THE "LITTLE ICE AGE" AND ITS GEOMORPHOLOGICAL CONSEQUENCES IN MEDITERRANEAN EUROPE

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Abstract. Alpine glacier advances in the "Little Ice Age" took place in the decades around 1320, 1600, 1700 and 1810. They were the outcome of anomalous winters and cooler summers than those of the twentieth century. Documentary records from Crete in particular, and also from Italy, southern France and southeastern Spain point to a greater frequency in Mediterranean Europe's mountainous regions of severe floods, droughts and frosts at times of "Little Ice Age" Alpine glacier advances. Deluges, when more than 200 mm of rain fell within 24 hours, are most frequent on mountainous areas near the coast. An instance is given of the geomorphological consequences of a great deluge which struck the Teich valley in the eastern Pyrenees on 17 October 1840. An increased frequency of deluges, probably at times when Alpine glaciers were advancing in the "Little Ice Age" and earlier in the Holocene, in areas known to be tectonically unstable and underlain by soft sediments, could better explain the occurrence of fluvial terraces in Mediterranean Europe sometimes known as the "younger fill", than soil erosion resulting from deforestation.

Key Words: Mediterranean Europe; "Little Ice Age"; floods; soil erosion

1. Introduction

Historical and geomorphological studies of Mediterranean landscapes often point to rapid sedimentation in river valleys and deltas in medieval and early modern times and attribute it to soil erosion. The soil erosion is claimed to be the result of population growth, agricultural expansion and deforestation. The evidence for the timing of clearance, and its effectiveness in promoting erosion is rarely demonstrated. Rural population growth was generally fastest from the mid eighteenth to the end of the nineteenth century, later than the sedimentation. Human activity, it is argued here, is only part of the explanation for the erosion. Climatic extremes, especially a greater frequency of deluges, possibly associated with "Little Ice Age" ice advances, were more important than is usually recognized.

2. The "Little Ice Age" and the "Younger Fill"

The "Little Ice Age" is best defined as being the interval within the second millennium A.D. during which glaciers extended further down their valleys than in the twentieth century. Glacier advances were especially marked in Alpine Europe in the decades around 1320, 1600, 1700 (in some cases), and 1810, and minor advances interrupted a general recession about 1850, 1885, 1915 and 1965.
(J.M. Grove, 1988, 1996, and this volume; Holzhauser, 1984a, 1984b, and 1997; Holzhauser and Zumbühl, 1996; Patzelt, 1996). The climatic conditions in the Alps associated with the advances were a greater frequency of cool summers and snowy winters. Certain individual years were especially severe, with great cold and very heavy snowfall. Others, especially between 1675 and 1715, are known for their severe dry winters (Pfister, 1994). Even within this period the 1690s were snowy. In particular, the winter of 1694-95 saw deep snow in Piedmont, as well as in Europe further north, and also flooding at places as far apart as Setubal, Bordeaux and Rome (Lindgren and Neumann, 1981). During the severe winter of 1697-8 in western and central Europe, cold weather in Spain, brought by cold air masses pushing south-westwards, coincided with long rainy periods in the eastern Mediterranean (Pfister, 1994; Kington, 1999).

Rumsby and Macklin (1996) have presented evidence from historical sources which suggests that 'river basins in north, west and central Europe experienced enhanced fluvial activity between 1250 and 1550 and again between 1750 and 1900'. What happened elsewhere in Europe during the decades of ice advance in Alpine Europe? Very few routine meteorological records go back beyond the beginning of the nineteenth century and few river flow records before the beginning of the twentieth century. In the records that do exist some regularities can be recognized. For example, Probst (1989), using 5-year moving averages, shows that fluctuations in the flow of the major French rivers this century, before 1980, were broadly synchronous. Furthermore, his diagrams for the period 1912-75 show a marked resemblance between the discharge curves of the Guadalquivir, Ebro and Po.

One might not expect the timing of climatic and river discharge extremes to correspond throughout Mediterranean Europe. The region's topography is complex. Globally it lies between the Azores High and the southwest Asian monsoon, with the west more under the influence of Atlantic weather systems than the east. There is a strong correlation of -0.6 to -0.7 between the North Atlantic Oscillation (NAO) index and December-March rainfall totals in Lisbon and Madrid, though the correlation weakens to -0.3 to -0.4 in the central and eastern Mediterranean (Hurrell, 1995).

Throughout Mediterranean Europe most of the rain is brought by eastward-moving cyclonic depressions. A minority are Atlantic depressions following southerly tracks, their number increasing when the NAO index is negative and winter storms move more freely into the Mediterranean (Kushnir, 1999). By far the majority of Mediterranean depressions are generated over the Sea itself, usually in certain well-recognized areas (Fluxs, 1988; Wigley, 1992). Conceived by invading northerly air streams, some coming from the Atlantic, some originating in Scandinavia and Siberia, they are born in the lee of the mountains, especially in the Gulf of Genoa, the Gulf of Lions and west of Crete. The strength and frequency of the cold air outbreaks varies through time, increasing with a more meridional circulation, decreasing with a more zonal circulation.
Documentary records from Crete in particular, and also from Sicily, southern France and southern Spain point to a greater frequency of severe floods, droughts and frosts in the decades around 1600 and 1700, than have been experienced this century. This has stimulated a re-examination of the causes of rapid erosion and sedimentation in Mediterranean Europe.

A possible starting point for discussion is Vita-Finzi's (1969) *The Mediterranean Valleys* in which he pointed to the widespread occurrence of a medieval fluvial terrace. He called it "the younger fill", to distinguish it from older terraces of glacial times - "the older fill". He pointed out that fluvial terraces of Roman and modern age are generally lacking, and that in modern times downcutting rather than sedimentation has been the rule. He concluded that it was therefore unlikely that the "younger fill" was the result of erosion accelerated by human activity and was inclined to attribute its formation to a climatic fluctuation, either the "Medieval Warm Period" or the "Little Ice Age", both of which had recently been brought to attention by Lamb (1963) and Le Roy Ladurie (1965).

Neither Vita-Finzi nor others made a serious attempt to explain what features of the climate might have been responsible for the greater geomorphological activity. In general there was a tendency to think only in terms of changes in mean temperature, though some consideration was also given to the possibility of Atlantic depressions taking more southerly tracks and the circulation over Europe displaying more meridional features. An exception was Bintliff (1982), an archaeologist, who hypothesised that "in the not too distant past the local climate was highly variable, with severe droughts inhibiting scrub colonisation and loosening the topsoil, alternating with dramatic rainfall, producing these great colluvial sediment flows; such a climate may have characterised the latter part of the 'Little Ice Age' in the Mediterranean up till the middle of the last century..." (p. 157).

Vita-Finzi's conclusions attracted much attention from archaeologists and geographers, the majority of whom were inclined to disagree with him (Grove, 1997). Most are still persuaded that the main cause of sedimentation in Mediterranean valleys is soil erosion, which they usually attribute to deforestation (e.g. Innocenti and Pranzini, 1993; Billi and Rinaldi, 1997; Guillén and Palanques, 1997). However, it is rare for evidence to be presented showing that the time of clearing corresponded with an acceleration of erosion, or to show that clearing has resulted in particular erosion episodes; such a rare example is the study of the Biferno valley in Molise, Italy, by Barker and Hunt (1995). In general, there has been a tendency not to distinguish geological erosion from soil erosion, to assume that alluvium consists of soil, and to take it for granted that trees are not capable of growing again when they have been felled. It is, admittedly, a difficult area in which to provide precise data but significant evidence is accumulating.
3. Deluges, Erosion and Deposition: A Particular Example

We know that in recent years much of the erosion that has occurred has been the result of unusually intense rainfall, deluges when more than 200 mm have fallen within 24 hours (Reichenbach et al., 1998). The disastrous mudflows in Campania, southern Italy, in April 1998 are a recent instance. An earlier, well-studied example is the very violent storm on 17 October 1940, which delivered over 500 mm of rain to 500 km$^2$ of the eastern Pyrenees, and as much as 1930 mm in 5 days to Saint-Laurent de Cerdans (Météo-France, 1995). It was calculated by Pardé (1941) that this “200-year storm” (the most violent in the eastern Pyrenees since that of 16 October 1763) removed the equivalent of 7.65 mm of sediment from the whole of the upper catchment of the river Tech, about as much as might be expected to be eroded over a hundred years without such an extreme event (Figure 1).

This should not automatically be attributed to soil erosion. Most of the sediment was derived, not from the wide-spreading slopes of the catchment, but from gullies, mass movements, and from Pliocene and Pleistocene valley fill, exposed by past faulting and uplift and now subject to mass movements and badland erosion (Calvet, 1993 and 1994). Pardé reckoned that about a half of the total product of erosion was deposited on the lower valley floor and a half was carried out to sea.

The river Tech escapes from its valley to reach the Mediterranean across a gently sloping alluvial fan. A recent study of documents applying for compensation payments by people in Elné has thrown light on the details of deposition on this fan area in October 1940 (Jacob, 1997). The floodwaters, spilling along former courses of the river and diverted by a railway embankment, scooped out deep hollows in some places and deposited spreads of sediment much more widely in others. Jacob calculated that 1.3 million m$^3$ were spread over the 700 ha of the Elné commune, and 290,000 m$^3$ were excavated and carried away from the flood plain by the floodwaters, giving a net accumulation 14 cm thick. The losses included a good deal of valuable soil; the gains consisted of pale sandy silt in some sectors and darker more organic alluvium in others, with greater thicknesses of coarse sand and gravel near channels and depressions where the floodwater moved fastest. At Bompas, in the same region but 15 km to the north between the Agly and Tet, about 3 m thickness of sediment somewhat similar to that at Elné covers a Roman road and the remains of medieval buildings (Calvet, 1993 and 1994). Presumably it represents several events like that of 1940 or, more likely, numerous lesser events.
Figure 1. Alluviation in Roussillon. Sediment brought down from the eastern Pyrenees by the Arly, Ter and Tech in the course of the Holocene has accumulated offshore and behind the coast. At Bonnac, 3m have accumulated on top of Roman remains (based on M. Calvet 1994, Figs. 219 and 222). Elsewhere, medieval buildings have been buried or partly buried. A deluge on 17 October 1940 resulted in the Tech depositing a net thickness of 14 cm of alluvium over 700 ha in the commune of Elne. (Derived from N. Jacob 1997, Figs. 1-4).
4. Location and Timing of Deluges and Erosion

Around the Mediterranean, very intense storms are generally confined to certain fairly well-defined mountainous areas: within 100 km of the coast of southeastern Spain, in the eastern Pyrenees, at the southeast corner of the Massif Central, in Liguria and Corsica around the Gulf of Genoa, in the Appenines especially in Calabria, in Montenegro, the Pindos mountains and highland Crete (Llasat and Rodriguez, 1997). In all of these areas, deluges of between 500 and 1000 mm of rain within 48 hours have been recorded. In one of them, near Mont-Aigoual overlooking the lower Rhone valley and near the source of several important rivers, the mean return period of 200 mm of precipitation falling in 24 hours (sometimes spread over two days) in the time span 1958 - 1994, was only about 2 years (Figure 2; see also Figure 1 in Obled and Tournas, 1992).

Many of the elevated, deluge-prone areas are also susceptible to erosion because they are tectonically unstable. They are in situations where uplift in Late Cenozoic times has been accompanied by incision and the development of steep slopes, and by the accumulation of great thicknesses of sediments which remain unconsolidated. These are liable to be incised by gullies and to collapse as a result of slumping and landslides, all of which yield large volumes of sediment (e.g. Calzolari and Ungaro, 1998). The evidence of former erosion is in the form of depleted soil profiles, gullies, landslips and badlands. Such features are usually difficult to date. More readily dateable, from their content of archaeological material and organic material, are the colluvial deposits, alluvial fans, fluvial terraces and river deltas composed of the products of erosion.

Figure 2. Isochrones of the return period in years of falls of 200 mm of precipitation in 24 hours, southern France, 1958-1994. Based on data in Météo-France (1998).
The “younger fill” composing the fluvial terraces studied by Vita-Finzi, is for the most part broadly medieval, but there are indications in Etruria (Potter, 1976), southern Spain (Bulitzer, 1980), and Provence (Bullais and Crambes, 1992), that there were two main periods of deposition. The first followed the end of the Western Roman Empire, from about A.D. 500-800, when Alpine glaciers advanced during the Götzinger Cold Phase II (Gamper and Suter, 1982, Holzhauser, 1997); the second lasted from the thirteenth to the seventeenth century A.D.

5. The Growth of Mediterranean Deltas

Mediterranean deltas are beginning to yield evidence of their rates of formation having varied through time. They began to accumulate about 7000 years ago when sea-level stabilized (Stanley and Ward, 1994). At first, estuaries and embayments were filled and then the deltas, notably the Ebro and Po but also a large number of others, began to prograde seawards (Trouvé, 1987; Jefthe et al., 1992). Tectonic subsidence has affected the situation, especially in the case of the Rhone. In the western and central Mediterranean, delta growth was especially evident in the sixteenth and seventeenth centuries, presumably as a result of the greater supplies of sediment reaching the mouths of rivers at that time. In the eastern Mediterranean, around the Aegean, it was more apparent in Antiquity (500 BC - A.D. 200). Nowadays delta fronts are everywhere being eroded by the sea on account of dams holding back sediment, and as the result of the extraction of sand and gravel from river beds.

6. Weather Conditions Associated with Mediterranean Deluges

From instrumental and from documentary records, it is evident that the heaviest deluges in the western and central Mediterranean, although they can occur in almost any month, mostly occur in October and November, a little earlier in the year than this in southeast Spain and the south of France, later in southernmost Spain, northern Italy and around the Aegean (López-Gómez, 1983; Russo and Sacchini, 1994; Llasat and Rodriguez, 1997). They are associated with cyclonic depressions which involve both cold air from the north, and warm air moving a long distance over a Mediterranean Sea where surface temperatures in the autumn may still be over 22°C and even as high as 28°C (Alport et al., 1990). The warm, moist air, in contact with cold air and lifted over mountain ranges 2000 m high, is extremely unstable and, especially if it is converging horizontally and the freezing level is high, can deliver an enormous mass of water within a few hours.

For intense rain in eastern Spain the warm winds need to be easterly; in most other deluge-prone areas, westerly winds are required (Millán et al., 1995).
For most deluges it would seem that the initial stimulus is an incursion of cold northerly air, generating a deep depression, which accentuates the uplift caused by convection. Some of the smaller storms are essentially convective, the larger ones are frontal; most are a combination of the two.

7. Relevant Features of the Climatic Record of Mediterranean Europe

Documentary records, most of which only begin to be of value for tracing climatic change about the thirteenth century, indicate that times of variable and extreme weather have been concentrated in certain decades when Alpine glaciers were advancing: 1. in the fourteenth century; 2. the decades around 1600; 3. the decades around 1700 and; 4. in certain decades of the nineteenth century.

7.1. THE FOURTEENTH CENTURY

The first major phase of extremes began in the 1310s and continued, with intervals, until the 1380s. It is recorded chiefly in northern Italy and the south of France. It was expressed in deluges and cold winters, but also in summer rain and occasional drought (Alexandre, 1987; Pfister et al., 1998).

Camuffo and Enzi (1996) point to a peak in Po flood frequency at the beginning of the fourteenth century and it may be significant that the rerouting of the Brenta to the south, the first diversion of rivers to prevent silt in the Vegetian Lagoon, began in 1324 (Camuffo, 1987). There were floods all over middle Italy on 3 November 1333 (the present Ponte Vecchio in Florence replaces a bridge then swept away) and in early autumn 1345 (Porta, 1990-91). The Arno and the Po froze in the winters of 1354/5 (Pfister et al. 1998) and 1367/8. In Siena, processions and prayers for rain early in 1368 were followed by floods the following season. In 1371/2 there were processions for rain at Florence in December, followed by processions praying for the rain to stop in May.

7.2. THE DECADES AROUND 1600

There was frequent flooding of the Tiber at Rome in the last third of the fifteenth century and of the Po in the decades around 1500 (Camuffo and Enzi 1996). However, the greatest cluster of weather disasters in Mediterranean Europe began in the 1570s, reached a peak in the 1590s, and tailed off in the 1640s. Droughts, floods, cold winters, and other exceptional events appear wherever in the Mediterranean we have records. Eight winters between 1595 and 1614 are rated by Camuffo and Enzi (1992) as great or severe. Anomalous climatic events recorded in the chronicles of the Alessandria area of Piedmont were especially numerous between 1590 and 1620. (Pavese et al., 1992). In the lower valley of the Po, cereal yields were seriously reduced in the period 1590-1630, especially in the years between 1589 and 1600, in large part as a result of excessive rainfall.
and flooding (Guidoboni, 1998). The Venetians, afraid that increased silt deposition might close the mouth of their lagoon, diverted the mouth of the Po to the southeast between 1604 and 1607 (Cencini, 1998). Flood frequency at Rome reached a maximum between 1589 and 1660 (Camuffo and Enzi, 1996). The flood of December 1598 carried away the ancient Aslian Bridge and drowned 1400 people (Davidson, 1985). In Tuscany and the south of France the 1590s were marked by crop failures, attributed variously to drought, cold, and out-of-season rain; these led to wheat being imported, unusually, from northern Europe, which was itself in trouble (Braudel, 1966). Font Tullot (1988) records many unusual snowfalls in Spain. Rodrigo et al. (1994, 1996) find 1575-1650 to have been a generally wet period in southeast Spain, punctuated by occasional droughts such as that of 1604-5. Catastrophic floods were unusually frequent between 1571 and 1630, especially in Catalonia (Barriendos Vallvé and Martín-Vide, 1998). 1617 was a 'deluge year' throughout eastern Spain, with intense rain in October; this was repeated throughout Spain early in 1626.

Weather is well documented for Crete for the period 1548—1648, possibly better than for any other part of the Mediterranean. Venetian administrators sent home a great mass of reports and letters mentioning, among other things, droughts, cold winters, great heat, and out-of-season rainfall. These are precise, first-hand descriptions made by observers present at the time. The records demonstrate a high frequency of intense rain (and droughts) especially in the last decades of the sixteenth century (J. M. Grove and Coester, 1995).

Some of the storms had a more severe and more widespread effect than any in recent years. In 1576 the Governor-General reported that:

...the very heavy and unusual rains we have had this year in June, July and August have greatly ruined the vintage...the said rain has also destroyed the salt-works of Suda and Spinalonga.

(Foscari, 14.9.1576, Archivio di Stato, Venezia, Provveditori da Terra e da Mar, File 738)

These places are 150 km apart.

On 14 October 1590 a deluge hit the city of Réthymnon, which being on a promontory is not ordinarily susceptible to flooding:

Most of the inhabitants of Réthymnos fled out of their houses and sheltered themselves as well as they could, especially in some of the churches. All the rivers flooded the town of Réthymnos, and the countryside, destroying a lot of buildings and causing high water. Eighty old buildings have fallen down... A lot of lands have been completely ruined.

(Nicol Prili, Rector of Réthymnos, 22.11.1590, Archivio di Stato, Venezia, Provveditori di Terra e da Mar, File 753)
7.3. THE DECADES AROUND 1700

After a period of quiescence in the mid-seventeenth century, the extreme events in and around 1600 were repeated a century later in Crete and elsewhere. On the smallish Aegean island of Tinos the Venetian authorities reported that the winter of 1682/3 was one of strong winds, continuous rain, heavy snow and 'very intense cold'; 480 cattle and 3427 sheep and goats perished. The Turkish authorities in Crete reported that torrential rain had caused serious damage to aqueducts. Matters got worse in the 1690s. In July 1692 the Governor-General of the remaining Venetian islands reported that:

the scantiness of a very thin crop of wheat having increased the worry that this current year of harvest is almost universal, so that there is very little help from the mainland and from the kingdom of Morea [Peloponnese].

(Vendramin, 28.7.1692, Archivio di Stato, Venice, Provveditori da Terra o da Mar, Fisca 1175)

There was similar trouble in 1694.

Camuffo and Enzi (1994) mention numerous floodings in northern Italy between 1682 and 1707, very cold winters between 1684 and 1694 and the particularly cold winter of 1709. In Sicily there was a run of disastrous harvests in the 1690s (J.M. Grove and Contiero, 1994). In 1691, 1692, and 1694 the wheat stored in a depot at Termini Imere, was spoilt in summer, either because of rain during the harvest or because out-of-season rain got into the warehouses. In 1693 and 1694 wheat and barley crops were scanty. In 1700 the Duke of Campiliero noted that even less wheat had been brought down from the mountains to the various stores than in the past few years 'even though the crop then was poor'; he speculated that this was due to the climate having become colder and wetter. In 1692 heavy snowfall was reported from Castroreale.

Mediterranean Spain experienced intense rainfall in 1684 (Rodrigo et al., 1996). According to Barriendos Vallvé and Martin-Vide (1998), much of this region was spared catastrophic floods between 1691 and 1720, though Molina Sempere et al. (1992) refer to Segura floods being numerous at this time.

7.4. THE NINETEENTH CENTURY

The records of flooding and freezing of the Rhone at Arles brought together by Pichard (1995), show a good correspondence between freezing of the river and the frequency of floods reaching over 4 m. Flood frequency on the lower river during the later stages of the "Little Ice Age" was much higher than in this century, especially in the late sixteenth century, 1701-1710 and 1811-1820. The frequency of autumn and winter floods over 6 m at Beaurepaire, upstream of the Rhone delta, mainly generated by deluges in the Massif Central and the Durance, is associated with freezing of the river and glacier advances. Of the 29 floods reaching to over 6 m between 1800 and 1920, 19 were in three decades; four
between 1836 and 1846, six between 1882 and 1891, and nine between 1907 and 1917 (Pardé, 1924-5).

In southeast Spain, the Segura flooded on numerous occasions in the decades either side of 1900 (Molina Sempera et al., 1992). Between 1888 and 1895 there were five occasions when peak discharges of the Ebro at Zaragoza exceeded 3000 m³/sec⁻¹, a value which was not to be reached again until 1926 (Gellatly et al., 1995). The clusterings of high floods in the middle and again towards the end of the nineteenth century coincided with glacier advances in the Alps and Pyrenees.

3. Holocene Glacier Advances and River Alluviation

Starkel (1991) has referred to what he calls “second order” fluctuations in the regimes of central European rivers in the Holocene. He argues that rivers draining mountainous areas (as do practically all the rivers of Mediterranean Europe) are under the “upstream control” of floods and that, as a result, their channel forms and fills have responded to Holocene climatic fluctuations similar to that of the “Little Ice Age”.

A number of other geomorphologists have begun to attribute more active episodes of erosion and sedimentation in southern Europe and the southwest USA to a greater frequency of deluges associated in some cases with glacier advances. A study in the Cantabrian region of northern Spain indicates the possibility that mass movements there were more frequent at certain periods in the Holocene; in the Pre-Boreal (8500-7500 BP), in the Sub-Boreal (3000-2500 BP), and in the last few centuries (500-300 BP) when rainfall totals are believed to have been higher than they are now (Diez et al., 1996). Enzel and Wells (1997) provide evidence from southern California that “the most extreme modern storms and floods were more frequent by at least an order of magnitude during specific time periods in the course of the Holocene”. Similarly, Ely (1997) finds that the largest floods in Arizona and southern Utah over the last 6000 years cluster into distinct time periods: 5000-3600 14C yr BP (i.e. 3800-2200 BC), 1100-900 BP (A.D. 900-1100) and after 500 BP (A.D. 1400). Over the last 1000 years, site notes, there is a positive relationship between the paleofloods and long-term variations in the frequency of El Niño events.

In Mediterranean Europe, archaeological and geomorphological studies have provided dates for fluvial terraces, constituting the “younger fill”, which accumulated at various periods in the Holocene. Some of the terraces, judging by their dates, were the results of slope erosion and accompanying valley floor alluviation during periods of Holocene ice advance before the “Little Ice Age”. For instance, alluviation on riverine plains in northern and central Italy was widespread during the glacier advances of Goschenen Cold Phase II, between A.D. 500 and 800, burying Roman towns, bridges, roads and centuriation networks (Vegiani 1983, Cremaeli et al., 1994). In the Peloponnese (southern
Greece), both the Píróschróni and the Argolid, which has been dated to 2300-1600 BC (Jameson et al., 1994), and a 10 m gravel terrace of the Alphiós, overlying wood dated, (Q-2942), to 3660±30 BP, about 2000 BC (Grove and Rackham, in press) were deposited, at least in part, about the time of the L'Obben ice advance of 1930-1250 BC (J. M. Grove, 1997; Holzhauser, 1997). More dates from these and other prehistoric alluviations are needed to confirm a correspondence between them and Alpine ice advances earlier in the Holocene, similar to those of the “Little Ice Age”.

9. Conclusion

There appears to be a link between glacier advances and some types of extreme weather close by in the Mediterranean. Glaciers advance when a succession of snowier winters is reinforced by reduced ablation losses in spring and summer. The same weather systems that gave heavy autumn and winter snowfall in the Alps in the “Little Ice Age” and contributed to glacier advances of a similar kind earlier in the Holocene could also account for much of the flooding and alluviation responsible for the “younger fill” of river valleys in southern Europe. Such extreme weather events also occurred in regions like Crete, which, though remote from the meteorological systems of the western Alps, are also liable to be affected by outbursts of cold air into the Mediterranean generated by high pressure systems over central Europe (Alpert and Reisin, 1986). Rarely does it seem necessary to invoke forest clearance, the spread of agriculture, or the abandonment of land to explain the sedimentary features.

References


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