WHAT ROLE FOR GEOMORPHOLOGY IN STUDIES ON QUATERNARY ENVIRONMENTS?

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The question "*What role for geomorphology in studies on Quaternary Environments?"* rises here from the fact that, since several decades, researches on the Quaternary Epoch of the Geological history of our Earth are getting more and more complex because of an increasing diversity of scientific domains involved in what used to be mainly studied -since the 19th century- by Physical Geographers and, more precisely, by Geomorphologists (*Annex 1*).

Today, Quaternary researches are flourishing. They concern specialists of:

- "classic" scientific domains such as Geomorphology, Geology (palaeontology, stratigraphy, tectonics, sedimentology, mineralogy etc.), Climate, History, Biology, Prehistory (archaeology-anthropology), and, increasingly:

- specialists from other domains, working on indicators of the evolution of climate and on its possible impacts and/or relationships with human societies, such as: chemistry, soil sciences, hydrology, vegetation and faunal associations, human geography, genetics, palaeoecology, chemistry, statistics, economy, modelling, etc.

A mirror of this increasing addition of approaches to past environments can be well observed in the titles of scientific journals interested in publishing data and discussions on "Quaternary environments", from specialist journals[1] to more specialized ones[2], or less specialized ones[3]. This profusion/plethora of scientific approaches for the study of the evolution of life and environments on our Earth during the last 2 Million years (Myrs), is producing a creative dialogue in which Geomorphology has a place to occupy (or to keep). This place and the contributions from geomorphologist's works cannot be replaced by those of other sciences.

The following discussion will thus focus on why and how, as well as for which expected results, researches on environments in whatever time slice in Quaternary, do or may need scientific approaches performed and tools used by geomorphologists and physical geographers.

[1] eg. Geomorphology; Progress in Physical Geography; Zeitschrift für Geomorphologie; Quaternary International; Quaternary Science Reviews; Quaternary Research; Earth Sciences Reviews; Earth Surface Processes and Landforms ; Palaeogeography, Palaeoclimatology, Palaeoecology; Earth and Planetary Science Letters; The Holocene; Global and Planetary Change; Catena ; Journal of Geosciences; Terra Nova; Quaternaire; Geoarchaeology… etc.

[2] eg. Quaternary Geochronolology; Sedimentary Geology; Marine Geology; Geophysical Research Letters; Paleoceanography; Naturwissenschaften; Journal of Palaeolimnology Boreas; Journal of Archaeological Science; Review of Palaeobotany and Palynology, Catena; Relief, processus, Géomorphologie; Tübitak Journal of Earth Sciences; etc.

[3] eg. PlusOne; Nature; Science; Journal of the Geological Society of London; American Geological Society Bulletin; Antiquity; Paléorient; Current Anthropopology; Journal of Anthropological Archaeology; World Archaeology; etc.

I –DEFINING QUATERNARY, ENVIRONMENT and GEOMORPHOLOGY WITHIN THE FRAME OF INCREASINGLY INTER-DISCIPLINARY SCIENTIFIC RESEARCHES

The recent development of multi-disciplinary approaches for a better understanding and reconstructions of Quaternary environments has been tremendously rapid. The scientific literature about “Quaternary environments” are today studied and debated by much more disciplines than before the 1970’s. At that time, Quaternary was studied only by scientists working in their own field of research: Geomorphologists, Physical Geography, Archaeologists, Palynologists, Geologists (in Turkey: mainly about tectonics; in France mainly about sediments and palaeontology).

The situation has now changed. Studies involving several scientific domains are increasing in number and scopes, with a burst of subjects attracted by (1) the relationships between environment and climate during the Quaternary and, more strickly (2) the relationships between rapid changes in climate and human societies. Papers about the latter subject have increased exponentially after the publication of Weiss et al., (1993), followed notably by Dalfes et al. (1997). Within this literature, the interpretation of data from “hard sciences” such as geology, chemistry, botany etc. (as well as the purpose of data collection) follows a deterministic trend ascertaining a human history constrained by climatically-driven social behaviors. Because of today’s climate change which humanity has to face urgently, the number of duality-based researches, with climate having a determinist role in the history of increasingly complex human societies (ie since the Chalcolithic), is steadily increasing (eg. among others: Weiss et al., 1993; deMenocal, 2001; Migowski et al. 2006, Weninger et al., 2006; Diamond, 2011; Bar-Matthews and Ayalon, 2012; Kaniewski et al., 2013). However, with some time-delay, nuanced researches introducing more human sciences (archaeology data from the field, social behaviors, economics, anthropology, history, politics etc.) in the debate, are starting to apply new approaches to the subject of climate in human history, evidencing the necessity to abandon the binary view opposing climate and human societies (eg. among others: Geyer, 2001; Wilkinson, 2003; Kuzucuoğlu and Marro, 2007; Rosen, 2007; Kuzucuoğlu, 2002, 2006, 2009, 2012, 2014, 2015; Miroschedji de, 2009; Kuzucuoğlu in Roberts et al., 2011; Berger, 2012; Berger et al., 2016; Lespez et al., 2016 Flohr et al., 2016). The present paper is a contribution to this debate. It aims at demonstrating the necessity of geography- and geomorphology-based approaches in studies of (1) environments inhabited by human societies and of (2) environmental records which are always (more or less, but always) connected with complex geographic contexts triggering a variability of these records with regard on time and space scales.

1 - Defınıng Quaternary

According to the *International Commission on Stratigraphy* (ICS: Cohen et al., 2013), the **Quaternary is a Period** which is the most recent of the three periods of the Cenozoic Era (the other ones being the Paleogene and the Neogene: **Fig. 1**). Within the **Cenozoic Era**, it follows the Neogene Period which ends ca 2.6 Myrs ago. Spanning from 2.588 ± 0.005 Myrs ago to the present, the Quaternary is divided into two epochs:

- the **Pleistocene Epoch** (2.588 Myrs ago to 11.7 kyrs ago[4])
- the **Holocene Epoch** (11.7 kyrs ago to today)[5].

1.1. The geological/palaeontologial definition of the Pleistocene Epoch

The Pleistocene Epoch is divided in three phases:
- the Early Pleistocene, from 2.6 to 0.78 kyrs;
- the Middle Pleistocene, from 0.78 to 0.126 kyrs;
- the Late Pleistocene, from 0.126 kyrs to the start of the Holocene.

This partition is constrained by the evolution of fossils, especially fauna. It is thus logical that the off-on signal between Pliocene (the last Epoch of the Neogene Period) and Pleistocene corresponds to the apparition of ~~one of~~ our oldest ancestors: *Homo habilis* (**Fig. 2**). Before the appearance of the *Homo* gens, the *Australopithecus* lineage had however started during the Pliocene ca 4.2 Myrs ago, producing stone tools ca 3.4 Myr, ie during late Pliocene. If the capacity of producing tools had been the definition of Man, then the Quaternary would have started ca 3.4 Myrs ago. But the Quaternary starts with (1) the *Homo* species who is known to have been capable of producing tools as well as to have a complex social behavior, and with the extinction of a specific fauna signing the end of the last stage of the Pliocene (Villafranchian)

The Holocene is mostly defined on the basis of climate, with its onset coinciding with the start of our interglacial global warming (see below).

1.2. Climate phasing allows an additional definition of the Quaternary Period

Based on German geomorphology researches published between World Wars 1 and 2, four glaciations were defined in the northern Hemisphere. These glaciations (named Würm, Riss, Mindel, Günz by Penck and Brückner, 1901-1909) have long been considered as characterizing the whole Quaternary Period. In this model, each of these glaciations is separated by an interglacial episode during which glaciers have retreated and/or disappeared in the upper parts of valleys in the Alps and similar mountain ranges of the northern Hemisphere (**Fig. 3**). This "relative chronological" system continued to be used when the first radio-chronometric results (^{14}C ages) enabled to date sediments from the youngest Glacial phase ("Würm"). This phase was then attributed to a 40-20 ka time-span. Consequently the following warm phase (the Holocene) could also be dated and interpreted as an interglacial.

Beyond the four glaciations identified in the 1920's in the Alps, and also beyond the ^{14}C dating that started after the 1950's, advances in the study of glacial records in the poles demonstrated, after the 1970's, that the Quaternary Period is characterized by multiple glaciation episodes separated by as many multiple and short interglacial phases. As a result, the Quaternary Epoch is today typically defined by the cyclic growth and decay of continental ice sheets associated with Milankovitch cycles and the associated climate and environmental changes that occurred (**Fig. 4**).

The climatic phases of the Quaternary Epoch are now defined on the basis of a very-well controlled chronology (ie layer counting) and records of temperature proxies (especially the curves of $\delta^{18}O$ measured in shells of foraminifers from marine sediments, and the curves

[4] The date is not certified yet. It varies from 11.7, 11.6, 11.4 or 11.2 kyrs. It is possible that this uncertainty depends on the geographic and climatic conditions attached to the localization of the record concerned.

[5] We will not evoke here the Anthropocene, which is still debated within the ICS. Its definition and/or existence are still debated within this Commission although it is more and more referred to in analyzing stratigraphy of the latest periods (ie highly human-impacted) of the Holocene.

of CO_2 content in gas measured in ice cored in the poles). These proxies are now used all over the world as a base-reference for climate evolution and times of changes during the last 800 kyrs (**Fig. 4**). Noteworthy is to recall that these curves are global scaled.

As a result, the former definition of Quaternary glaciations and interglacial periods, that was based on the study of superficial formations and landforms in a given relief/geographic context, has been replaced by another definition based on global-scaled records provided by analyses of snow and sediment sequences cored in non-continental and extreme contexts.

The "old" approach was thus analyzing changes in environmental dynamics and records on the one hand, and climate on the other hand, on the basis of

* landforms and correlative sediments studied in glacial, lake, river and wetland systems (ie continental systems)

* the responses of these systems to local and regional contexts fixed by physical geography (geology and geomorphology),

* the possibility of highly variable combinations of impacts/responses between the local to regional geographic contexts of sequences and global climate.

This means that the approach applied by physical geographers, geologists and climatologists until the publication of the ice-based global curves illustrating the impacts of the Milankovitch cycles on the Earth's climate during the Quaternary, allowed the study of continental sediment and landform records controlled by their geography and physical environment. For example, changes in glacial extend respond to a combination of changing hydrological and climatic factors, in the context of a given watershed and under the control of local factors (eg. lithology, slope, altitudes, orientation etc.). As a result, **the data obtained on the basis of geomorphological approaches allow the study of the variability of environmental responses introduced by the specificities of space- and time-scales or geography-defined territories**.

While the geography and geomorphology-based approaches have the capacity to produce temperature-controlled as well as humidity-controlled records in continental environmental systems (**Fig. 3**), the "new" definition of Quaternary climate change is based on only one but very well-controlled indicator of climate on the global scale: temperature (**Fig. 4**). The difference in data meanings between such a global approach providing a very good and no environment-related record of one climate component on the one hand, and a local to regional approach studying proxies recording climate AND environment on various scales within continents, must be taken under consideration. In addition, the physical geographic and geomorphologic approaches allow to study multi-component functioning of continental systems which varies with time (eg. a possibly different timing and/or intensity etc.) and space (eg. a possibly different sensitivity and/or connectivity with morphogenic systems) (Kuzucuoğlu, 2009: Kuzucuoglu et al., 2014; Berger, 2016).

1.3. Defining "Environments"

The "s" added to the word "Environment" in this sub-chapter is important, because the object "environment" is anything but "one" (*Annex 2*). Environmental systems result from the addition and interactions of several dynamic components which have also connections with their own environment (ie their surroundings: see *Annex 2*), like within an open box (**Fig. 5**): This complexity has to be taken into account when studying and reconstructing past environments. The main components (in addition to "air/atmospheric circulations/climate")

1.3. 1. Fauna and flora are ***groups of animals and plants living an "ecosystem"*** usually defined by balanced (or disturbed, dysfunctioned) relationships between (1) a physical and chemical system (the biotope) and (2) all the animal, vegetal and cellular species (biocenosis, ie a biological community) living in and from the biotiope and multiplying in it.

1.3. 2. Climate intervenes in environments by the types, causes, processes, circulations of air masses, as well as the physical (eg. temperature, humidity, particulates) and chemical (eg. elements, isotopes,) characteristics of ***air and air masses***. In addition, orbital parameters and oceanic currents are climate-controlling factors.

1.3. 3. Hydrology represents the presence, dynamics, amounts, budget etc. of ***water and sediment*** in all the forms of water (rain/snow, river, lakes, ice). At the surface of the earth, hydrology concerns water at the surface of the earth, in the air, and underground in basement rocks.

1.3. 4. Sediments respond to the ***physical processes acting on the surface of the earth and in connection with its underground***. The sediments aged Quaternary are superficial formations, which are the main objects of study for geomorphologists. The process and context relevant for the study of environment through analyses of sediments are attached to the following fields (1) geology (lithology, stratigraphy, tectonics), (2) physical (grain size, internal structure, facies …), (3) chemical characteristics of soils (weathering, leaching etc.) and ***(4) the interface between the actions of water, soil, rocks and sediments(erosion, accumulation)***. These elements act together for transforming and constructing the environment(s).

1.3. 5. Finally, geography and relief also highly control environments, through ***topography, localization, orientation,*** latitudes/longitudes, altitudes, relief organization, soil, connected landforms etc.

In the list above, the three last components (hydrology, sediments, physical geography) concern directly the processes controlling the dynamics of landforms at the surface of the earth -which are the objects of study by the research field of geomorphology-. They also control the records of environmental data informing about the functioning and the evolution of environmental systems, from past to present, whatever the scales of time and space of these changes. They thus intervene in the resulting environmental proxy-based climatic records.

1.4. Defining Geomorphology

Geomorphology is defined as the study of landforms, that goes together with study of the superficial formations and processes, the actions of which result in shaping the landscapes and landforms we see on the surface of the earth.

With regard to the subject of this paper, which looks at the relationships between geomorphology on the one hand, and environment and climate on the other hand, it is evident that geomorphologic systems rely as much on (1) hydrological systems (ie.water bodies such as rivers, streams, glaciers, lakes and wetlands, drainage areas, etc.), depositional systems (ie flood valleys, glacial valleys, lake deposits, river terraces, archaeological mounds, marshes, sand dunes, volcanic flows and fall-outs, coastal zones, etc.), weathering process (pedogenesis, calcification, karstification, thermal impacts etc.), and morphogenic landforms (slopes, cliffs, river beds, polje bottoms, craters and volcanoes, sea and lake coastal features, karstic wetlands etc.), as on (2) climate systems.

As a result, geomorphology studies, during phases of the Quaternary which have left correlative sediments and landforms recording the evolution of relief, the indicators and the processes setting in relation the climate with the relief, the hydrology and the erosional/depositional systems.

This means that the geomorphological approaches are part of palaeo-environment studies. This means also that approaches using geochemical and biologic proxies in terrestrial environments (eg. pollen, diatoms, charcoals, plant remains, insects, ostracods, seeds, isotopes of oxygen and carbon, elementary composition etc.) gain other scales and understanding of the relationships of these environments with climate if they connect to geomorphological approaches. The example of watersheds, of water drainage areas, of river or lake basins… (ie. whatever name is given to a hydrologic area controlling the dynamics of a marsh, a lake, a river, a slope…) is typical: climatic records can change from one watershed to the neighboring one, because local contexts of the punctual record are different (eg. Marro and Kuzucuoğlu, 2007 ; Kuzucuoğlu, 2007, 2009, 2015; Roberts et al., 2016), and from one part to another part of a lake basin (Kuzucuoğlu 2007; Kuzucuoğlu et al. 2007, 2014).

II – GEOMORPHOLOGY AND PAST ENVIRONMENTS?

1. Why to work on past environments?

The main reason for working on past environments is the fear rising from today's climatic change and its future consequences on our own life, way of life and future of our children and environment[6]. This climate change is occurring undoubtedly in front of our eyes, ears, senses, intelligence. The change is well visible in the increasing number of extreme (ie. unusual) and repetitive climatic (ie. intense, rapid) or climatically-triggered (catastrophes with high damage and death casualties) events. These events are indicative of two main global changes which have been monitored since several decades.

* the economic and demographic transformation of our societies, increasing the pressures on the environment and impacting the climate and environmental equilibrium. These pressures present all kinds of different scales (from local to global) with regard to

- space (all the components and dynamics of environments and of their relationships), and

[6] A few weeks ago in Bonn during the COP 23 (UN Climate Change Conference 2017), tens of the mostly known specialists of the world keep on alarming that causes of today's climate change are increasing, leading to a closed (decadal) future with no way back from issues threatening humankind, also because of the irreversible poisoning and degradation of its environment (including air).

- time (seasonal to yearly or decadal), ie. immediate, accumulated, delayed, reported answering timing.

* the global change affecting the climate on the global scale (**Fig. 6**),. This trend is changing the dynamics of energy accumulation and transfers through our globe, ie is threatening the geography of human societies, their resources, as well as their capacities for technology and development, for territorial organizations and politics a.s.o.

In summary, these changes concern not only human societies as well as the functioning of environments, but also the relationships between these human societies and their environment. A better understanding of these changes, and of the relational model between the elements confronted in the loss (or change) of balance, is thus now proposed to be searched in the study of past phases where a comparative situation could be found, ie in the past of mankind.

Consequently and for purpose of comparing present and past evolutions, increasing researches also concern the relationships between past civilizations that disappeared, moved, or were deeply transformed at times of disequilibrium (including the so-called "collapses") recorded in environmental records or resources, whether these records relate to climate or environmental "resources" (ie. natural, managed, economic, modified by technology, used for religious or political purposes, variously owned, contested etc...

2. State of the art on geomorphological approach to the reconstruction of past environments: three examples out of many others

The number of studies on past environments has been thus exponential since the 1980's. Ever since, geomorphology has been confronted with the necessity to produce accurate scientific contributions for reconstructing past environments and their evolution. But geomorphologists also work, in addition to the time evolution of environments, on the systemic relationships that bind the superficial formations that the discipline studies with other elements of the ecosystems, including human societies when the ecosystems are humanly modified and, overall, the variability of geomorphologic answers to a same climatic stimulus because the sensitivity and the functioning of ecosystems responding to a climate change varies in function of physical conditions fixed by the relief and soil, and controlled by the hydrology (erosion, accumulation) and the sediments available in the system..

From this specificity, geomorphology indeed works on:

* past environments and their dynamics, as well as

* cause-effect relationships between environmental dynamics and human actions on soil, water, vegetation and ecosystem, and

* how these changes can, in turn, influence human actions (in whatever field of action that is concerned by geography, whether physical, human or organizational).

Many examples of this contribution of our field of research can be found in studies about lakes, marshes, river flood valleys, coastal areas, territories of past communities living in tells or cities etc. (**Fig. 7**). For this presentation, three examples have been selected in Turkey:

(1) **The Troia region and Karamenderes downstream valley and delta**, with: how biologic indicators have reconstructed vegetation landscapes and land uses in a palaeogeographic frame produced by detailed geomorphologic researches (Kayan, 2006, 2014; Riehl and Marinova, 2008)

(2) **The connected lake and river landforms and superficial formations in the watershed of Lake Van** where:

a. detailed geomorphological studies,
b. stratigraphy reconstructions,
c. DGPS measurements
d. facies analyses

Allowed to produce a contrasted chronology and lake level variations (out of the area covered by lake water today) (Christol et al., 2010, 2013; Kuzucuoğlu et al., 2010), distinguishing

a. accumulation and erosion terraces,
b. successions of transgression and regression of different magnitudes, magnitudes which also varied in time (and areas concerned by the lake up and down movements,
c. river and bedrock terraces buried by lake series,
d. discontinuities and continuities of erosion and depositional processes and landforms between upstream and downstream parts of rivers, which were inter-related too,
e. deposits fossilizing older surfaces marking a lake retreat phase etc.

Among other results, these works show that

- "environments" reconstructed by pollen (a biologic proxy of various spatial significance, from the local to, more often, several kilometers or tens of kilometers the spot cored) can well be compared chronologically and climatically with the geochemical indicators found in the poles and marine records (Litt et al. 2014 and other authors cited in Randlett et al., 2017; Stokhecke et al., 2017),

but they do not seem to allow

- the reconstruction of major events happening in the area that do not modify the vegetation, such as tectonism, volcanism and rapid changes, or anything related with the water budget of the lake (Mouralis et al., 2010; Schmincke et al., 2014). This latter proxy is an indicator responding directly to the humidity budget and the air temperature variations (precipitation/run-off/evaporation/water losses) (Christol et al., 2010, 2013) on both the sides of the lake and on the mountainous watershed where glaciers, karstic areas and high slopes are.

- morphological studies evidence landforms that testify for major impacts of eruptions and/or lake level changes on the construction and destruction of landforms in the area, which may have had (or may have in the future) tremendous impacts on the functioning of the watersheds of the lake and of its neighbor rivers.

(3) **The Late Glacial and Holocene wetlands in the Bor Plain**, which record responses to climate changes happening out of, or in, the plain in connection with

a. the distance to reliefs,

b. the location of the recording site with regard to the source of humidity and its trajectory, the type of sediments involved, the type of water source(s) involved, the type of sedimentary processes involved (eg. alluvial fan growth, spring, lake etc.).

The results of such a study typically show the importance of the geomorphological context of the palaeoenvironmental record, and the necessity to multiply the records in order to understand the basin-scaled functioning. Basin are indeed composed of joined or isolated ecosystems impacting one another (Kuzucuoğlu et al., 2014; Kuzucuoğlu in Berger et al., 2016).

CONCLUSIONS

The results of the studies evoked above, typically show the importance of the geomorphological context of the palaeoenvironmental record, and the necessity –sometimes- to multiply the records to study in order to catch the whole functioning of a region composed of joined or isolated ecosystems impacting or not on each other.

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FIGURES

I – DEFINITIONS

Figure 1: The Geologic definition of Quaternary

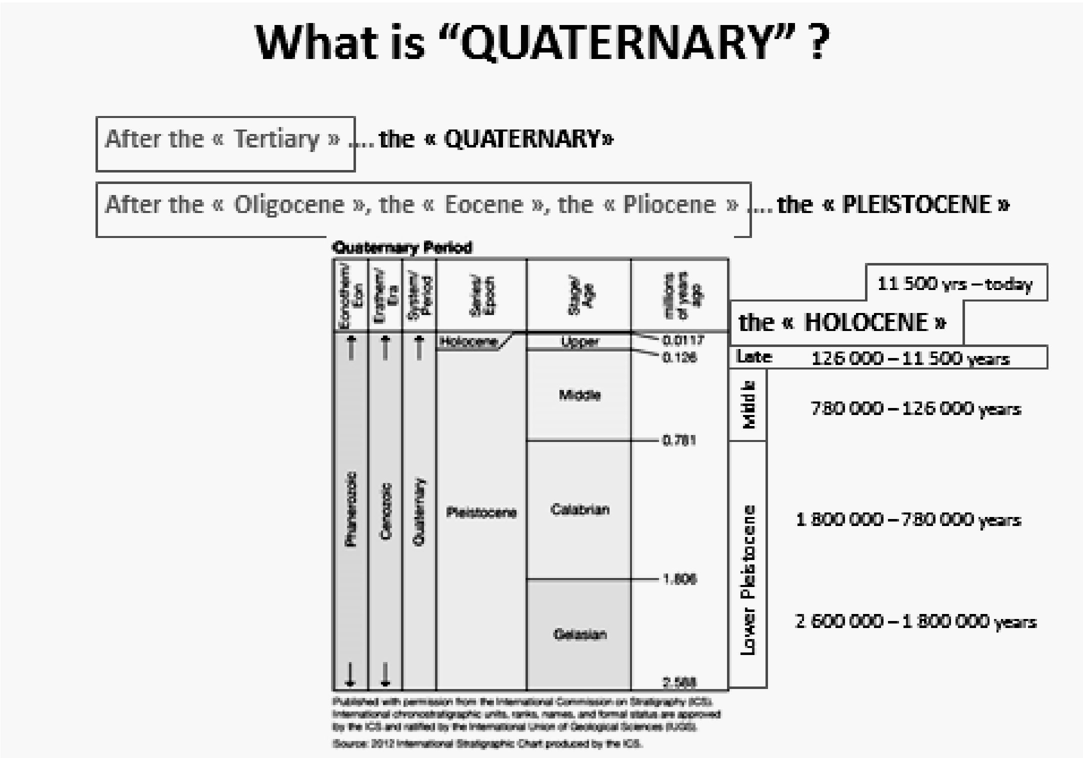


Figure 2: The anthropologic definition of the Quaternary

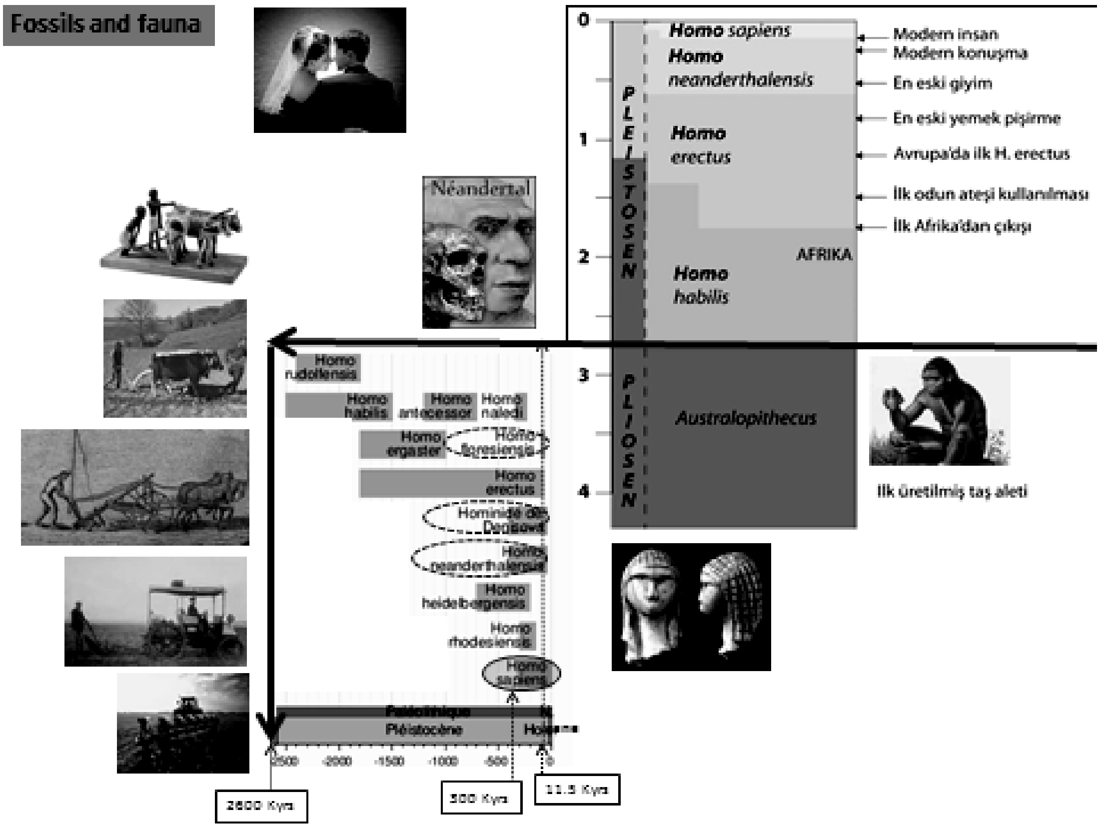


Figure 3: The climatic definition of Quaternary: a succession of Glaciations and Deglaciations.

CLIMATE CHANGE, with successions of GLACIATIONS and DEGLACIATIONS

Old chronology : FOUR Quaternary glaciations identified (relatively) in FOUR regions of the NORTHERN HEMISPHERE

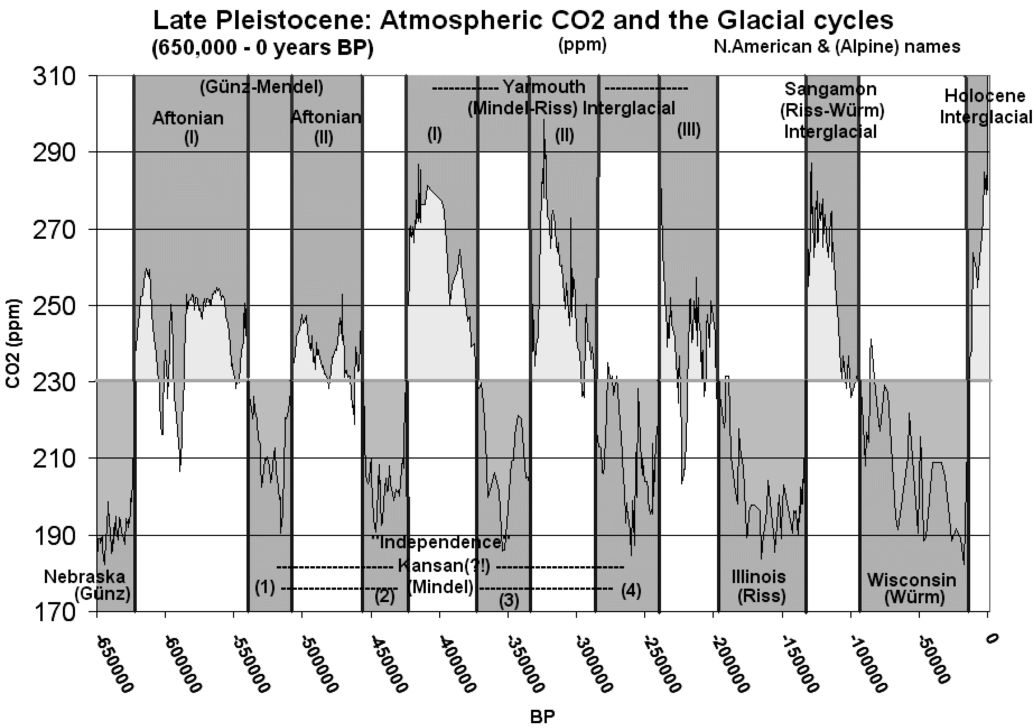
Region	Glaciation 4	Glaciation 3	Glaciation 2	Glaciation 1
Alps	Würm	Riss	Mindel	Günz
Northern Europe	Vistulian	Saalian	Elsterian	Eburonian
Great Britain	Devensian	Wolstonian	Anglian	Beestonian
Midwest (US)	Wisconsian	Ilinoi	Kansas	Nebraska

THREE INTERGLACIALS

Region	Interglacial 3	Interglacial 2	Interglacial 1
Alps	Riss-Würm	Mindel Riss	Mindel-Günz
Northern Europe	Eemian	Holsteinian	Waalian
Great Britain	Ipswichian	Hoxnian	Cromerian
Midwest (US)	Sangomanian	Yarmouthian	Aftonian

Chronology replaced by isotopic chronology of global climate changes

Figure 4: The more recent climatic definition of Quaternary, based on Glacial and Interglacial cycles evidenced by atmospheric CO2 content in air bubbles sampled in ice cores, and on the basis of isotopic records in water, gas, and foraminifers from ice and marine sediment cores



Note: The stage names are part of the North American and the European Alpine subdivisions. The correlation between both subdivisions is tentative.

Note: These curves evidence the correspondence between CO2 concentration and the temperatures of the atmosphere.

Source: *Data modified from ncdc.noaa.gov, drawn by Tomruen*

Figure 5: The components of what we call "Environment"

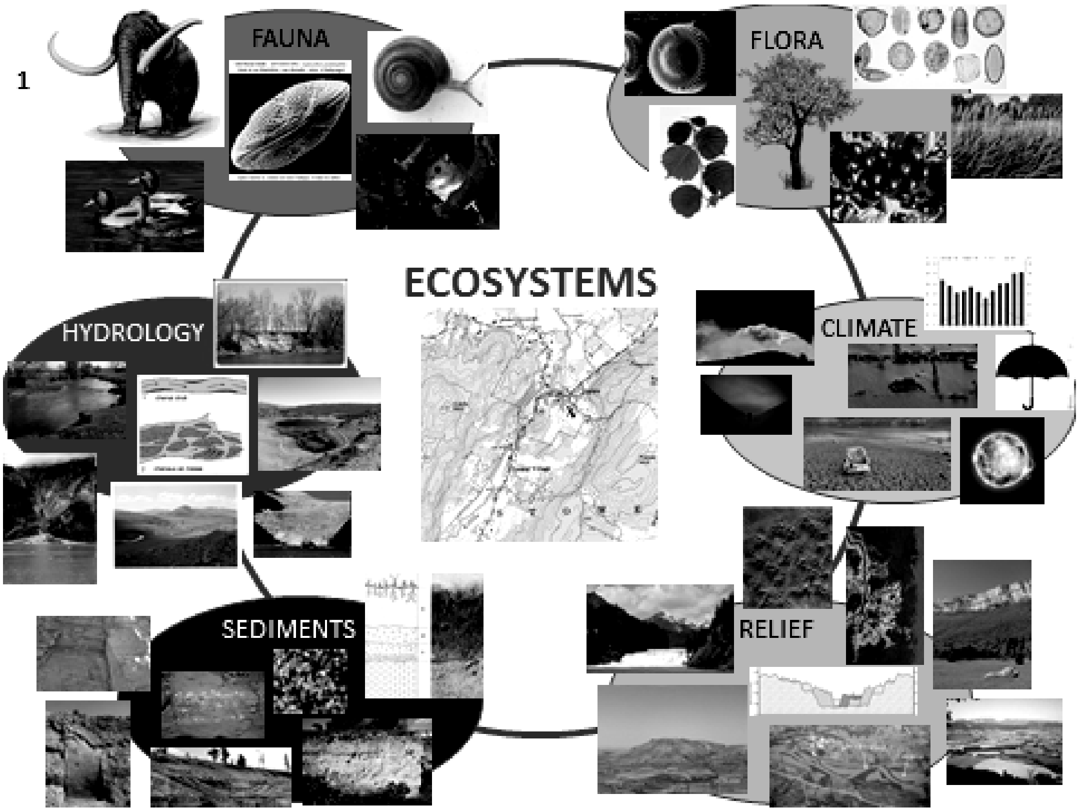
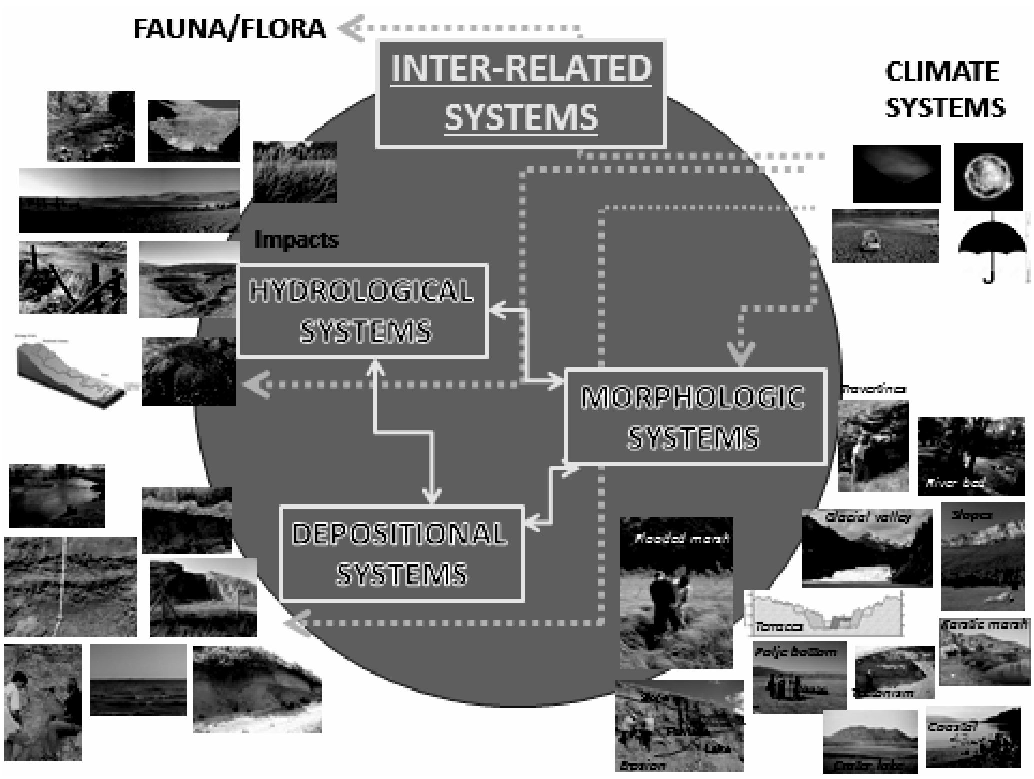


Figure 6: The systemic organization and interfaces of elements acting in a given "Environment".



II – WHY WORKING ON PAST ENVIRONMENTS

Figure 7 : Evidence of climate change and of some of its main impacts on water budget, land, sea ecosystems, and biodiversity

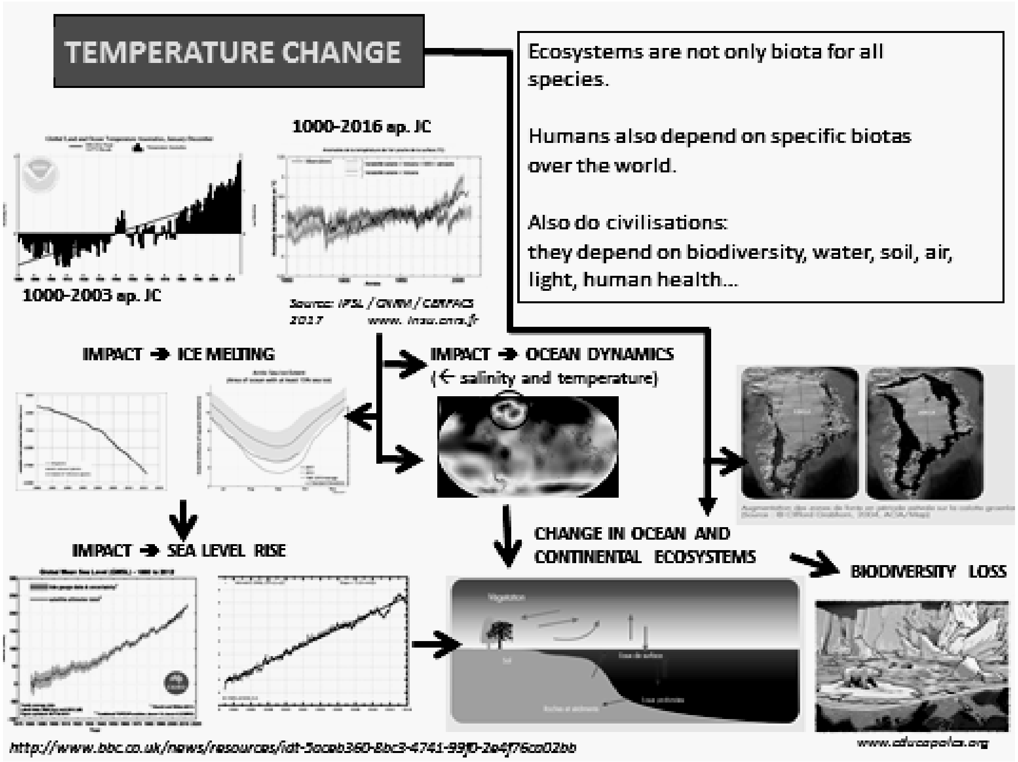
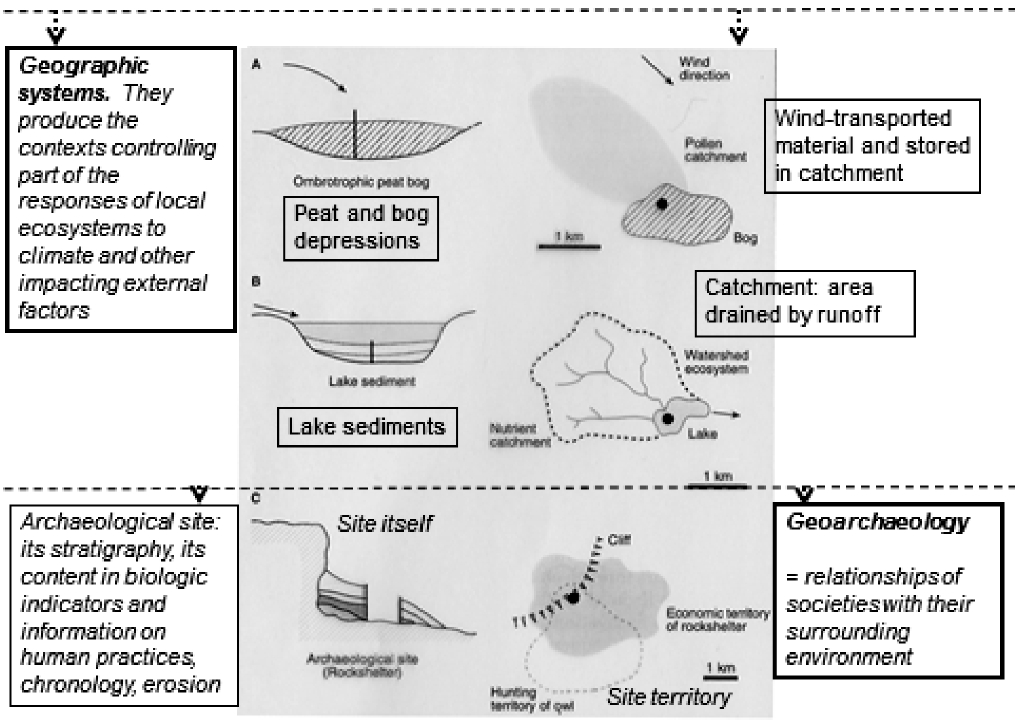


Figure 8: One example of how geographic systems control the context of ecosystems responses to a climate change, in time (parallel or delayed chronologies) and space (according to distribution of the relief setting or recording environments)



ANNEXES

Document n°1 : A quick overwiew of "Environment" definition on the web.

According to:

1) **Collins English Dictionary** – Complete and Unabridged, 12th Edition 2014 © HarperCollins Publishers 1991, 1994, 1998, 2000, 2003, 2006, 2007, 2009, 2011, 2014
    a. external conditions or surroundings, especially those in which people live or work
    b. (Biology) *ecology* the external surroundings in which a plant or animal lives, which tend to influence its development and behavior

2) **Random House Kernerman Webster's College Dictionary**, © 2010 K Dictionaries Ltd. Copyright 2005, 1997, 1991 by Random House, Inc. All rights reserved.
    a. the aggregate of surrounding things, conditions, or influences; surroundings; milieu.
    b. the air, water, minerals, organisms, and all other external factors surrounding and affecting a given organism at any time.
    c. the social and cultural forces that shape the life of a person or a population

3) **The American Heritage® Student Science Dictionary, Second Edition. Copyright © 2014**
All of the physical, chemical, and biological conditions that together act on an organism or an ecological community and influence its growth and development. Soil, air, water, climate, plant and animal life, noise level, and pollution are all components of an environment. To survive, organisms must often adapt to changes in their environments.

4) **American Heritage® Dictionary of the English Language, Fifth Edition**. Copyright © 2016 by Houghton Mifflin Harcourt Publishing Company. All rights reserved.

    a. The totality of the natural world, often excluding humans: "Technology, of course, lies at the heart of man's relationship with the environment" (Mark Hertsgaard).

    b. A subset of the natural world; an ecosystem: the coastal environment.

    c. The combination of external physical conditions that affect and influence the growth, development, behavior, and survival of organisms: "Conditions in a lion's environment can drive it to hunt people" (Philip Caputo).

    d. The complex of social and cultural conditions affecting the nature of an individual person or community.

    e. The general set of conditions or circumstances: a terrible environment for doing business.

Annex 2 : Geomorphology, an academic discipline

The objects by geomorphology have been pointed first by **Aristote**, (384-322 BC), **Pline the Elder** (23-79 AD), **Strabo** (64 BC-21/25 AD), **Seneque** (4-1 BC – 65 AD), **Ibn-Sina** (AD 980-1037), **Shen Kuo** (AD 1031-1095). Our discipline today has been elaborated by a succession of researchers since the 2nd half of the 18th centrury AD, with a specific contribution of geographers and travelers.

- Alexander von Humboldt (1769-1869) founded the bases for Physical Geography that he developed in many of his books, especially those about South America where he travelled and collected masses of data on geology, relief, climate, fauna, flora and environment, as a whole and within the interrelationships composing it.

- **James Hutton** (1726-1797) who proposes that the earth has been gradually formed under the control of forces which are still at work today. He is thus the first scientist to propose a several million years old age for the Earth, as well as the possibility that adaptation was the key factor for understanding the evolution of species.

- **John Playfair** (1748-1819), a mathematician who first evidences some erosion dynamics, explained why glacial valleys are V-shaped, and which processes are involved in the transportation of erratics. He also supported efficiently, together with Charles Lyell, Hutton's proposal of uniformitarism as an explanation for the evolution of species.

- **Carl Friedrich Naumann** (1797-1873) is the first scientist to have used, in one of his books of geology, the words *« Morphology of the Earth Surface»* (1858).

- After **Charles Lyell** (1797-1875) who developed the stratigraphy science, **William Morris Davis** (1850-1934) set up a cyclic model of erosion. As such, W.M. Davis is considered as the "father of American geography" and the "father of geomorphology".

- On the bases of evidence interpreted from erratics in Alpine valleys, **Albrecht Penck (1858-1945),** a climatologist, geologist and geographer specialist of glacial landforms, studied the role of glacial erosion in the landforms of the Alps, in a very famous book co-signed with **Edouard Brückner (1862-1927)** who was a meteorologist and palaeoclimatologist[7].

- **Emmanuel de Martonne** (1873-1955) is a geographer specialist in Physical Geography and Climatology. With his contributions on physical geography and geomorphology of France, he is considered as the father of geomorphology in France, and also as one of the main contributors to the knowledge and classification in physical geography geography in Europe[8]

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[7] A. Penck, E. Brückner. 1901-1909. *Die Alpen im Eiszeitalter*. Leipzig, C.H. Tauchnitz, in German)

[8] Published by Armand Colin, Paris : *Traité de géographie physique : Tome 1: Notions générales, Climat, Hydrographie. Tome 2: Relief du sol. Tome 3: Biogéographie*, (1909). *Abrégé de géographie physique* (1922). *Géographie physique de la France* (1942). *Europe centrale* (1930-1931) and *La France Physique* (1941) in G. Vidal de la Blach *Géographie Universelle* Tomes IV and VI.
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