithostratigraphic units (mostly of fluvial origin and of a mainly gravel- or, subordinately, sandy-silty grain-size), erosional or accumulation surfaces and by soils with various characters. The terraces as specified by means of the categories defined in Ch. 3 are shown in Fig. 1 as an example.

The proposed classification proved efficacious for the study because:

- a) it allows a complete description from the stratigraphical, geomorphological and pedological viewpoint of all the observed facts;
- b) it is adaptable enough to include all the available data without losing its logical exactness. This is possible because "unit", "complex", and "set" are structured by the operator himself on the basis of the available data and according to the study requirements;
- c) it makes the mapping much easier. In fact, the necessity to superpose symbols representing various information (stratigraphical, geomorphological and pedological) is overcome by using different colours (or graphical symbols) to show each unit, set, or complex.

Moreover the proposed classification has a quality of general validity which goes beyond the topics we already mentioned. As a matter of fact, it provides us with a solution to one of the main methodological problems in the Quaternary cartography that is particularly felt when flat areas are concerned: namely, the necessity to map both superficial formations and those beneath them whenever these also are of Quaternary age. It would avoid that superficial formations that are in general of exiguous thickness and great extent hide in the map the underlying formations which are often of major importance for the significance of the map itself. Maps such as those proposed in item c) give an immediate solution to this problem because they show

the extent of zones having the same sequence of essential elements (i.e., formations, forms, and soils) instead of representing only the areal distribution of single lithostratigraphic units.

The only objection which can be made against such maps is the terminological one about whether they can still be defined "geological maps". In the writer's opinion this is a mere rethorical question if it is accepted the theory (cfr. footnote 9) seeing Quaternary geology as a practically inseparable combination of stratigraphical, morphological, and pedological events.

5. CONCLUSIVE REMARKS

Such as it was outlined in Ch. 3, the proposed terminology aims specifically at overcoming the difficulties hindering a functionally satisfactory and logically acceptable integration among the categories proper of stratigraphy, morphology and pedology.

However, it is worth noting that the informing principles of the proposed categorial scheme may be applied in wider contexts. For instance, if the parallelism between a stratigraphical sequence and a morphosequence is examined more in detail from the point of view of their possible logical subdivision, a morphosequence could be divided -- such as it has been done in the stratigraphic field -- into units homogeneous for elements of geomorphological interest such as climate, genetic processes, and time. In other words, we could try to single out specific "units" among all the forms present on the surface or in the underground of a definite region (that is, in its morphosequence) which are homogeneous as far as climate, (erosive or sedimentary) genetic mechanisms, and lapse of time are concerned⁽¹⁵⁾. The logical process used for the definition of such units (genetic morphosequential, climatic morphosequential and chrono-morphosequential units) matches that used in stratigraphy to define stratigraphic units (lithostratigraphic, biostratigraphic, and chronostratigraphic units).

As far as chrono-morphosequential units are concerned, it is stimulating to hypothesize that the geological time, besides being defined in stratigraphy by sequences of rocky bodies, can be defined also in geomorphology by using sequences of forms. Yet, on a higher speculative level and always in relation to a geological evaluation of time, it can be said that a

(15) To develop such an operation would obviously be necessary to overcome difficulties connected with re-modelling phenomena by means of detailed analyses and appropriate definitions. As a matter of fact, re-modelling phenomena may make it difficult to attribute a form to a definite genetic mechanism or to a particular climatic period. It is obvious as well that to individualize the 3 subsets would make it inadequate at all the definition of "form" as proposed in Ch. 3.

morpho-pedo-lithostratigraphic complex may have an analogous role to the one played by a continuous sedimentary sequence in chronostratigraphy. In both cases, the considered sequences are the continuous evidence of the time elapsed between the lower and upper limit of each of them.

To accept such analogy would be very significant in Quaternary geology because it would be possible to define reference chronological units not only on the basis of marine sedimentary theoretically continuous sequences but also on the basis of discontinuous sedimentary sequences, which can be found in continental environments.

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