Sicily in the last one million years*

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1 Geographical-phisical aspects of Sicily

The morphologic set up of Sicily, as regards complexity of geological structure, is extremely varied and can generally be considered representative of different geomorphological contexts characterizing the Mediterranean area. The geological structure of Sicily is schematically divided into three sectors:

1. chain sector, that develops along the northern cost of the island, from the Peloritani Mountains to the Aegadi archipelago, and consists of geological bodies with different lithologies tectonically overlapping.
2. foredeep area, that occupies almost the whole mid-southern area of the island, divided into two sedimentation basins (Caltanissetta Basin and Castelvetrano Basin) separated by the Sicani Mountains which represent the southern part of the chain.
3. foreland area, situated in the south–eastern portion and made up of mainly carbonaceous rocks of the Hyblaean area.

The chain, that representing the continuation of the Apennine is then called Sicilian Apennine, divides into several reliefs. The easternmost one consists of the Peloritani Mountains between Capo Peloro and Portella Mandrazzi, whose peaks seldom reach over 1,000 m. The highest summit (1,374 m) is Montagna Grande. They consist of a series of steep reliefs, made up mainly of metamorphic rocks and, in the western sectors, of sedimentary rocks in facies of Flysch. Westwards, the Sicilian Apennine continues with the Nebrodi Mountains, usually higher than the forementioned peaks, reaching even 1,847 m with Mt. Soro, characterised by smoother features for the outcrops of mainly clayey and arenaceous rocks, highly erosive. The Peloritani and Nebrodi Mountains are drained by numerous rivers, with mouth along Tyrrhenian and Ionic shores, characterised by steep slopes and reduced length of the streams which flow throughout wide alluvial plains (*fiumare*).

West of the Nebrodi Mountains, separated by the valley of the Pollina River, is the Madonie Mountains, made up of carbonatic and arenaceous–clayey rocks, reaching 1,979 m with Pizzo Carbonara, Sicily's second highest peak.

The great diffusion of calcareous rocks had favoured remarkable development of Karst that has widely shaped the high Madonie's landscape, and has originated many caves,

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some of which hosting prehistoric settlements (caves in the area of Isnello). The highest reliefs are bordered by wide slopes mainly covered by talus involving to superficial and deep landslide phenomena. Even more westwards, following the valley of the Imera Settentrionale and Torto Rivers, the chain, whose lithological composition becomes mainly calcareous, divides into the Termini Imerese–Trabia Mountains, reaching 1,326 m with Mt. San Calogero, and into the Palermo Mounts, reaching 1,333 m with Pizzuta. The reliefs, today almost completely lacking of arboreous vegetation, are affected by the remarkable diffusion of epigean and hypogean karst morphologies and with these, in the costal areas, there are also numerous sea caves used by prehistoric man (caves of Addaura, San Ciro, Carburangeli, Puntali, etc.).

At last, separated by Piana di Partinico, there follow the calcareous Trapani Mounts, of which the Aegadi Islands form the westernmost part. The highest point is Mt. Sparagio, in the peninsula of San Vito, reaching 1,110 m. The whole area is characterized by hill and steep reliefswith several caves of remarkable archaeological importance, as Grotta dell'Uzzo.

The northern coastal zone, characterised by areas with low and sandy coasts alternating areas with cliffs, is divided into numerous gulfs; the largest is the Castellammare Gulf, till a couple of decades ago, characterized by dune-like sandbars but no longer existing today because of the presence of man. Moreover, the coast still saves in different areas edges of degrading marine terraces witnessing different Pleistocenic sea levels and presents a wide coastal plain bordered by marine terraces which is located in the central part of the Termini Imerese Gulf; such plain has originated not to long ago from flood supplies of the Torto and Imera Settentrionale Rivers.

Besides the rivers already mentioned, also the S. Leonardo and the S. Bartolomeo Rivers debouch along Sicily's north coast, the former in the Termini Imerese Gulf and the latter in the Castellammare Gulf.

The Sicani Mountains, which occupy the south–west sector of the island, set up a southern appendix of the chain's western segment, similar as for the geological structure profile. It is a very articulated mountain range with isolated reliefs, as Rocca Busambra (1,613 m), Mt. Cammarata (1,578 m) and Mt. Genuardo (1,180 m).

The foredeep area is characterized by Tertiary and Quaternary rocks of different lithologyAmong these, very important are the Messinian evaporitic successions, whose most common lithological type is gypsum, that, due to its solubility, is involved with karstic phenomena; the gypsum caves of this area too, host important sites of prehistoric settlement.

West of the Sicani Mountains, there are inner areas characterised by hilly reliefs that join the coast by means of marine terraces lowering at sea. Hydrography is characterised by the wide Belice River basin, whose end sector is morphologically characterised by fluvial terraces. Eastwards there is the typical hilly landscape of the Altopiano Solfifero dominated by wavy forms due to the Miocenic outcrops of gypsum and evaporitic limestone and, in some cases, of sandstones and conglomerates. The widespread outcrops of clayey rocks favours the development of intense erosive processes and landslide phenomena which render these lands extremely unstable and deserted.

Going towards East, there rise the Erei Mountains, made up of arenaceous and calcareous-arenaceous rocks, isolated and generally hilly, where the selective erosion processes, has generated tabular (*mesas*) and monoclinal (*cuestas*) reliefs.

Such sectors are crossed by Sicily's major streams as the Platani River and the Imera Meridionale (or Salso) River.

This last one flows into the great Gulf of Gela forming a vast alluvial coastal plain edged by wide dune–like fields that, in some places, have originated humid coastal zones (Biviere di Gela), but there are now upset by agriculture.

The widespread evaporitic rocks are connected to most of the small and ephemeral Sicilian lakes. In fact, except for few summit lakes on the Nebrodi Mountains (Biviere di Cesarò, Quattrocchi, etc.), for small Naftia lake near Palagonia (whose origin is due to hydrocarbon emissions), and for coastal ponds, most lacustrine basins occupy karstic depressions as Preola and Gorghi Tondi lakes, near Mazara del Vallo, small Gorgo lake, south of Cattolica Eraclea, "Lo Sfondato", near S. Cataldo, and Pergusa Lake that, being 1,83 km^2 wide, is Sicily's largest lake, today threatened by man's heavy presence.

The south–east part of the island is occupied by the Altopiano Ibleo, made up of calcareous and calcareous-arenaceous rocks, characterised by its generally tabular morphology due to the subhorizontal bedding, crossed by deep fluvial incisions. The eastern sector between Peloritani and Hyblaean area is dominated by the Etna that, with its 3,340 m, is the highest active volcano in Europe. The volcanic building starts in the wide Piana di Catania, originated during the Quaternary by the alluvial contribution of the Simeto River, river with the widest drainage basin of Sicily, and of its present tributaries. Piana di Catania has recently (1950) undergone a deep anthropic change due to the drainage of the Biviere di Lentini (the largest humid area in Sicily) dried up by means of water canalization of Dittaino and Gornalunga Rivers and their deviation into the Simeto River.

Moving towards north, along the Ionic cost, there is the Alcantara River that originates from the southern slope of the Peloritani and that, fed by waters flowing from the northern side of Etna, represents the stream characterised by the greatest average flow in Sicily. The growth of the Etna Volcano, due to north migration of emission centers that had previously realized the most ancient Hyblaean volcanism, has caused progressive deviation of Simeto and Alcantara River and has created lakes of volcanic obstruction (Gurrida lake) and humid areas characterised by uncertain pattern directions.

2. The environment in Sicily from Middle Pleistocene to Holocene

At present there are no specific studies as regards climate and environment conditions of Sicily during Middle Pleistocene-Holocene, yet it is reasonable to say that the paleoclimatic situation of the island must have been similar to the one of the Italian peninsula, taking into account that the closeness of the African coast probably used to stress aridity during temperate-warm climatic phases and used to mitigate climatic harshness during glacial phases. Probably, the climate of the northern mountain sector was quite different from the hilly one or, coming down south, from the plains; perhaps the island was an environment mosaic, with microclimatic differences strongly influenced by physiographic features.

Paleoenvironmental reconstructions, limited by the almost complete absence of pollinic data, are mostly based on paleontologic information (observation of continental mammal associations and of sea deposits) and on geomorphologic data. Climatic variations, and the consequent eustatic oscillations, have left traces in morphology and in sedimentary features of the talus, in paleosoils and in fluvial deposits. Along the coasts, wing furrows mark the different sea level.

The geodynamic evolution of Sicily, characterized by particularly active neotectonics that has caused the raising and emerging of large areas, has interacted with the significant climatic fluctuations and the eustatic oscillations, aiding remarkably in the landscape evolution.

2.1 The environment during Middle Pleistocene and Early-Upper Pleistocene (1,000,000-75,000 years B.P.)

Data belonging to environment conditions in the first part of Middle Pleistocene are poor and fragmentary. Most likely, at the end of the Lower Pleistocene, the Sicilian-Maltese insular complex had a rather different paleogeography than today's. The islands basically consisted of a partially emerged chain, continuously raising, that was the bone structure of the present Sicilian Apennine; such structure was built up during Middle Pliocene and towards south-east, in a large sublevel emerged area corresponding to the structure of the Hyblaean foreland. Between these areas was the wide foredeep sedimentation basin divided into two sub-basins (Caltanissetta and Castelvetrano Basins) separated by a structure.

The first part of the Middle Pleistocene is characterised by an important widespread phase of sea withdrawal (*Regressione Romana*, Ruggieri & al. 1984) happened ca. between 0.9 and 0.8 millions of years before present (Ma B.P.). During this phase there is a further elevation of the northern chain and, more to the South, the emersion of large areas (northern portion of the Caltanissetta Basin and most of the Castelvetrano Basin) which still show their emerging tendency, already manifest in the previous period.

Moreover, raising too were narrow sectors as Mt. Pellegrino, Mt. Gallo and the promontory of Capo Milazzo. In the south-east sector, the raising determines the widening of the Hyblaean area, that at those times extended from Capo Passero, SE, to Licodia-Grammichele-Mineo sector, NW, and the widening of Siracusa's coastal areas (Magnisi and Maddalena peninsulas). Along the north and west coasts, the areas near the chain were characterized by variable direction movements, nevertheless tending to ultimate emersion. Exceptions of this general picture, showing a strong lowering tendency, are certain sectors of Sicily's south-west coast (areas of Capo Bianco, Selinunte, Mazara del Vallo and Marsala) and the Piana di Catania (Ghisetti & Vezzani 1982).

The north zone and most of the central sector of the island seem still, while the coastal areas reported oscillations of the sea level and transgressions that, in some cases, reached also inner areas, causing the formation of wide terraces whose most representative examples are in the coastal area of Trapani, Agrigento and the Hyblaean zone (Bonomo & al. 1996; Carbone & al. 1982).

This long period is characterized by climatic oscillations that, especially during the initial phase, seems to have met hot-arid fluctuations significant enough for the shaping of wide planation surfaces (like pediment located in some areas of Southwestern Sicily (Ruggieri & Unti 1977).

A general tectonic raising of the island is well documented after Eutyrrhenian (125,000 years B.P.); as a matter of fact, throughout Sicily there are *Strombus* deposits located at different altitudes (even over 100 m above actual sea level in the Peloritani area) which lead to the hypothesis of areas characterized by different raising values, corresponding to crustal sectors with different geodynamic evolution: the Aegadi Islands, with a raising rate of 0,02 meters/per one thousand years (m/ka), the northern sector, with a raising of ca. 0,19 m/ka, the south-eastern sector, with rates of 0,2-0,7 m/ka, as well as the Peloritani area that raised with velocity ranging from 0,6 to 0,99 m/ka (Cosentino & Gliozzi 1988). The progressive increase noticeable going from west to east clearly shows the differential raising the island has undergone in the last 120,000 years, phenomenon due to greater geodynamic activity of the Calabro-Peloritanous arc, responsible as well of the intense seismic activity existing in the area of the Stretto di Messina.

In this period, Sicily is also the scene of deep geographic changes connected to an intense volcanic activity, still persisting. Etna's great volcanic building, extremely significant in the island's present geography, starts its formation ca. 700,000 years ago with submarine activities, as basal hyaloclastites show, occupying the wide pre-Etna gulf (Malatesta 1985;); such gulf was situated between the Peloritani and the Hyblaean Mountains and during the Lower Pleistocene probably extended till today's Piana di Gela, being thus a sea sound connecting the Ionic Sea with the Canale di Sicilia. The origin of the Aeolian archipelago is connected to more ancient volcanic activities; in fact, radiometric dating carried out on submarine volcanoes of the archipelago's western sector have suggested the starting of submarine vulcanism at 1.3-1.1 Ma, while, as for the more

ancient islands, they emerged ca. at 0.6-0.5 Ma (Savelli 1984). The various buildings, according to activity and orientation of deep crust fractures to which they are connected, formed in two different periods. The first, dating 0.33 Ma, saw the coming forth of Alicudi, Filicudi, Panarea and, partially, also Lipari and Salina. The second period, dating 0.15 Ma, saw the development of Lipari and Salina and then Vulcano and Stromboli, both still active

volcanoes (Malatesta 1985).

The Ustica island, instead, was originated by the eruptive activity of the late phases (0.5-0.4) of the stretching tectonics connected with the sinking of the Tyrrhenian basin.

The same age dates the beginning of submarine eruptive manifestations in the Canale di Sicilia causing the formation of Pantelleria, while more ancient is the volcanic activity that originated the nearby Linosa, about 1 Ma.

Some paleogeographic information, for a time interval included between some 6-700,000 years and 450,000 years B.P., result from the study of fossil mammals on the insular faunal complex of *Elephas falconeri,* the pigmy elephant exclusive of the paleo Sicilian-Maltese archipelago.

Paleoambiental information deducible from this association, whose elements have been modified by processes of endemic evolution, is rather modest, even though the presence of the insectivorous *Crocidura* (shrew) would indicate a climate with aridity characters.

Mammals population consisted, besides the forementioned elephant, of three species of endemic micro mammals (two kinds of dormouse and the shrew) and of an otter. Among reptiles, there is a typical giant tortoise. Both the characteristics of the existing species and the structure of association, in which there are neither big size mammals nor big predators, show a marked endemic character, proving that the paleo Sicilian-Maltese archipelago was affected by difficult connections, often extremely discontinuous, with emerged continental areas. The poor diversification of association and the geographic distribution of the locations in which were found mammals remains traced back to this population phase (Bonfiglio & Burgio 1992) suggest that the emerged lands were significantly less extended than today and that paleogeography was much more fragmented, perhaps consisting of emerged areas separated by narrow sea straits, by lagoons or ponds that actually were biogeographic barriers.

The provenance of the mammals of the faunal complex of *Elephas falconeri* is still unknown, therefore it is still uncertain if the paleo Sicilian-Maltese archipelago had, in those times or just before, geographical connections with Africa and/or the Italian peninsula.

In the late middle Pleistocene the paleogeographic situation must have been very different. The island had reached conditions very similar to present and was populated by a mammals association well differentiated and balanced under the trophic point of view: there are both big and medium herbivores, as the rather moderate size elephant, *Elephas mnaidriensis*, a hippopotamus, a wild ox, an aurochs, which is the only species with clear boreal affinities present on the island, two species of deer and predators as wolf, bear, tiger-wolf and lion. Such association shows not too significant endemic characteristics, in fact, except for *Megaceroides carburangelensis*, all herbivores are just slightly smaller than their continental equivalent, and they are extremely similar, though impoverished, compared to association of mammals that lived on the Italian peninsula during the same period.

In numerous sites, faunal elements and associations of this complex date around 200,000 years B.P. (Bada & al. 1991), while other age determinations recently carried out on analogous faunal association found in Contrada Fusco (Siracusa) have established an average period going from 147,000 and 88,000 years B.P. (Rhodes 1996). These periods roughly coincide with the isotopic stages 7,6 and 5 and mostly agree with stratigraphic relations between deposits containing the association of *Elephas mnaidriensis* and the marine terraces in eastern Sicily (Bonfiglio 1991; Bonfiglio & Insacco 1992). Yet, the oldest finding of an elephant connected to this faunal complex seems to prove that in early times (maybe around 450-400,000 years ago) there were favourable conditions for animals coming from Southern Italy, along the migration route, or an equivalent one, used afterwards by numerous other animals and by man during the Upper Paleolith and Mesolithic.

During temperate climatic phases (isotopic stages 11?, 9, 7, 5) the island was probably woody, as shown by the presence of abundant fossil remains of deer, as well as bear and wild pig of this period and by the scarce presence of pollen found in the above-mentioned Contrada Fusco (Arobba 1996). The sea used to reach higher levels than today's, as witnessed by marine deposits outcropping on surface at various altitudes near the coast. The intense pedogenetic activity had caused the formation of typical hot-temperate climate soils that, in areas where substratum consists of calcareous rocks, become reddish (*terre rosse*) and are usually on terraced marine deposits.

During glacial phases (isotopic stages 10?, 8, 6, that is last two to Rissian glaciation), most of the continental platform emerged forming wide coastal plains, probably occupied by shrubby steppe, even though woods were always present at least in certain sectors of the island. The climate, by now colder and more arid, caused degradation of vegetation and favoured rather active winds, responsible indeed for the formation of aeolian deposits.

2.2 From Pleniglacial to Tardiglacial (75,000-10,000 years B.P.)

During the highest glacial expansion phase, Sicily had a geographic outline significantly different than today's. In fact, the eustatic lowering, that during glacial acme reached -130 m level compared to today's, uncovered large portions of the sea floor, especially along the south coast. The Hyblaean area stretched south, joining the Maltese islands, and the western cusp of Sicily pushed out towards west, including the Favignana and Levanzo islands, that were just reliefs imposing from the large surrounding plain. The coastal sector between Mazara and Sciacca stretched south-west too, generating a vast promontory and, because of the contemporaneous expansion of Africa's north coast, the present Canale di Sicilia was only a narrow sea strait ensuring difficult continuity between west and east Mediterranean; such two seas were considered two marine basins with different oceanographic features.

The widespread lowering of the base level determined an increase in the erosion of the stream floors causing thus a deeper hydrographic net of the island and a stress in slopes dynamics processes. Temperature decrease and the following reduction of snow limits brought about periglacial conditions on the highest reliefs, favouring physicalweathering processes . Therefore, slopes became seat of weathering processes that were feeding the great debris found, with a certain continuity, along the piedmont strip of major reliefs; analogous side deposits are also located below the actual sea level, as seen in the submarine reliefs of the Aegadi archipelago (Agnesi & al. 1993). Perhaps, taking into account the existence of Würmian glaciers on Mt. Pollino and in Sila, the highest reliefs have, for some time, welcomed glaciers.

Along the northern coast, dominant winds were able to move sandy sediments of sea floors uncovered by Würmian Regression, to deposit them at the base of the reliefs. This mechanism explains the genesis of powerful and spread aeolian deposits that are found along northern slopes of Trapani and Palermo Mounts. Perhaps, many of these deposits formed during the Upper Pleniglacial. The strong dune-like formations that cover the north-west side of Mt. Palmeto (Terrasini) are veiled by side deposits, typical of a more humid climate, most likely originated during the Tardiglacial period and deeply altered and cemented during the hot-humid climatic phase of the Early Holocene. Generally, the existence of colder phases spaced out by phases of milder climate (interstage), is witnessed by the alternation of aeolian deposits and debris, at time, at levels alternating different granulometry (*èboulis ordonnès*); these cover, in various locations, beach deposits of the Eutyrrhenian, well known in the Aegadi islands and in the Palermo Mounts (Agnesi & al. 1993; Hugonie 1982).

The phase of glacial acme and the Tardiglacial, including deglaciation, are important faunal exchanges between Sicily and Italy. During this period human populations of Epigravettian culture and open environment animals reached the island. Among these animals there was the wild donkey (*Equus hydruntinus*), animal common in the Italian peninsula during the Tardiglacial period that preferred shrubby steppe and well tolerated even moderate arboreous covers (Abbazzi & al. 1996).

The strips emerged from the platform, perhaps lacking trees, were probably used by such animals to enter the island. The founding of abundant remains of *Terricola savii*, a

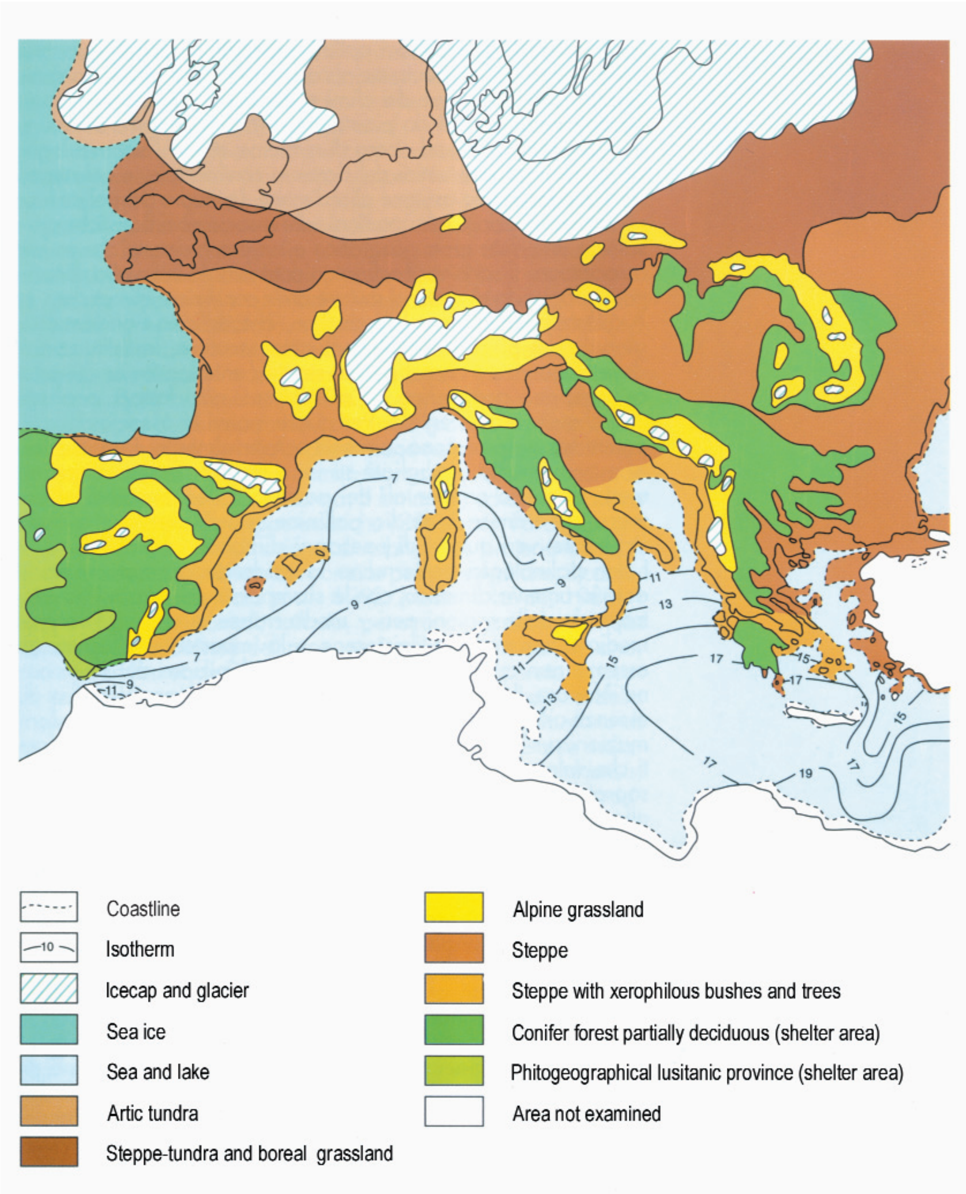

Fig. 1. Vegetation-line, shoreline and seawater surface temperature during the upper Pleistocene. From Agnesi & al. (1997).

field mouse still diffused in Southern Italy, wants on one hand, underline the degraded environment, and on the other, mark a certain temperate valence of the climate

2.3 From Holocene to Present (from 10,000 BP to present time)

The sea level rise, due to the fusion of huge glaciers ending right after the beginning of the Holocene, causes in Sicily a drastic reduction of coastal plains that used to welcome human settlements and were favoured habitats for great open space mammals as aurochs and asses. Such event deeply changes the geography of the west and south coasts causing again the isolation of some topographically prominent areas that go back to insularity (Favignana, Levanzo and Maltese islands). The eustatic rise in the sea level following the acme of the Upper Pleniglacial seems to have happened through at least four phases, as shown by depth contour morphology around the Aegadi Islands (Agnesi & al. 1993); such step took place around 6,500 years B.P. (Antonioli & al. 1994).

At the same time the climate changes significantly and so does the landscape creating a greater arboreous covering which during glacial acme must have been prevailingly on mountain valleys, both towards mountain peaks and low altitude areas.

This climatic change is connected with the diffusion of the Mesolithic culture on the Island dating back to ca 10,000 years B.P. in the Grotta dell'Uzzo. Mammals association in this location prove a climatic improvement in Sicily, with diffusion of arboreous covering. It may be deduced from the dominance of remainders of deer and wild pigs among the animals hunted by the Mesolithic and First Neolithic population, and from the presence of water vole (Arvicola), living in humid environments and today extinct in Sicily. The field mouse is still present in the stratigraphical succession of Grotta dell'Uzzo at least until the first cultural phase of the Lower Neolithic (dated ca. 6,700 years B.P.), but seems to be absent in the horizons referring to the Middle Neolithic. Similar indications reach us from the remains of the field mouse and dormouse coming from the Neolithic site "Fossato trincea" (ditch) in Partanna (Trapani), dating ca. 5,700-6,600 years B.P.). The presence of the dormouse, a strictly arboricolous rodent which today lives only in Sicily's wood areas (Etna, Nebrodi), tells us that, in those times, the arboreous covering reached the lower Belice region, area at present deforested, giving us a further hint of a more humid climate than today's.

Throughout following climatic phases, in the southern regions of the Italian peninsula, there is a rainfall increase and a slight rounding of seasons contrast (Indeed during these phases, the north-African climate affects Sicily with its apparent tendency to climatic aridity, especially in the south and south-east area of the island, almost coinciding with the new expansion of desert zones towards the coastal sector of north Africa.

Minor climatic variations characterize the historic period too, as shown by alternating soils and aeolian deposits (cool-humid and hot-dry phases, respectively), that mantle archaeological vestiges in numerous sites of the Mediterranean area, as for example in Selinunte.

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