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Pleistocene screes in Cyrenaica (Libya)

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With 2 figs.

Abstract: Northern Cyrenaica is an area of limestone hills with deep and narrow valleys. On the sides of these valleys are Pleistocene screes of two ages. The earlier are cemented and are interbedded with terraced gravels, the later are not cemented and have no associated terraces. Both series of screes can be correlated archeologically with the sequence in the cave of Haua Fteah, where a climatic succession has been obtained by HIGGS (1961). It is found that they correspond to two successive cold phases in the late Pleistocene. They are ascribed to frost-shattering, which would thus be indirectly responsible for the terraced gravels. An attempt is made to interpret these results in terms of temperature and rainfall.

Zusammenfassung: Nord-Cyrenaika besteht aus einem Gebiet von Kalksteinhügeln, welche von tiefen und schmalen Tälern durchsetzt sind. Auf den Abhängen dieser Täler finden sich Schuttdecken zweierlei Alters, wovon die älteren festverkittet und mit terrassiertem Kies wechsellagern, während die jüngeren nicht verfestigt sind und keine zugeordneten Terrassen haben. Beide Schichten können archäologisch mit der Schichtfolge in der Haua Fteah-Höhle korreliert werden, wo HIGGS (1961) eine klimatische Folge nachgewiesen hat. Es wurde gefunden, daß die beiden Schichten zwei sukzessiven kalten Zeiten des Spätpleistozäns entsprechen. Die Gerölle werden dem Spaltenfrost zugeschrieben, welch letzterer daher mittelbar für die terrassierten Kiese verantwortlich wäre. Es wird versucht, diese Resultate als abhängig von Temperatur und Niederschlag zu erklären.

Introduction

Much of northern Cyrenaica is occupied by the Gebel Akhdar, a mass of limestone hills rising to heights of more than 800 metres. On its north side it falls steeply to the sea, making a high and well-defined escarpment; this feature also continues round the west side of the Gebel, though here it gradually retreats further inland. At frequent intervals along the whole of its length the escarpment is notched by wadis, most of them dry at all times except for a few days of violent flooding each year. Perennial springs are rare, and only a few are copious enough to maintain a stream as much as a kilometre in length.

In these wadis and along the coastal escarpment various Pleistocene deposits are found, of which an account was given by me in McBURNEY & HEY (1955). With regard to the non-marine deposits, I concluded that they belonged to two distinct phases of deposition, both subsequent to the Last Interglacial. First, much tufa and calcareous marl were laid down in some wadis, together with small amounts of gravel. The climate of this time I believed to have been wet and temperate. Then, after a period of down-cutting, great quantities of gravel were laid down, forming terraces in almost all the wadis and alluvial fans on the coastal plains. These, which I called the Younger Gravels, I attributed to frost-shattering under conditions much colder than those of today. Both series of deposits contained Levalloiso-Mousterian artifacts, which were also found on top of the Younger Gravels.

Meanwhile, Dr. McBURNEY had completed his excavations at Haua Fteah, a cave on the north coast in which deposition had been virtually continuous from before 50,000 B.P. down to Classical times. A full report on the cave has not yet been published, but in 1961 HIGGS put forward a climatic succession based largely upon his own analysis of the faunas. His climatic phases and their archaeological associations are given in Table 1, which also incorporates such radiocarbon dates as were then available.

Table 1.

Climatic and archaeological succession of Haua Fteah, after HIGGS (1961)

Dates B.P.	Climates	Archaeology
9,800 - 6,800	Somewhat wetter and cooler	Mesolithic
11,500 - 9,800	Warm and dry	Upper Palaeolithic
32,000 - 11,500	Cold, possibly wet	Upper Palaeolithic
43,000 - 32,000	Warm and dry	Upper Palaeolithic succeeding Levalloiso-Mousterian (changeover at c. 36,000 B. P.)
51,000 - 43,000	Cold, wetter than before	Levalloiso-Mousterian
Over 51,000	Warm and dry	Early Levalloiso-Mousterian

Some information on absolute temperatures was also provided by EMILIANI (in HIGGS, 1961), who carried out oxygen- isotope determinations on marine gastropods found in certain layers of the cave-deposits. He suggested that sea-water temperatures during the warm periods were much the same as today, but that during the cold periods they sank in winter at least as low as 8 degrees C. Finally, the lithology of the deposits provided what appeared to be one further climatic indication, for both cold periods were represented by layers with abundant angular fragments of limestone (McBURNEY, 1960, pp. 199-200, and personal information). This again suggested frost-shattering, implying winter conditions perhaps even more severe than those indicated by EMILIANI's results.

Up to a point, correlation with the wadi-deposits was easy. The tufaceous deposits had yielded artifacts which, accrding to Dr. McBURNEY, resembled those found in the cave in layers dated to about 50,000 B.P.; the deposits would thus denote an especially wet phase at the very beginning of the first cold period. The Younger Gravels, on the other hand, had artifacts which were less distinctive and which, according to the Haua Fteah time-scale, could have been made at any time between 50,000 and 36,000. Since the gravels could now more confidently be ascribed to frostshattering, it seemed at first that their obvious place was before 43,000, that is, within the first cold period. There was, however, another possibility: that debris loosened by frost might initially have remained in place, to be deposited only when the succeeding warm, dry conditions had led to the destruction of vegetation.

Other doubts, of a more fundamental kind, arose from the fact that no direct evidence for frost-shattering had been found outside the cave. The Younger Gravels themselves were indirect evidence, while the second cold period, so far as I knew, was represented in the wadis by no deposits whatever. A suspicion thus remained that the angular fragments in Haua Fteah might after all be the products, not of frost-shattering, but of some unknown and purely local process.

In the hope of resolving these uncertainties I revisited Cyrenaica in 1962. This has enabled me to reach certain conclusions which amplify those of HIGGS and which may, also, be of interest to geologists who are obliged to base climatic deductions solely upon lithological and morphological features, without help from fossils.

Most of my new observations were made on or near the coast between Derna and Susa (Apollonia) (Fig. 1). The escarpment here runs very close to the sea, and rises in places to over 500 metres. The bedrock consists almost entirely of very gently dipping limestones of Upper Cretaceous and Lower Tertiary age. They are typically fine-grained, massive and poorly jointed, and there is an almost total absence of incompetent beds, such as shale, which might induce slipping. As a result the lower reaches of the coastal wadis form deep, narrow, steep-sided gorges.

Younger Gravels and contemporary deposits

I had already noted that the Younger Gravels included, in addition to normal gravel and some mudflows, material "so angular as to be indistinguishable from scree" (McBURNEY & HEY, 1955, p. 74). A further examination showed that such material was even more abundant than I had supposed.

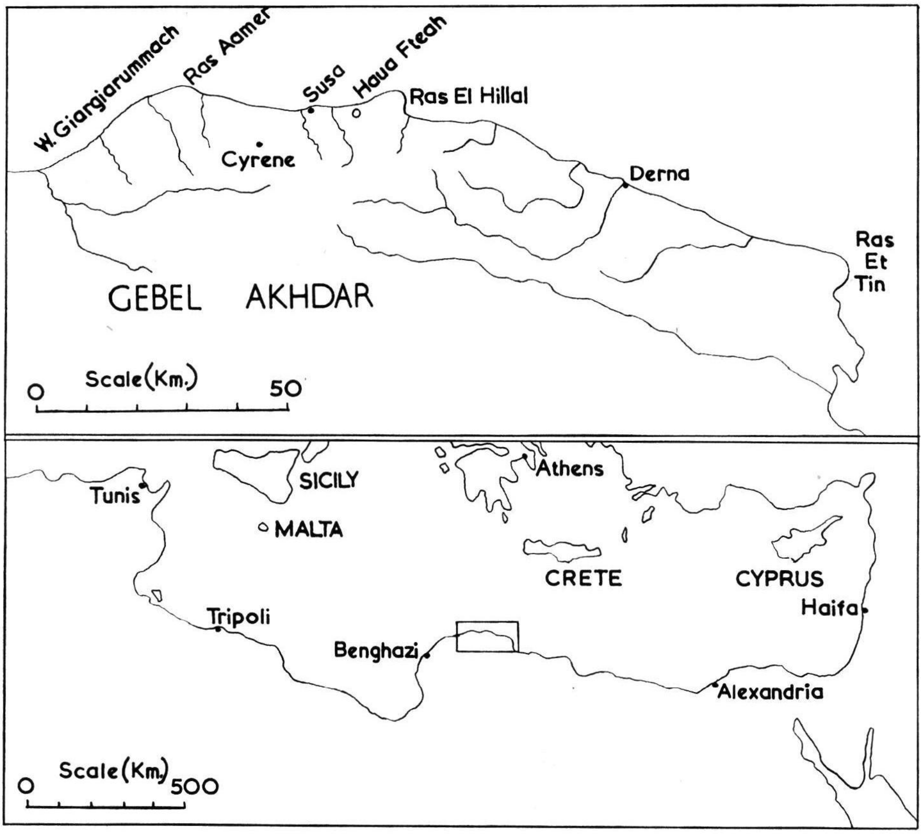

Fig. 1. Maps showing the area examined in 1962 (above) and its setting in the eastern Mediterranean (below).

At numerous points along the length of any wadi, sections of the terraced Younger Gravels showed intercalated beds of angular limestone fragments, each bed sharply distinct from the rounded gravels above and below but itself showing little or no internal stratification. Often there were several such beds in one section, and in a few places the entire terrace consisted of angular unbedded material from top to bottom.

Moreover, sections at right angles to the wadi-axes showed that these intercalations were in reality no more than the lower margins of great sheets of breccia, plastered against the sides of the wadis (Fig. 2a). These sheets were discontinuous and seldom more than a few metres thick, but could often be traced to great heights above the wadi-floors. The rock-fragments in the breccias were mostly between 25 and 100 millimetres across, though a few were much larger. Generally they lay in contact with one another, the interstices being filled with a compact, fairly hard matrix, full of impressions of rootlets. This was found to contain between 50 and 80% of calcium carbonate, the remaining material being a red or brown clay.

The distribution of the breccias gave a clear indication of their mode of formation. In the first place they were found only on slopes of 30 degrees or more, and for this reason were uncommon outside the gorge-like lower reaches of the wadis. Secondly, they were further restricted to positions directly below vertical cliffs, such as those formed by especially resistant beds of limestone. From this it was clear that they were simply con-

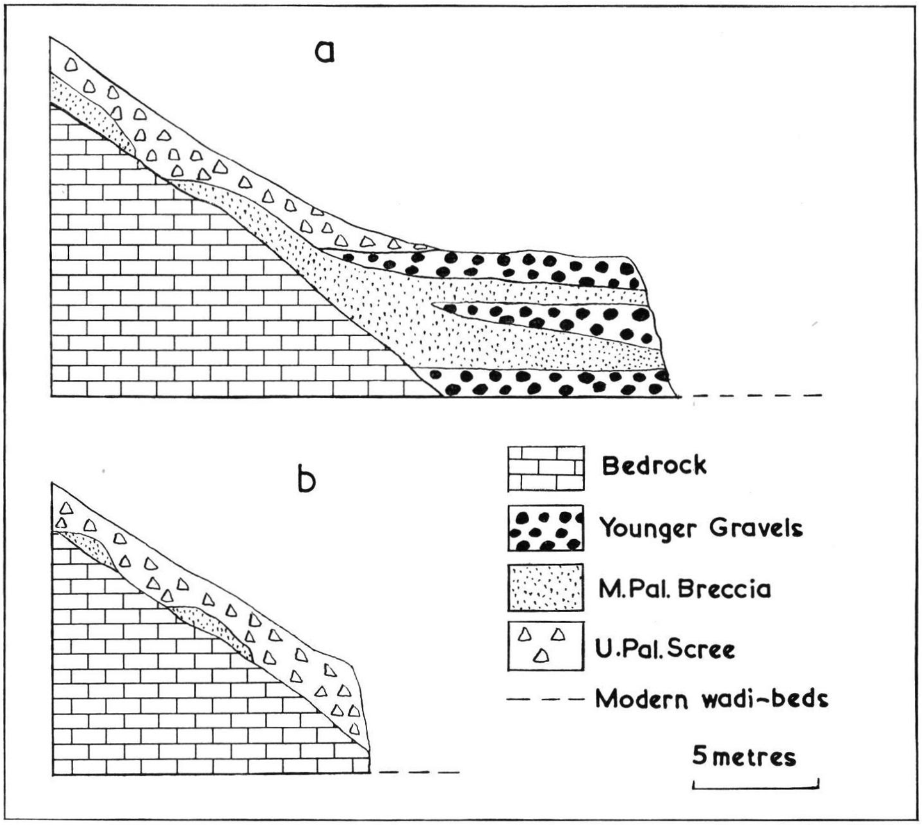

Fig. 2. Schematic sections showing the disposition of Pleistocene deposits in the wadis of northern Cyrenaica. (a) Younger Gravels forming a terrace, which is only partially covered by the later screes. (b) Younger Gravels absent, later screes descending to the wadi-bed.

solidated sheets of scree, formed in the usual manner by the disintegration of vertical "free faces" and not by any more general form of weathering.

Since the breccias were interbedded with gravels containing Middle Palaeolithic artifacts, a few being also found in the breccias themselves, there could be little doubt that they were the equivalents of the layers with angular rock-fragments in Haua Fteah, which represent the first cold period of Higgs. This, then, was a time when disintegration was widespread, not merely confined to the cave. It occurred, moreover, at all altitudes, for some of the cliffs from which the breccias were derived stood less than 20 m. above sea-level, lower even than Haua Fteah itself. This was so, for example, in several minor wadis just west of Derna.

Higgs had admitted (1961, p. 149) that the faunal evidence for his first cold period was not so good as for the second. Nevertheless, I could see no alternative to the conclusion that the disintegration was indeed caused by frost-action, effective even near present sea-level. Though this is perhaps a surprising conclusion for a country such as Libya, it will be remembered that the same suggestion was made by Ramsay & James Geikie as long ago as 1878 to account for cemented Pleistocene screes at Gibraltar, and has since been made many times elsewhere in the Mediterranean region.

As for the Younger Gravels, it was clear that they were deposited at the same time as the formation of the screes, and that the screes themselves had in fact provided most of their material; evidently the supply of debris had far outstripped the transporting power of the streams. At times, indeed, this power must have been very great, for the gravels contain large boulders. Nevertheless, they contain no aquatic snails or other signs of perennial water, and it is therefore thought that the wadis at this time were occupied only by occasional floods, such as occur today.

Deposits later than the Younger Gravels

Many wadis were searched for deposits later than the Younger Gravels. Numerous fragments of a low alluvial terrace were, indeed, identified by Mr. VITA-FINZI, who was with me in 1962, but in his opinion these were all post-Classical. A few masses of tufa were also found which might have been late Pleistocene, but none compared in size with the great Middle Palaeolithic deposits of Wadi Derna and elsewhere.

On the sides of the wadis, however, I found other deposits which proved to be of greater interest. These were in the form of sheets of scree, often with an earthy matrix but never cemented. They resembled the breccias in their thickness of one or two metres and in the mean size of their rock-fragments, though in this case there was a greater abundance of boulders, several metres across, either imbedded in the scree or lying along its lower margin. Like the breccias, again, the screes occurred at all altitudes, and always beneath steep cliffs, and thus the two deposits were often found together. Where this was so the scree was always uppermost, but in general it was more continuous and more widespread than the breccia and often overlapped it on to solid rock. The upper surfaces of the screes formed slopes of about 30 degrees, very near the angle of rest, and were generally free from gullies or other signs of erosion.

I had noticed these screes before and had assumed them to be modern. I had also noticed, however, that they were often covered with vegetation and showed no convincing signs of being added to at the present day. Moreover, in 1948 I had collected artifacts from within a similar deposit at the mouth of Wadi Giargiarummach, and Dr. McBURNEY had shown that these belonged to the Dabba culture of the Upper Palaeolithic. Even in this case I had suspected that the scree might still be modern, the artifacts being perhaps derived from some surface site higher up the slope.

In 1962, however, I found artifacts in many other places, both on and within the screes. The principal localities were the lower reaches of Wadi bu Msafer, Wadi en Naga and Wadi ben Gebara, respectively 5, 9 and 25 km. west of Derna, and a restricted area near the springs of Wadi Susa, 4 km. south of Susa. Of the 850 specimens collected very few were recognisable tools and most of these, according to Mr. HIGGS, appeared to be of Middle Palaeolithic types. Nevertheless, since the collection also included large numbers of blades, Dr. McBURNEY advised me to make a statistical analysis of the specimens according to frequencies of lengths and of length-breadth ratios. This he had already done himself for the various industries of Haua Fteah, and had obtained very consistent results for each culture. My own results showed clearly that the majority of the artifacts from both within and upon the screes must be assigned to the Dabba culture, the few Middle Palaeolithic specimens having almost certainly been derived from the underlying breccias.

In Haua Fteah the Dabba culture, the earliest of the local Upper Palaeolithic, made its first appearance during the second warm period. Thereafter it continued throughout most of the second cold period, to be replaced by the Eastern Oranian only at about 15,000 B.P. Since the cavedeposits of this cold period, as of the first, are full of angular limestone fragments, I could only conclude that this was also the time when the loose screes were formed. The lack of erosion during the past 12,000 years is certainly remarkable, and especially so since the underlying breccias had been heavily eroded even before the screes were laid down. The most probable explanation is that the screes, being highly porous, cannot support surface drainage, whereas the matrix of the breccias is more or less impermeable.

Once again, therefore, there was evidence for widespread distintegration during a known cold period, and again I had to conclude that frost-shattering was responsible. In this case, however, the results were different, for no terraces had formed in the wadis.

The reason for the difference emerged from a study of the lower margins of the screes. In a few places they descended almost to the present wadi-bed (Fig. 2b): this only increased the difficulty, for it showed that screeformation had been preceded by downcutting and that at least one important condition had existed for the formation of a second terrace. More commonly, however, the lower edge of the scree rested upon the surface of the terrace of the Younger Gravels, and where this was it often failed to cover more than a part of the width of the terrace (Fig. 2a). This showed that most of the scree could never have reached the wadi-beds, whereas the products of the first phase of disintegration had done so in sufficient quantity to provide the material for vast amounts of gravel.

In other words, the first cold period, though probably shorter than the second, must have produced many times as much debris. This in itself was an adequate explanation for the absence of a sccond Pleistocene terrace; it was not necessary to invoke either a greater contemporary flow of water or total removal of debris by subsequent erosion.

Since so little of the debris had been removed, it was often possible to make a rough estimate of the volume of rock lost during this period of disintegration by one particular cliff, and hence of the distance by which the cliff had receded. The estimated distances ranged from 1.6 to 6 metres, giving average rates of recession of from 0.08 to 0.3 millimetres a year. All these results were obtained from low-lying screes; higher values would presumably have been obtained at higher altitudes.

Discussion of climatic implications

Altough the process of frost-shattering is still imperfectly understood, it seems generally agreed that there are two main climatic requirements: adequate precipitation, and temperatures oscillating on either side of freezing-point. Once these requirements are satisfied, the rate of disintegration will presumably depend partly on the amount of precipitation, partly on the frequency of frost-changes (oscillations of the temperature through freezing-point). The amplitude of the frost-changes must also be important, for the degree of frost will govern the depth to which the rocks will be penetrated in a given time.

With so many variables, any climatic interpretation of my estimated rates of disintegration can only be tentative. Moreover, such an interpretation will only be possible with a knowledge of modern weathering processes and climatic conditions in other areas which, besides being cold enough for frost-shattering, are also geologically similar to northern Cyrenaica. Fortunately there is at least one suitable area where such information is available. A. Rapp (1960) has carried out a study of this kind at Tempelfjorden, Spitsbergen, where the rocks resemble those of northern Cyrenaica both in their lithology and in their low dips, the only important difference being that they are apparently better jointed. Here he found extensive screes, lying, as in Cyrenaica, beneath vertical cliffs, and for the present rates of recession of these cliffs he obtained figures remarkably close to my own: 0.02 to 0.2 mm. a year.

The area where Rapp worked receives about 300 mm. of precipitation a year. In Cyrenaica, the annual rainfall at Derna is only 200 mm., but elsewhere on the coast of the Gebel Akhdar it is generally over 300 mm., while on the higher parts of the Gebel it rises to 600 and 700. During the cold periods the rainfall, according to Higgs, may have been still higher, so that even Derna would have had a greater annual precipitation than present-day Tempelfjorden. Though the effect of this would be reduced by a higher rate of evaporation, it seems reasonable to conclude that, with similar rates of disintegration, frost-changes on the Cyrenaican coast during the second cold period would have been somewhat fewer and of smaller amplitude than at Tempelfjorden today.

According to RAPP (1960, p. 18) frost-changes now occur at Tempelfjorden on an average of 59 days each year and their maximum amplitude is 5.5 degrees C. Thus, the lowlying Cyrenaican screes may not necessarily imply more than two months of moderate nightly frost each winter, with a January mean temperature perhaps a few degrees above zero. Even so, this represents a climate appreciably more severe than that of today, when the temperature at sea-level rarely falls below 7 degrees and the January mean temperature is about 14.

In Spitsbergen, of course, winter temperatures are so low that frost-shattering ceases altogether over long periods. It is conceivable that this was also the case in Libya, and this is certainly suggested by results obtained by EMILIANI (1955) from a deep-sea core collected some 550 km. east-north-east of Derna. Applying the oxygen-isotope method to planktonic foraminifera, he estimated that, at 17,200 B.P., summer surface-water temperatures in the eastern Mediterranean sank to 8 degrees C., some 20 degrees lower than they are today. These results have, however, been questioned by PARKER (1958, pp. 238-40). In any case so cold a climate would hardly have permitted the survival of animals such as the gazelle, which HIGGS shows to have been present throughout this time; it would also have induced phenomena such as cryoturbation, of which no traces have been found even on the highest parts of the Gebel.

For the first cold period no estimates of rates of disintegration can be made. Reasons have already been given, however, for believing that they were far higher than during the second. This was an unexpected conclusion, for PARKER, working on frequencies of foraminifera from deep-sea cores, agreed with EMILIANI that temperatures in the eastern Mediterranean were lower at about 17,000 B.P. than at any other time during the past 100,000 years (PARKER, 1958, Fig. 2; EMILIANI, 1955, Fig. 1). It can only be supposed that, during the first cold period, cracks in the rocks were more consistently filled with water than during the second; in other words, that the climate, though not so cold, was wetter. This would agree with the results of HIGGS, and with the fact that extensive tufa deposits are associated with the first cold period but not with the second. It also agrees with conclusions reached elsewhere in the Mediterranean region (e.g. BUTZER, 1958, pp. 101—2).

Finally, some consideration must be given to the matrix of the screes and breccias. Clay is the main constituent in the case of the breccias, the only constituent in the case of the screes, and is itself of doubtful origin. Since the limestone are mostly very pure it can hardly be a product of chemical weathering within the deposits; most probably it originated on the plateaux between the wadis and was washed or blown on to the scree-slopes during their formation.

The real point of interest is that only the older deposits are cemented. Since the water-table must always have been low in this region of cavernous limestone, the water by which the calcium carbonate was mobilised must have come from above, not from the underlying bedrock. The uniform cementing of the breccia suggests that it percolated slowly downwards from a uniform cover of vegetation, for which evidence exists in the form of rootlet-impressions. Rainfall must have been sufficiently heavy and frequent, during a part of each year, to keep the deposits damp without actually causing leaching; there must, at the same time, have been a definite dry season, to allow the calcium carbonate to be redeposited.

The process of cementing cannot have begun before the scree was stabilised. It must, on the other hand, have been completed long enough before the deposition of the later screes to have allowed some erosion to take place. The erosion itself may well have been the result of destruction of vegetation during the intervening warm period; it is being continued today wherever the breccia is exposed. The cementing thus seems to represent a time at the end of the first cold period when the rainfall remained high even though frost-shattering had already ceased.

After the stabilisation of the later screes, the climate, as shown by the uncemented matrix, must have been relatively dry up to the present day. There are, indeed, some signs of incipient cementation, in the form of thin films of secondary calcium carbonate around many of the rock-fragments; these must denote a brief wet season, such as there is today. Again, the state of the matrix gives no direct indication of conditions during the accumulation of the scree. If, however, the former level of rainfall was again maintained for a time after the screes became stable, that level must have been very much lower than during the first cold period. This, of course, is a conclusion already reached on other and more convincing evidence.

Summary of conclusions

It will now be useful to summarise my conclusions concerning the climatic and physiographic history of northern Cyrenaica during the last 50,000 years.

Dates B.P.	Climatic and Geological events
About 50,000	Temperate and very wet, perhaps only for a few millennia. Deposition of tufa and calcareous marl in some wadis.
50,000 - 43,000	Cold; winters still very wet, summers probably dry. Active frost-shattering in winter, leading to formation of screes and re-deposition of much debris in the wadis as the terraced Younger Gravels. Screes cemented soon after their final stabilisation.
43,000 - 32,000	Warm and dry. Erosion of cemented screes, down-cutting in wadis, no deposition.
32,000 - 12,000	Cold; winters wetter than today but not so wet as in the previous cold period; summers probably dry. Frost-shattering less active than before, leading to scree-formation but not to deposition in wadis. No cementing of screes.
12,000 - present day	Generally warm and dry. Renewed down-cutting, no deposition.

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