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# Vegetational History of Buran-Kaya III

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Pollen studies of the sediments in the multilayered site of Buran-Kaya III (eastern Crimea) reveal vegetational dynamics in the site and its vicinity over a long period of the site's existence—from the Middle Paleolithic to the Neolithic. The site's deposits (up to 3 m thick) accumulated within the rockshelter, which was formed in the limestone of the internal ridge of the Crimean Mountains (maximum altitude 350 m above sea level). The rockshelter is located in the steep right slope of the Burulcha River Valley, where it cuts the ridge at 250 m above sea level, 8 m above the water level. The rockshelter is exposed to the south-west and is presently wide-open to the light. A buried karst channel was discovered in the inner part of the shelter (personal communication, A. Yanevich), indicating that the Buran-Kaya III cavity was part of an underground drainage system. At the present time, water still seeps on the walls and moistens the lowermost deposits of the shelter.

Buran-Kaya III is located within the low mountain forest-steppe region (forests of *Quercus pubescens* Willd. and meadow steppes) of the Euxinian forest province, Crimean Mountain subprovince (Barbarych 1977). Arboreal vegetation is mainly found in river valleys and ravines, and consists of oak (*Quercus pubescens* Willd., *Quercus petraea* Liebl., and *Quercus robur* L., the first strongly predominates) with an admixture of maple (*Acer campestre* L.), ash (*Fraxinus excelsior* L.), and elm (*Ulmus suberosa* Moench.). The undergrowth is formed by spindle tree (*Euonymus europea* L.), hazelnut (*Corylus avellana* L.), shrub hornbeam (*Carpinus orientalis* Mill.), cornelian cherry dogwood (*Cornus mas* L.), bloody dogwood (*Cornus sanguinea* L.), buckthorn (*Rhamnus cathartica* L.), Christ's thorn (*Paliurus spina-Christi* Mill.), and smoke-tree (*Cotinus coggygria* Scop.). Hawthorn (*Crataegus pentagyna* Jacg.), blackthorn (*Prunus spinosa* L.), rose (*Rosa corymbifera* L.), and wild pear (*Pyrus elaeagnaceae* Pall.) grow in drier spots. Steppic plants dominate the plateau-like tops of the ridge, and consist of grasses (Gramineae) and Herbetum mixtum. The grasses are primarily sheep's fescue (*Festuca sulcata* Hock.) and feather-grass (*Stipa* L.), whereas the Herbetum mixtum includes many plants of the Lamiaceae (*Thymus*, *Satureja*, *Teucrium*, *Scutellaria*, *Salvia*), Rosaceae (*Filipendula*, *Potentilla*), Ranunculaceae (*Adonis*, *Thalictrum*, *Actaea*), Fabaceae (*Genista*, *Medicago*), Apiaceae (*Pimpinella*), and Asteraceae (*Centaurea*, *Xeranthemum*) families. Most of the above-mentioned species of Lamiaceae and Asteraceae, as well as *Genista* and *Pimpinella*, are well adjusted to the xeric conditions of limestone substrata.

The soils that formed on limestone under the steppe vegetation are turf-carbonate soils (rendzinas), whereas the soils formed under the low mountain forests are dark-brown mountain soils (brown rendzinas). The soils of the valley bottoms are meadow-chernozems; these are the most rich in humus and the thickest in depth.

Palynological investigations of Crimean Upper Pleistocene deposits were carried out at the Mousterian site of Zaskalnaya V, located in eastern Crimea (Gubonina 1985), at the Middle Paleolithic site of Kabazi II located in western Crimea (Gerasimenko 1999), and at the Final Paleolithic site of Skalisty in western Crimea (Cohen et al. 1996). The pollen spectra of the deposits in western Crimea display a much higher proportion and a greater diversity of arboreal pollen than the deposits in eastern Crimea, indicating a wetter climate in western Crimea. Presently, the eastern Crimean forest-steppe also has a more continental climate (greater temperature variation, longer frost period, shorter vegetational period) than western Crimea. From west to east, the precipitation drops from 600 mm to between 500–470 mm, resulting in more extensively distributed and taller stands of forest, as well as a more mesophytic composition of steppe coenoses in western Crimea as compared to the eastern Crimea forest-steppe.

## Materials and Methods

A series of 24 pollen samples from the Buran-Kaya III sedimentary sequence was analyzed. The sample processing involved treatment with 10% HCl, 10% KOH, 15% $Na_4P_2O_7 \times 10\ H_2O$ and flotation in a Thoulet solution. The pollen frequency was generally low (8–33 grains per slide), yet enough to count between 100 and 200 grains per sample and to plot the pollen diagram (Figure 2-1). Two samples from Level 6 did not yield enough pollen to be included in the diagram. The highest pollen frequencies were observed in the sediments of Levels 3A, C, B, 6-3, basal portions of Levels 6-1 and 6-5, and at the top of Level 4, respectively. Layer 5 was the poorest in pollen.

Differential preservation of microfossils was found within each sample. Spores and arboreal pollen were consistently well preserved, whereas pollen grains of herbs had both good and bad preservation rates. The pollen grains of dicotyledonous herbs in particular were creased, while microfossils of Cyperaceae and Gramineae were frequently broken. This suggests that the arboreal pollen found in the site was mainly airborne, while herbaceous plant pollen was deposited in Buran-Kaya III both by eolian and slopewash transportation. The presence of a karst channel indicates that there was surface runoff into the rockshelter. Spores have a very high resistance to destruction and are therefore usually well preserved.

Generalized studies of surface samples in modern vegetational zones and in mountain vegetational belts (Grichuk and Zaklinskaya 1948; Klopotovskaya 1976) serve as the basis of the pollen diagram interpretations. Since the Buran-Kaya III pollen spectra are dominated by herbaceous pollen, studies of surface samples in the steppe zone are especially important (Dinesman 1977; Arap 1972; Bezusko et al. 1992, 1997). The characteristic feature of the Buran-Kaya III pollen diagram is a high percentage of spores—these account for an average of 37% (and up to 65%) of the total number of microfossils. High percentages of spores are typical for forest and tundra belts. Yet, the Buran-Kaya III pollen spectra point to neither forest zone (due to low percentages of arboreal pollen), nor tundra (due to the consistent presence of Polypodiaceae). Thus, the abundance of spores is a local feature of the pollen spectra formation dictated by paleovegetation in the immediate vicinity. Spores do not spread far from the plants that produce them, and both mosses and ferns usually grow in rock cracks and cavities. Within the modern steppe belt of Ukraine, certain rock outcrops are refugia for several fern taxa, enabling their preservation (Genov 1987).

The very low percentages of *Pinus* pollen (less than 11%) indicate that pine did not grow near the site, and also that pollen spectra formation in the rockshelter was not strongly affected by long-distance wind-blown transport. The pollen sequence from Buran-Kaya III reflects the vegetational dynamics only of the immediate site surroundings.

Specialized pollen studies of both mountain (Klopotovskaya 1976) and plain regions (Spiridonova 1991) have shown that the airborne pollen that accumulates on valley slopes and on terraces is derived mainly from pollen producers in the valley bottoms, and that upward air movements prevail in valleys. In Buran-Kaya III, the pollen spectra formation was affected by pollen input from runoff and slopewash processes, so the spectra reflect the vegetation of both higher and lower topographical altitudes, although lower altitude vegetation tends to dominate. It should be noted that Ranunculaceae pollen, a frequent member of meadow coenoses, as well as Fabaceae and Apiaceae pollen, are always well preserved. The highest numbers of disfigured pollen grains were seen in Lamiaceae, Rosaceae, Brassicaceae, Asteraceae, some Cichoriaceae, and Chenopodiaceae. This suggests that the representatives of these families grew in the higher topographic areas. Still, many pollen grains of Chenopodiaceae, *Artemisia*, and almost all of *Ephedra*, as well as part of Lamiaceae, Rosaceae, and Cichoriaceae, have very good preservation. This means that they contributed to the pollen spectra as wind-blown components from either the floodplain or the plateau.

In order to differentiate the regional environmental changes and the specific local features controlled by rock crevices, some adjustments are made in the pollen diagram (Figure 2-1). Arboreal pollen (AP) and non-arboreal pollen (NAP) percentages, as well as the percentages within each taxa of these groups, were calculated from the sum of arboreal and herbaceous pollen. Percentages of spores were calculated separately, from the total number of microfossils. Two special pollen sums were calculated within NAP: one comprised of xerophyte pollen (Chenopodiaceae, *Artemisia*, Plumbaginaceae, and *Ephedra*) and the other comprised of Herbetum mixtum pollen. This latter term is traditionally used in Russian geobotanical literature to designate dicotyledonous herbs that form a mesophytic component of steppe associations in the Eastern European Plain and that are especially abundant in meadow steppe environments (Herbetum mixtum steppes of the present day forest-steppe belt). The abundance of Herbetum mixtum in the steppe composition progressively decreases southwards in direct relation to lessening precipitation and increasing Gramineae and xerophytes in the steppe coenoses. Thus, the proportional representation of these two groups in the pollen percentages enables hypotheses about climatic conditions. Pollen of the Asteraceae family, which has both xerophytic and mesophytic representatives, is not included in Herbetum mixtum and is counted separately. The other more specific problems of pollen interpretation will be discussed below, after the description of the diagram's pollen zonation.

## Pollen Zonation

Fourteen pollen zones were recognized in the Buran-Kaya III deposits (Figure 2-1). The basal portion of sedimentary sequence was studied in the exposure from the 2001 excavations (shown in the lower part of the diagram).

### Pollen Zone I (3.00–3.05 m, Level E)

Zone I is one of few zones in the diagram with a forest-steppe type pollen spectrum (20% AP, 80% NAP). The arboreal pollen is dominated by boreal taxa: *Pinus*, *Alnus*, and *Betula*, though the presence of a single pollen grain of the broad-leaved *Tilia cordata* Mill. is notable. The good preservation of the *Tilia* grain excludes the possibility that it was redeposited. The non-arboreal pollen is dominated by Herbetum mixtum (especially Lamiaceae) and Cyperaceae. Asteraceae pollen is also rather abundant, whereas xerophytes (Chenopodiaceae) and Gramineae are underrepresented. Spores make up a significant proportion of the total number of microfossils (40%), and are dominated by Bryales (24%). Polypodiaceae are second in prevalence (9%), and primarily represented by Pterideae spores. The other spores are from Lycopodiaceae and *Botrychium* sp.

### Pollen Zone II (2.55–2.90 m, Level D)

Pollen Zone II corresponds to Level D and is homogenous in its pollen content, with steppe pollen spectra (16% AP and 84% NAP). The arboreal pollen consists of boreal taxa: *Alnus* (dominating) and *Betula* consistently, and *Pinus* in the upper part of the level. Herbetum mixtum is a major component of the non-arboreal pollen, Cyperaceae are second in prevalence in the lower spectrum, while Gramineae and Asteraceae counts increase in the upper spectrum. Xerophytes are not significant, although *Artemisia* and *Ephedra* appear together with Chenopodiaceae. The composition of the Herbetum mixtum is not diverse: Lamiaceae, Rosaceae, and Brassicaceae dominate, and Rubiaceae and Cichoriaceae are noticeable, but Ranunculaceae pollen, present in Level E, has disappeared.

Two subzones, associated with Levels D3 and D1, can be distinguished based on their spore content (33% and 50% respectively). Counts of Lycopodiaceae and *Botrychium* are the same in both subzones (and match the values of zone I), whereas Polypodiaceae, and especially Bryales, first decrease in the lower level, then increase again in the upper level.

Level D1 is rich in Pterideae spores, although a distinctive feature of the level is the abundance of the other Polypodiaceae (Asplenieae, Aspidieae, Polypodiaceae s. str., et al.).

### Pollen Zone III (2.30–2.40 m, Level C)

Zone III has the same general pollen content as Level D (16% AP, 84% NAP). The zone III non-arboreal pollen differs from zone II both by an increase of xerophyte pollen counts and by the diversification of Herbetum mixtum. The maximum number of Chenopodiaceae for the Buran-Kaya III 2001 section is seen in this zone, and Plumbaginaceae, *Artemisia*, and *Ephedra* contribute to the xerophyte pollen complex. Herbetum mixtum includes 10 families, with Lamiaceae and Cichoriaceae strongly prevailing in number. Arboreal pollen includes *Pinus*, Cupressaceae, *Alnus* (dominating), and *Betula*. The spore content (33%) is average for the section—Bryales prevail (11%), while counts of other spores are equally distributed among Lycopodiaceae, *Botrychium*, Pterideae, and the other Polypodiaceae. The pollen sample from Level C is enriched in microscopic charcoal.

The main part of the sedimentary sequence was studied from sample taken during the 1998 excavations at Buran-Kaya III (Figure 2-1 *supra*).

## Pollen Zone IV (2.30–2.50 m)

Zone IV is characterized by steppe pollen spectra (5–12% AP, 88–95% NAP). The arboreal pollen consists only of *Pinus* and *Alnus*, with a distinct *Pinus* predominance in the lower part of the pollen zone. Xerophytes and Herbetum mixtum prevail in the non-arboreal pollen, followed by Gramineae pollen. Xerophytes (Chenopodiaceae, *Artemisia*, and *Ephedra*) are particularly prominent in the upper part of the zone, forming one of the xerophytic maxima in the pollen diagram. The lower part of the pollen zone has a higher Cyperaceae pollen content and a more diverse composition of Herbetum mixtum. Spores (35–45%) are predominantly Bryales (10–15%) and Pterideae (10–13%). The sediments of pollen zone IV are poorer in microfossils than Levels E, D, and C.

In the sedimentary sequence from the 1998 excavations at Buran-Kaya III, the deposits containing pollen zone IV underlie Level C, the pollen of which was analyzed from the 2001 excavations. What could be the position of pollen zone IV relative to the lower pollen sequence (Figure 2-1 *infra*) from Buran-Kaya III 2001? It has features both in common with and distinct from pollen zones II and III (Levels D and C respectively), though it definitely differs from zone I.

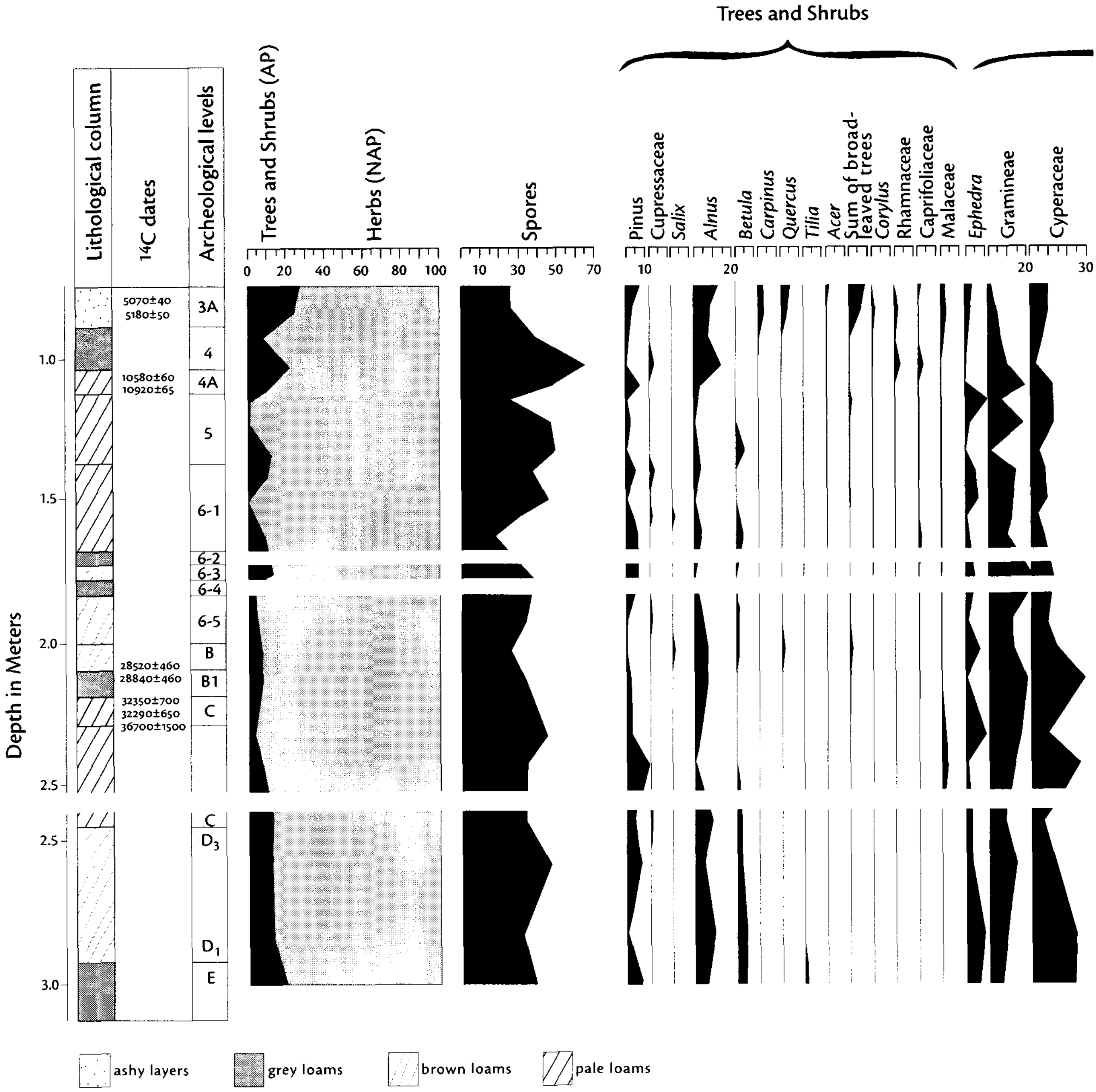


Figure 2-1—Pollen diagram of Buran-Kaya III.

From bottom to top, zone IV shows the same trend of increasing xerophytes and decreasing Cyperaceae as seen in the zone II and III sequence. Based on the non-arboreal pollen composition, it is possible to position zone IV between zones II and III as a kind of transition. Yet, discrepancies appear then with the arboreal pollen content and composition. Zone IV generally is poorer in arboreal pollen than zones II or III, and particularly poorer in *Alnus* pollen. It is also important that *Betula* pollen, rather typical for zones I–III, is absent in zone IV, which has arboreal pollen dominated by *Pinus*. The other difference is that in pollen zones D and C, Herbetum mixtum dominates over xerophytes, whereas the opposite ratio is found in pollen zone IV. From the standpoint of the pollen, it seems that there is no equivalent to pollen zone IV in the Buran-Kaya III 2001 sequence, or that the sediments of pollen zone IV were formed under conditions having very limited eolian pollen input (the inner part of a cavity, a narrow entrance).

## Pollen Zone V (2.00–2.20 m)

Zone V represents Levels B and B1 and was identified by having common characteristics of steppe pollen spectra: (1) the same general composition of pollen

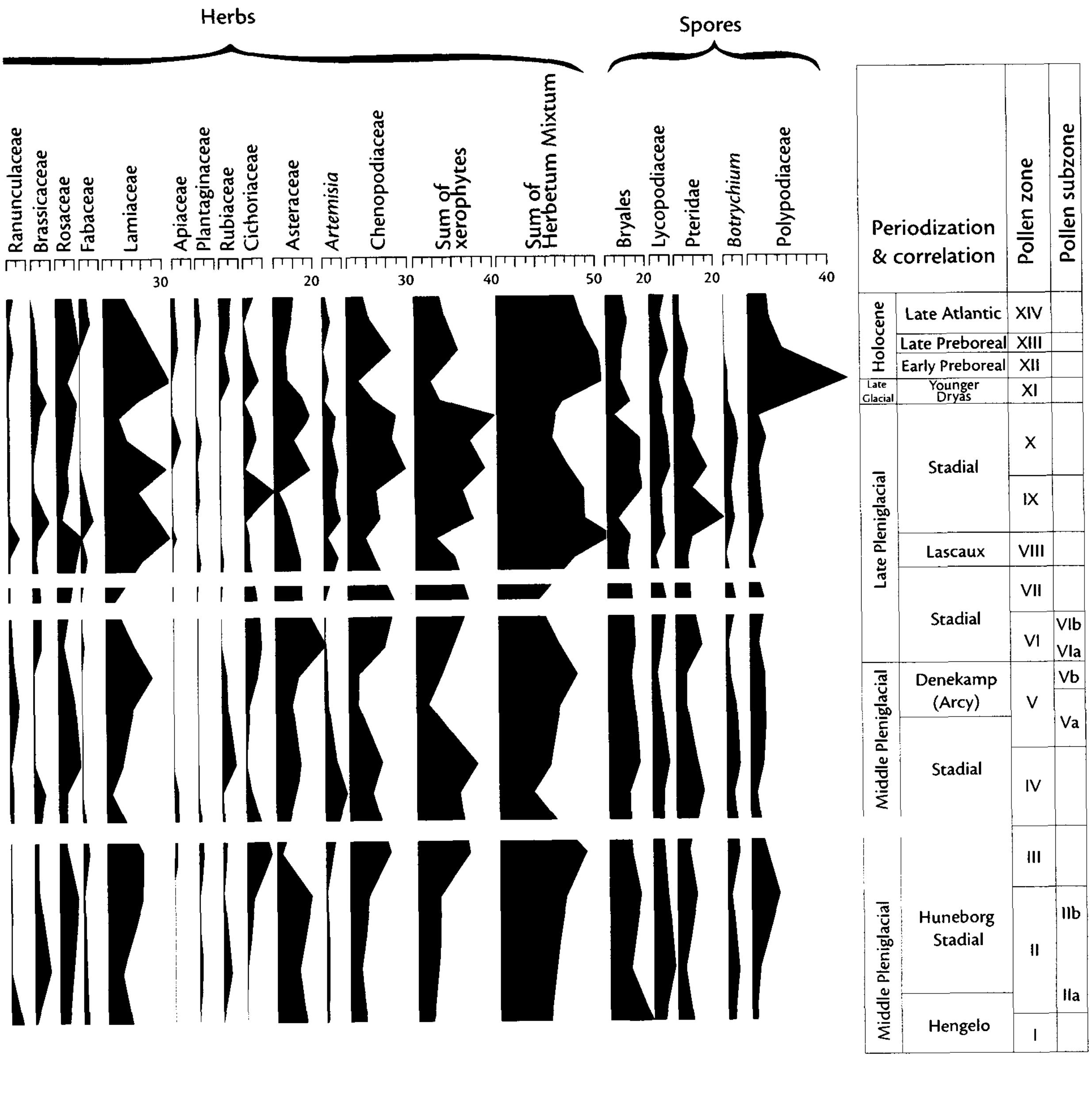


Figure 2-1 continued—Pollen diagram of Buran-Kaya III.

(8% AP, 92% NAP), (2) a lower percentage of spores than the average seen in the rest of the section, (3) a low number of xerophytes in the non-arboreal pollen, (4) the same taxa composition of non-arboreal pollen, (5) the predominance of *Alnus* in arboreal pollen, and (6) low values of Lycopodiaceae and *Botrychium* sp. The low proportion of xerophytes is a distinctive feature of pollen zone V in the diagram. Also distinctive is the significant number of grains from the Ranunculaceae family, which includes many mesophytic species. The boreal tree *Betula* is underrepresented in pollen zone V as compared to its counts in the lower archeological units (only a single *Betula* pollen grain was found).

Zone V can be subdivided into two subzones representing Levels B and B1, based on differences in the two pollen spectra. The lower subzone (Va, Level B1) is richer in Cyperaceae pollen and in spores, while the upper (Vb, Level B) has a higher count of Herbetum mixtum (at the expense of Lamiaceae) and of xerophytes (at the expense of *Ephedra*). The arboreal pollen of Layer B has a more diverse composition of boreal taxa (*Salix*, *Alnus*, and *Betula*), and single pollen grains of *Quercus* were noted. The well preserved *Quercus* pollen (*Quercus pubescens* Willd.) was not redeposited. Given the absence of *Pinus* microfossils (only one pollen grain of pine was found in Level B1), long-distance pollen transport into the site did not occur, and oak must have grown in the site vicinity. The sample from the upper Level B is enriched in microscopic charcoal.

## Pollen Zone VI (1.80–1.9 m, Level 6-5)

Zone VI is rather similar to pollen zone V in most of the indices, including in the overall pollen and spore content (6–7% AP, 93–94% NAP, and 34–38% spores of the total sum) and diversity of taxa. The distinctive features are a higher number of xerophytes (mainly Chenopodiaceae) and Asteraceae, and lower values of Herbetum mixtum and Cyperaceae than in zone V. The lower part of zone VI is somewhat different from the upper part. The lower spectrum displays the Asteraceae maximum for the diagram, whereas the upper spectrum displays the Gramineae maximum for the diagram. Xerophytes are more abundant and Herbetum mixtum is less abundant in the upper part of the zone. The arboreal pollen in the lower spectrum is similar to that of zone V: *Alnus* (dominating), *Betula*, and Cupressaceae (*Juniperus* sp.). The arboreal pollen of the upper spectrum is comprised of only a few *Pinus* grains. Thus, the lower part of zone is a kind of transition between zone V and top of the zone VI. The upper sample is also poorer overall in pollen than the lower one and pollen zone V. This is the only sample contaminated by modern-day pollen of *Juglans regia* (3 grains), which presently grows near the section (A. Yanevich, personal communication). The spore group is dominated by Bryales, though Pteridae are abundant in the lower part of the zone. The remainder of the spore complex has the same values as pollen zone V, with slightly more Lycopodiaceae.

## Pollen Zone VII (1.8–1.62 m)

Zone VII corresponds to the pollen-rich Level 6-3, and probably to Levels 6-4 and 6-2, as well, which are very poor in pollen. Levels 6-4 and 6-2 have been combined with the same pollen zone as Level 6-3 due to similarities in their overall pollen composition (14–16% AP, 84–85% NAP), the same arboreal taxa, and the prevalence of Herbetum mixtum over xerophytes in the non-arboreal pollen. The proportions of spores are higher in Levels 6-4 and 6-2 than in Level 6-3 (18%). This might be related to the better resistance of spores to those destructive factors that definitely affected the spectra formation of the two pollen-poor levels.

The arboreal pollen of pollen zone VII includes only boreal taxa: *Pinus*, *Alnus*, and *Betula* (in equal proportions). The non-arboreal pollen can be statistically characterized in Level 6-3, and is dominated by Herbetum mixtum and xerophytes. A drop in Gramineae, as compared to pollen zone VI, was observed. Herbetum mixtum is diverse in composition and as abundant as pollen zone V (Levels B and B1). Yet, the Cyperaceae counts are lower and the xerophyte values higher than in pollen zone V. The increase of *Artemisia* is noteworthy: beginning with this zone, it is an important component of the xerophyte complex in the diagram (up to the Holocene). The low spore percentage in subzone 6-3 is due to the very low counts of Lycopodiaceae and Polypodicaeae (with the exception of Pteridae), and to the absence of *Botrychium* spores. Pteridae and Bryales are more abundant in Level 6-2 and particularly in 6-4.

## Pollen Zone VIII (1.55–1.62 m)

Zone VIII was distinguished in the lower part of Level 6-1 based on its having the maximum value of Herbetum mixtum in the Pleistocene part of the sequence, as well as having the lowest percentage of xerophytes. Nevertheless, the pollen spectrum for zone VIII is a steppe type (9% AP, 91% NAP), and the arboreal pollen includes only boreal taxa, though with a rather diverse composition (*Pinus*, Cupressaceae, *Salix*, *Alnus*, and *Betula*). Herbetum mixtum pollen is also diverse, but still dominated by Lamiaceae and Rosaceae. Pollen from the Ranunculaceae family, which includes many mesophytic species, is noticeable, while the total number of Cyperaceae is very low. Spores are dominated by Bryales and Pteridae, and only few *Botrychium* spores were found. The pollen sample is rich in pollen and in microscopic charcoal.

## Pollen Zone IX (1.40–1.55 m)

Pollen zone IX corresponds to the middle and upper part of Level 6-1, and is identified by its high numbers of xerophytic and non-arboreal pollen (90–100%). Arboreal pollen is totally absent in the lower sample, whereas in the upper one, several pollen grains of *Juniperus* sp., along with *Pinus* and *Alnus*, were found. *Juniperus* pollen is typically poorly preserved in the sediments, so its presence in the sample indicates that this plant definitely grew near the site. The characteristic feature of the non-arboreal pollen is a rather high proportion of both *Artemisia* and *Ephedra*, in addition to the significant Chenopodiaceae component of xerophytic pollen. The taxa composition of Herbetum mixtum is poor, especially in the lower sample (only 4 families), and has a strong prevalence of Lamiaceae. The upper sample is rich in Cichoriaceae pollen, however. Beginning in pollen zone IX, Ranunculaceae disappears until the Holocene. Spores are fairly abundant, dominated by Bryales and Pteridae, although *Botrychium* also increases in number.

## Pollen Zone X (1.15–1.40 m, Layer 5)

Zone X is rather homogenous in its spectra components, and has several distinctive features for the Buran-Kaya III pollen diagram. First, it displays the maximum values of xerophyte pollen and the lowest values of arboreal pollen (2%, 2%, and 7% of the samples). In the lower part of the zone, *Betula* pollen is noticeable (and this is the last zone in the sequence with *Betula*), whereas in the upper samples, only single grains of *Alnus* and *Pinus* were found. Xerophytes are represented by Chenopodiaceae, *Artemisia*, and *Ephedra*, while the Herbetum mixtum composition is very poor: two to four families in the lower samples. This low frequency may be connected to the low pollen frequencies in these samples overall; pollen has the same relative abundance as the spores, which are far more resistant to destruction. Asteraceae pollen is well represented, and Lamiaceae is predominant among the Herbetum mixtum. Spores are dominated by Bryales, although the Lycopodiaceae and *Botrychium* counts are significant. The percentage of Pteridae is high in the basal portion of the zone.

## Pollen Zone XI (1.10–1.15 m, Level 4A)

Zone XI displays a steppe type composition (10% AP, 90% NAP), but the composition of the non-arboreal pollen spectrum is different from that of zone X. The group is dominated by Herbetum mixtum and Gramineae, and Asteraceae are noticeable, but xerophytes, represented only by Chenopodiaceae, drop sharply in number. The Herbetum mixtum composition continues to be very poor (three families), and Lamiaceae prevails. Arboreal pollen includes *Alnus* and *Pinus*. Spores are very abundant (48%) and dominated by different Polypodiaceae, though not so much by Pteridae. Bryales and Lycopodiaceae have relatively high counts, but *Botrychium* is represented by only a few grains.

## Pollen Zone XII (1.00–1.10 m)

This zone corresponds to Level 4 (the lower part) and has a forest-steppe type of spectra. Spore counts reach their maximum in the diagram in this zone (65%), and, for the first time, the arboreal pollen count (21%) is at the same level as it was at the bottom of the sequence (pollen zone I). The arboreal pollen consists of boreal taxa—mainly *Alnus*—but still has rather diverse shrub pollen: *Juniperus*, *Rhamnus*, and Caprifoliaceae (*Viburnum*?). Xerophytes have the same low proportions seen in pollen zone I, whereas Herbetum mixtum has the absolute maximum in the diagram, and is more diverse than in pollen zone XI. Lamiaceae prevail, while Asteraceae are not important. Starting from this level, Herbetum mixtum pollen counts never return to the low values of the Pleistocene part of the diagram. Spores are absolutely dominated by Polypodiaceae (Asplenieae, Aspidieae, Polypodiaceae s. str.). Pteridae and other components of the spore complex (Bryales, Lycopodiaceae, and *Botrychium*) do not appear in significant numbers.

## Pollen Zone XIII (0.90–1.00 m)

Zone XIII is found in the upper part of Level 4, and has steppe type pollen spectra that is similar to pollen zone XII (9% AP, 91% NAP, 39% spores). Zone XIII differs from zone XII by having a higher proportion of *Alnus* in the arboreal pollen, and by having lower values of Gramineae and higher values of Herbetum mixtum in the non-arboreal pollen. The diversity of this group is significant (Lamiaceae and Rosaceae prevail). Spores are still dominated by Polypodiaceae, but are only a third of the pollen zone XII values. Lycopodiaceae and Bryales are present, but *Botrychium* disappeared from the pollen diagram in this zone.

## Pollen Zone XIV (0.76–0.90 m, Layer 3A)

Zone XIV demonstrates an important change in the diagram: the appearance of broad-leaved taxa, including *Quercus*, *Carpinus*, *Acer*, their satellite *Corylus*, and *Rhamnus*. *Alnus* is still a little higher in pollen counts than the broad-leaved taxa, but *Pinus* is lower. The pollen spectra are of forest-steppe type (20–29% AP, 71–80% NAP, 26% of spores from the total sum). Herbetum mixtum with a rich composition (nine families) strongly dominates the non-arboreal pollen, whereas xerophytes are second in abundance

(Chenopodiaceae dominates, but *Artemisia* and *Ephedra* are also present). The low proportion of Gramineae pollen is the other distinctive feature of the complex. Spores are dominated by Bryales and Polypodiaceae, though the number of Pteridae spores are the lowest in the section. Lycopodiaceae is average for the section, while *Botrychium* sp. is absent.

## Main Characteristics of the Pollen Diagram and its Components

The main feature of the Buran-Kaya III pollen diagram is a distinct predominance of steppe pollen spectra, combined with a high proportion of diverse spores. These are explained by the impact of both regional and local factors on pollen spectra formation. Forest-steppe type pollen spectra were discovered at the base of the sequence (pollen zone I, Level E) and at the top of the sequence (pollen zone XII, the lower part of Level 4, and pollen zone XIV, Layer 3A). In two cases (Levels E and 3A), the forest-steppe spectra include pollen of broad-leaved taxa, which is rather abundant in Layer 3A. Pollen zone XII has only boreal pollen taxa. The only other appearance of a few pollen grains of broad-leaved species (namely *Quercus*) occurs in pollen zone V (the upper subzone, Level B). The arboreal pollen in the remainder of the diagram are boreal taxa.

The low percentages of *Pinus* pollen testify to its long-distance wind-blown origin. *Alnus* (alder) pollen is consistently the main component of the arboreal pollen. The alder pollen grains are normally developed, which means that the trees were well adapted to the environment (the Burulcha River floodplain). *Betula* (birch) pollen is found in small quantities in pollen zones I through X (the lower part), and disappears in the upper part of the section. The *Betula* pollen are arboreal forms (*Betula* sect. Albae), and are usually underdeveloped (small pollen grains with weak exines and weakly developed pore apertures). The environment was therefore not favorable to *Betula*'s pollination and growth. At the present time, the boreal tree *Betula* rarely grows in the temperate climate of the Crimean Mountains, it was obviously also at the limit of its natural habitat in the area under investigation during the Upper Pleniglacial, although for a quite different reason. In the colder northern part of Ukraine, well developed *Betula* pollen is present, including pollen of arcto-boreal shrub forms (*Betula* sect. Costatae et Fruticosae). Furthermore, normally developed *Betula* pollen grains have been found in Upper Pleniglacial deposits in western Crimea (Gerasimenko 1999). This may indicate that not the cold, but the aridity of the climate, was the factor limiting the distribution of *Betula* in eastern Crimea.

The other tree whose pollen punctuates the diagram in pollen zones III to XII (Levels C to 4) is *Juniperus*. This heliophytic plant can grow in the undergrowth of light pine forests, or may form separate associations in open landscapes. The latter definitely was the case for the Buran-Kaya Pleistocene environments. Pollen of other shrubs—*Corylus*, Rhamnaceae, and Caprifoliaceae—appear in the uppermost part of the diagram (pollen zones XII–XIV), whereas single pollen grains of *Salix* (willow) were found in the middle part of the diagram, and obviously originated in the floodplain. Willow pollen occurred in zones having a low proportion of xerophytes among the non-arboreal pollen (zones V and VIII, corresponding to Layer B and the lower part of Level 6-1).

Minimal arboreal pollen (0–2%) is characteristic of pollen zones IX and X (the upper part of Level 6-1 and Layer 5). Concomitantly, these zones are distinguished by the highest values of xerophytes and the lowest values of Herbetum mixtum in the diagram. The samples derived from the 2001 excavations of the site have a richer arboreal pollen content (16–20%) than the samples taken during the 1998 excavations (2–14%). This may be related to the different availability of the two sections to wind-blown pollen.

The lowest counts of xerophyte pollen are found in zones I, II, V, VIII, XII, and XIII (corresponding to Levels E, D, B1, B, the lower parts of Levels 6-1 and 4, and Level 4A). The minima in the lower three zones are correlated to maxima of both Herbetum mixtum and Cyperaceae, whereas the minima in the upper three zones are related only to Herbetum mixtum peaks. The environmental adaptations of these two wet-loving herbaceous groups are different. Herbetum mixtum mainly includes mesophytic plants reliant on precipitation, while Cyperaceae in the boreal and temperate belts grows azonally and relies on ground moisture. Cyperaceae are zonal components of ground cover in tundra and the sub-alpine belt of the Carpathians where there are low evaporation rates. They are also typical for Crimean *Yaila* meadow-steppe landscapes where precipitation is not less than 600 mm per year. It is assumed that precipitation during the Late Pleniglacial of eastern Crimea was not so high, since it is presently below 500 mm. On the other hand, the low temperatures of the Pleniglacial resulted in substantially lower evaporation rates, and much lower amounts of precipitation were thereby needed to produce an environment humid enough for Cyperaceae distribution (wet meadows), at least in valleys. As with all the Pleniglacial valleys before the Holocene terrace erosion, the Burulcha River Valley was less deep than today, and the Buran-Kaya III site was closer to the floodplain. This, as well as possibly higher precipitation during the formation of the pollen spectra of zone I and the lower parts of zones II, IV, and V were the cause of the Cyperaceae peaks (Level E, the lower parts of Levels D, B1, and the base of the 1998 excavation). During the formation of the upper pollen zones rich in Herbetum mixtum pollen (VIII, XII, and XIII), either the precipitation was lower or the temperature was higher, in order to produce wet meadows beyond the alder groves in the floodplain.

The impact of the adjacent river valley can be seen in the predominance of Herbetum mixtum in the nonarboreal pollen of most of the pollen spectra. With the exception of the zones richest in xerophytes—IX and X (the upper part of Level 6-1 and Layer 5)—the other zones with a predominance of xerophytes over Herbetum mixtum are zone IV and the upper part of zone VI (substrata of Layer B and the upper part of Subzone 6-5). The indicator for a typical steppe landscape is Gramineae pollen. It is usually underrepresented in pollen spectra because of its poor preservation rate, so even values of 15% Gramineae can indicate extensive distribution of a grass steppe in the vicinity (Dinesman 1977). In the Buran-Kaya III diagram, this is seen in pollen zones IV–VI, XI, and partly in IX and X (Layer B with substrata, Levels 6-5, 4A, and partly 5 and 6-1).

Among xerophytes, *Artemisia* is the most specialized indicator of dry steppes, while Chenopodiaceae are present in most of the steppe zone pollen spectra. The continuous *Artemisia* curve, though it does not have high values, extends from zone VII to X (Levels 6-3 to 5). Another characteristic feature of the diagram is the almost constant presence of the steppe plant *Ephedra*, which is regarded as a typical representative of Late Pleniglacial and Late Glacial steppes (Khotinsky 1983; Bezusko 1999). Among Herbetum mixtum, Lamiaceae, Rosaceae, Brassicaceae, and Cichoriaceae are the most important. Representatives of these families grow in different environments: in meadows, steppes, and dry limestone slopes. Lamiaceae, the most richly represented pollen in the section, is similar to *Scutellaria* pollen, which presently inhabits steppes, rocky slopes, and limestone outcrops in Crimea. Pollen of *Thymus* and *Salvia*, which are presently abundant in the area, were not found, at least not well preserved. *Leonurus* and *Stachys* pollen types seem to be represented in the pollen spectra. Asteraceae, which are regarded as the most xerophytic of Herbetum mixtum (and have been counted separately here) are second in abundance after Lamiaceae among the dicotyledonous herbs in the diagram. They may also indicate eroded substrata. The zones richest in Asteraceae are I, II, VI, X, and XI (Levels E, D, 6-5, 5, and 4A).

Oscillations in spore content in the diagram are not regular and often demonstrate local environmental changes dictated by the development of fissures and caverns in limestone rocks. All of the Buran-Kaya III samples have a higher spore count than the zonal forest-steppe and steppe spectra (<20%) of the present-day temperate belt of the Russian Plain. This is obviously a result of the rock lithology and topography around the site. Some of the peaks of spores are also related to their better preservation rate in the sediments, and are observed only in pollen-poor zones. Still, several extremes in the spore counts in the diagram reflect climatic changes. These climatically dependent changes can be recognized by their direct correlation to changes in the other components of the pollen spectra. For instance, the maximum spore values in the diagram (pollen zones XII and XI, or Levels 4 and 4A) are related to the increase of mesophytic herbs, and partially to arboreal pollen. The minimum spore values are correlated with either the lowest pollen counts of mesophytic herbs and arboreal vegetation (pollen zone X, Layer 5), or with the appearance of broad-leaved taxa, and therefore a warmer climate and higher evaporation rate (zone XIV, Layer 3A, zone IV, Layer B).

The members of different taxonomical groups of spores in the spectra are important for paleoenvironment reconstructions. Bryales (green mosses) are common representatives in spore vegetation in steppes and even semi-deserts. The maximum spore values in pollen zones IX and X (Level 6-1, the upper part and Layer 5) are attained at the expense of Bryales, and are not unusual for steppe zones. The absolute maximum of spores in zone XII (Level 4, the lower part) is driven by moisture-loving Polypodiaceae (ferns), which is well correlated with the maximums of arboreal and Herbetum mixtum pollen here. In most of the spectra in the diagram, the Polypodiaceae contents are within the present limit for plain-steppe (<10%) and forest-steppe (<15%) zones. A peculiar feature of the Buran-Kaya III sequence is a significant amount of spores from the Pteridae subfamily of Polypodiaceae (which have been counted separately). Some representatives of Pteridae grow on limestone stones, fissures, and rock-shelters, while others (*Pteridium*, for instance) grow in light forests and meadows. Their presence within the steppe zone is connected only with mountain refugia and waterlogged areas that would provide sufficient moisture.

The other peculiar feature of the spore group composition is the presence of Lycopodiaceae and *Botrychium*, which are not presently typical of forest-steppe and steppe zones of the temperate belt, and are characteristic of forest and tundra zones. Nevertheless, representatives of these groups are described as typical components in the composition of the Pleniglacial steppe vegetation of the southern Russian Plain, where they are proportionally more abundant than in the Buran-Kaya III sequence (Bolikhovskaya

1995; Bezusko and Bogutsky 1986). Low numbers of Lycopodiaceae were found in the Middle Pleniglacial interstadials and interphasial deposits of the Kabazi II section (Gerasimenko 1999). In Buran-Kaya III, Lycopodiaceae, as well as *Botrychium*, also have their highest values in the lower part of the sequence (zones I–III, Levels E–C), and they appear throughout the sequence, though in small numbers. This is related to the closer position of Buran-Kaya III to the floodplain as compared to Kabazi II. These two spore taxa grow in meadows of the boreal zone. *Botrychium* spores drop in value and disappear upwards starting from pollen zone XI (Level 4A), and only unique examples appear in zones V–VIII (Levels B1–6-1, the lower part). The diversity of spores and the poor composition of arboreal pollen demonstrate that during this period, the Burulcha River Valley provided a habitat for many moisture-loving plants, but not to warmth-loving plants.

Generally, the Buran-Kaya III diagram is rather homogenous, especially in the portion framed by the uppermost and lowermost forest-steppe pollen complexes. The ratio of herbaceous xerophytes and mesophytic Herbetum mixtum is most characteristic of steppe pollen spectra. Despite the cyclic oscillations in the non-arboreal pollen components, the general trend is towards increasing xerophytes from the bottom to the top of the 2001 section (from Level D to Level C), and from the bottom to the top of the late Pleistocene sequence in the 1998 section (from Level B1 to Layer 5). Based on the counts of xerophyte pollen, the diagram can be subdivided into 4 major parts: (1) pollen zones I–III and V (Levels E–D and Layer B) with relatively low xerophyte content, (2) pollen zones VI–VIII (Level 6-5 through the lower part of Level 6-1) with middling xerophyte content, (3) pollen zones IX–X (Level 6-1 to 5) with the maximum xerophyte content, and (4) pollen zones XI–XIV (Levels 4A–3A) with low xerophyte content.

## Environments of Buran-Kaya III

### Level E Environment

Pollen zone I (Level E) indicates the existence of forest-steppe vegetation in the Burulcha River Valley, though open landscapes dominated over forest associations. The forest, made up of alder and birch, occupied the floodplain, and a few lime trees grew in protected locations on the slopes of the southern foothills. The herbaceous vegetation was dominated by meadow types, including mesophytic plants of the Ranunculaceae family. In many places, the ground was significantly waterlogged, which favored the extensive distribution of sedges and mosses. Ferns, as well as some club mosses and grape ferns, grew both in forests and in rock cavities. The rather high pollen counts of Asteraceae possibly reflect the development of erosional processes in the river valley.

The presence of *Betula*, club mosses, and grape fern (*Botrychium*) in the vegetational composition indicates a boreal climate for this interval, although the occurrence of the broad-leaved species *Tilia cordata* Mill. indicates that it was close to south-boreal conditions. Possibly, it was a transitional climate of the end of an interstadial: relatively humid and allowing for the forest-meadow type of vegetation in the Burulcha River Valley.

### Level D Environment

Pollen zone II (Level D) shows some reduction in forest areas in the river valley and the disappearance of broad-leaved trees. The open landscapes were still dominated by wet meadow coenoses at the beginning of the interval, but some xeric elements had already appeared (*Ephedra*, *Artemisia*). Later on, sedges were replaced by grasses and mesophytic Herbetum mixtum, and so the waterlogged areas in the valley were reduced. Erosional processes, recorded in the vegetation of disturbed substrata, developed around the site, especially at the end of the interval. It appears that at the end of the interval, the rockshelter itself had a lot of moisture—all spore plants (mosses, club mosses, and ferns) have their maxima in the diagram in this zone.

The vegetational composition of zone II indicates a boreal steppe climate that got colder and progressively drier than the climate of the preceding interval. The herb coenoses changed from wet meadows to Gramineae-Herbetum mixtum during the interval. Still, steppes were mesophytic, and birch-alder forest existed in the floodplain. At the end of the interval, an intense local input of moisture occurred in the rockshelter, causing an increase in the population of spore plants.

### Level C Environment

Pollen zone III (Level C) indicates a further increase of aridity of the boreal climate. Chenopodiaceae, *Artemisia*, *Ephedra*, and Plumbaginaceae formed separate xeric associations and replaced the grass coenoses in dry areas. Mesophytic herbs of with a rather rich composition were also extensively distributed in the river valley. Two families (Lamiaceae and Cichoriaceae) dominated mesophytic associations. Lamiaceae included many plants growing on limestone substrata, and are very typical of the modern herb cover of the Crimean forest-steppe. Cichoriaceae are common in meadow and steppe, but frequently produce maxima in the cultural horizons of archeological sites (Kremenetsky 1991), reflecting ruderal vegetation. The presence of Plantaginaceae pollen in the spectrum, which is also indicative of human impact on vegetation, is interesting in this context. The sharp drop in Asteraceae pollen might indicate that the erosional processes around the site stopped. The activities of Paleolithic peoples affected the same stable surface of the site for a longer period, and the traces of these activities are better reflected in the pollen spectra and the sediments (abundance of microscopic charcoal).

Birch-alder groves grew in the floodplain, and some bushes of the heliophytic plant *Juniperus* grew on limestone rocks. Climatic aridity (and human impact?) might be responsible for the drop in spore plants in the rockshelter. The relative abundance of club mosses, and particularly of grape fern, in the spore composition point to a boreal climate during the period.

Pollen zone IV (substrata of Level C in the 1998 section) shows the disappearance of birch-alder forest in the Burulcha River Valley. This episode is not recorded in the 2001 section. A boreal steppe zone existed in the area, with more xerophytic steppe coenoses than during the formation of Levels E, D, and C. At the beginning of the interval, waterlogged areas covered by sedges were present not far from the site. Later on, sedges were replaced by Herbetum mixtum, which needs less moisture. Grasses and xeric herbs (Chenopodiaceae, *Artemisia*, and *Ephedra*) were consistently abundant, but especially so at the end of the interval. Spore plants permanently grew in the rock cavities. From the beginning to the end of the interval, ferns became less abundant, whereas mosses, club mosses, and grape fern became more extensive. This, together with reduction of sedges, indicates the decreasing wetness of the site and its surroundings to the end of the interval. The lithological evidence may show evidence of whether this dry and cold spell happened before the formation of the lithological sequence of the 2001 section, or whether it is part of the arid interval with the harshest climatic conditions recorded in pollen zone III (Level C).

## Layer B Environment

Pollen zone V (Layer B) indicates steppe landscapes, though with more mesophytic herbs than in the intervals recorded in pollen zones II–IV (Levels D, C). At the beginning of this time span (Level B1), wet meadows with a high proportion of sedges occupied the floodplain. Mesophytic plants of the Ranunculaceae family also grew there. Grass associations were extensively distributed on the drier areas. Xeric coenoses were not widespread in the Burulcha River Valley. Alder trees framed the river channel.

In the second half of the interval (Level B), the meadows became drier and were dominated by Herbetum mixtum. Representatives of the Lamiaceae family were particularly abundant everywhere around the site. Pollen of *Scutellaria* and *Stachys* types was observed in the samples—the former is adapted to limestone substrata, the latter grows in meadows. Willow and birch occurred in the alder groves along the river, and a few oaks grew in the protected foothills of the southern slope. The spore population of rock cavities decreased, particularly in connection with a drop in boreal spore plants—club mosses and grape fern.

These vegetational changes demonstrate a climatic improvement as compared to the preceding intervals. The low number of boreal elements (both of birch and boreal spore plants) and the appearance of broad-leaved species (*Quercus pubescens* Willd.) may indicate warming. The very low number of xerophytes in the herb composition is evidence for increased precipitation than in the preceding stages of steppe distribution (especially at the beginning of the interval). Still, steppes dominated the landscape, and the participation of broad-leaved trees in the vegetation was low. This suggests that the interval was an interphasial.

## Level 6-5 Environment

Pollen zone VI (Level 6-5) reflects steppe landscapes with a more xeric composition of herb coenoses than during all the preceding intervals. Grass steppes with a high proportion of Chenopodiaceae prevailed during the second half of the period, whereas the beginning of the interval was a kind of transition from the previous wetter interphasial to full stadial conditions. At the beginning of the interval, Herbetum mixtum (especially Lamiaceae) still prevailed in the herb cover, and birch and alder trees lined the river. In the second part of the stadial, the area was treeless. At the beginning of the interval, erosional processes possibly developed around the site (recorded in the Asteraceae peak), and additional input of moisture to the rockshelter occurred (the high values of Pteridae ferns). Generally, spore plants were dominated by mosses and included a few boreal elements (club mosses and grape ferns).

## Levels 6-4–6-2 Environment

Pollen zone VII (Levels 6-4–6-2) enables the environmental reconstruction for only the middle part of the period (Level 6-3). It appears that the climatic conditions were also alike at the beginning and at the end of this interval because of the similarities in the main pollen spectra indices, but the pollen counts in the corresponding sediments are too low to provide detailed analysis. Obviously, throughout the interval, birch-pine groves grew in the Burulcha River floodplain and boreal steppes were present in the site's vicinity. During the sedimentation of Level 6-3, steppes were mainly dominated by Gramineae-Herbetum mixtum associations, though xerophytic coenoses also significantly contributed to the steppe vegetation composition. Dry steppe vegetation, such as *Artemisia*, started to spread in the area. Lamiaceae and Rosaceae dominated the Herbetum mixtum composition. The vegetation indicates a stadial climate, but one less harsh than at the end of the Level 6-5 interval. The distinctive feature is a decrease in spore plants around the site. Mosses did not change in number, but club mosses and ferns, especially grape ferns, practically disappeared.

## Level 6-1 Environment

Pollen zone VIII (the lower part of Level 6-1) also indicates a boreal steppe, but with more mesophytic herb coenoses than in the previous stadials. The area was occupied by meadow steppes, recorded in the maximum of Herbetum mixtum values and in the very low number of xerophytes. The distribution of the Lamiaceae family (pollen of *Scutellaria* and *Stachys* types) reached its maximum at this time. Ranunculaceae, the representatives of which grow in meadows, appeared. Alder, birch, and willow edged the river channel, and juniper bushes grew on slopes. The spore population increased in number around the site, and was dominated by mosses and Pteridae ferns. In fact, the vegetation was very similar to that of the interstadial and interphasial described in the Buran-Kaya III sequence, but broad-leaved species did not occur. The mesophytication of steppes reflects a strong decrease in climatic continentalism during this interval, and, conventionally, it could be related to an interphasial.

Pollen zone IX (the upper part of Level 6-1) shows a significant environmental change, as compared to the previous wet interval. Dry steppe associations (*Artemisia* and *Ephedra* in a complex with Chenopodiaceae) spread in the area and replaced the Herbetum mixtum coenoses. The latter were possibly restricted to only the floodplain. The valley was treeless, or, at most, only few alders and junipers appeared near the river. Lamiaceae dominated the Herbetum mixtum composition, although Cichoriaceae also became abundant at the end of the interval. The lower part of the pollen zone is marked by the maximum of Pteridae spores, which can only be explained by some very local changes in the rockshelter environment. Mosses dominated the spore composition in the latter part, while the number of wet-loving ferns decreased during this interval. The vegetation of this interval indicates a stadial with a continental climate, which was similar to, or more continental, than the climate recorded in the upper part of pollen zone VI (top of Level 6-5).

## Layer 5 Environment

Pollen zone X (Layer 5) demonstrates the further progressive increase of climatic continentalism, recorded in the maximum spread of xerophytes, including Chenopodiaceae, *Artemisia,* and *Ephedra*. Mesophytic coenoses of Herbetum mixtum still grew in the floodplain, but their distribution was significantly reduced, especially at the end of the interval. Concomitantly, the floristic composition of Herbetum mixtum became very poor.

At the beginning of the interval, a few birch and alder grew near the water, but later on, the valley was treeless. The increase in Asteraceae throughout the zone indicates a pioneer vegetation of disturbed substrata. The vegetation cover was probably sparse, and erosional processes developed elsewhere. The samples for zone X have the lowest pollen frequencies in the section. In this context, the high number of spores in the lower spectra of the zone appears to be related to the proportionally low number of pollen grains. In the upper sample, which is richer in pollen, the percentage of spores is low. Mosses dominated among the spore plants, whereas the more moisture-demanding ferns were generally reduced in number during the interval. It is notable that boreal spore plants (club mosses and grape ferns) got more abundant in this period than during the previous intervals that were recorded in the 1998 sequence. This may indicate that the climate was cold, as well as continental. Pollen zone X corresponds to the climatic pessimum for the entire diagram.

## Level 4A Environment

Pollen zone XI (Level 4A) shows some improvement in climate. Boreal steppes still dominated the vegetation, and only a few alder trees appeared in the floodplain. However, the composition of steppe associations implies an increase in precipitation. The number of xerophytes dropped sharply, and instead, Herbetum mixtum-Gramineae coenoses were extensively distributed in the area. The floristic composition of Herbetum mixtum did not recover after the peak in aridity of the preceding interval and was very poor (Lamiaceae, Rosaceae, and Brassicaceae), while plants of the Asteraceae family were still abundant. Spore plant population of the site increased, particularly at the expense of moisture-loving ferns. In contrast, the proportion of boreal grape fern decreased during this interval, which may indicate an increase in moisture and temperature as compared to the preceding interval.

### Level 4 Environment

Pollen zone XII (the lower part of Level 4) indicates forest-steppe vegetation. Alder groves spread extensively in the floodplain. Meadow steppes occupied the whole area, whereas xeric coenoses practically disappeared. The floristic composition of Herbetum mixtum became richer, but the most distinctive feature of the mesophytic vegetation was an extensive fern distribution. They obviously grew abundantly around the rockshelter, as well as in the floodplain forest. Elements of broad-leaved flora did not appear yet in the area, whereas bushes—Rhamnaceae and Caprifoliaceae—started to spread. The climate of the interval was wet, but was still boreal, and may correspond to an interstadial or to the beginning of an interglacial.

Pollen zone XIII (the upper part of Level 4) shows a return to a steppe landscape in the Burulcha River Valley, although the steppes were mesophytic with a rich floristic composition of Herbetum mixtum. Representatives of the Lamiaceae family were especially abundant. The area was dominated by boreal meadow-steppe, and alder groves framed the river valley. Ferns became much less widespread, but boreal club mosses somewhat increased in number. The climate was drier than during the preceding forest-steppe interval, but much wetter than during the previous stadials.

### Layer 3A Environment

Pollen zone XIV (Layer 3A) indicates a forest-steppe vegetation with a temperate climate. At that time, broad-leaved trees and bushes—hornbeam, oak, maple, and hazel—grew on the slope foothills, and alder groves spread along the river. *Rhamnus* and *Viburnum* grew in the undergrowth. Forests were not, however, dominant in the landscape; meadow steppe was widespread and included a very rich herb composition. Xerophytes, including *Artemisia* and *Ephedra*, grew on dry slopes. The amount of spore plants in the ground cover was below average for the period of the site's existence: shade-loving Pteridae ferns sharply dropped in number and boreal grape fern disappeared. The vegetation of the interval indicates a full interglacial, though it was an interglacial phase with a relatively continental climate favorable to meadow steppe predominence in a forest-steppe landscape.

## Temporal Correlations

The vegetational history of Buran-Kaya III provides evidence for the following series of environmental events: (1) interstadial with forest-steppe landscapes (Level E); (2) stadial, first with meadows (Level D), later with more xeric steppe coenoses (Level C); (3) interphasial with mesophytic steppe (Levels B, B1); (4) stadial with grass steppe (Level 6-5); (5) interphasial with meadow steppe (the base of Level 6-1); (6) stadial, first grass steppe (Level 6-1), later on, xeric steppe (Layer 5), and again, grass steppe (Level 4A); (7) interstadial, or beginning of interglacial (Level 4); (8) interglacial (Layer 3A).

The $^{14}C$ dates obtained for Buran-Kaya III provide the chronological framework for the correlation. In the lower part of the sequence, the AMS dates for Level C are 32,350 ± 700; 32,200 ± 650; and 36,700 ± 1,500; for Level B1 are 28,520 ± 460 and 28,840 ± 460; and for Level 6-5 are 28,700 ± 620 and 34,400 ± 1,200 kyr BP (Chabai et al. 2000). The interphasial seen in pollen zone V (Levels B and B1) can be correlated then with the Denekamp/Arcy interstadial at 28–30 kyr BP. The arid climate of eastern Crimea restricted the distribution of arboreal vegetation and was possibly why this warm spell was registered as an interphasial in the Buran-Kaya III sequence. In the eastern Crimean site of Zaskalnaya V Layer I (Gubonina 1985), broad-leaved vegetation was likewise absent during the interval that is correlated with Level B (Chabai 2000). As is the case in the Buran-Kaya III section, this interval at Zaskalnaya V Layer I is distinctive in its predominance of meadow steppe, the incidence of birch and alder, and the extensive distribution of spore plants.

The cold spell with boreal steppe vegetation recorded in Levels D and C corresponds to the last stadial of the Middle Pleniglacial, which occurred between 30–36 kyr BP. The interstadial of pollen zone I can be correlated then with the end of the Hengelo, or with a cooler Huneborg/Les Cottés interphasial occurring around 35 kyr BP (Hammen 1995). In Kabazi II, this interphasial was also characterized by a low proportion of broad-leaved trees in the vegetational composition, though pine forest was extensively distributed. The differences in the ratio of steppe and forest in landscapes during this interval in Western and eastern Crimea may have been controlled by differences in the climatic continentalism of the two areas, also observed in the present day.

Based on the archeological correlations (Chabai et al. 2000), the Les Cottés interphasial of Kabazi II corresponds to Zaskalnaya V Layer II and the latter might therefore be correlated with Buran-Kaya III Level E. Nevertheless, the pollen of Zaskalnaya V Layer II differs from Level E by a steppe type of spectra and higher counts of xerophytes, and is more similar to the pollen complexes of Levels D and C. According to the available pollen data, Levels D and C belong to different phases of the same stadial, and show a progressive increase in aridity from the beginning to the end of the period. Concerning the characteristics of herbaceous vegetation of the last Middle Pleniglacial stadial in Kabazi II and Buran-Kaya III, it appears that the latter site was richer in hydrophytes during the first half of the stadial (Level D). We can explain this only by the closer position of Buran-Kaya III to the floodplain, providing waterlogged substrata for hydrophytic Cyperaceae coenoses.

Level 6-5 does not differ from Level B in its $^{14}C$ dates, but its pollen spectra indicate a stadial climate. The lower part of the zone represents a transition from interstadial to stadial conditions, with meadows and alder trees in the valley, while the upper part corresponds to full stadial conditions with a predominance of grass steppe. A prevalence of boreal grass steppe was also established at this time, overlying Denekamp deposits in Kabazi II—the Bug pollen zone and the beginning of Upper Pleniglacial.

Buran-Kaya III was surrounded by boreal steppe during the formation of the upper part of the sequence, up to and including Level 4A. Radiometric dates for Level 4A place it in the Younger Dryas (10,580 ± 60 and 10,920 ± 65), corresponding to the upper chronological limit of the Late Glacial. The Upper Paleolithic was replaced by the Final Paleolithic (Swiderian) culture at this time (Yanevich 1999).

Layer 5, characterized by the harshest continental climate seen in the Buran-Kaya III sequence, is the last level of the Pleniglacial. The second half of the Pleniglacial (the upper part of Level 6-1 and 5) was distinctive for having more xeric steppe coenoses than the first half (Levels 6-1–6-3). This corresponds well to the view of two glacial vegetational phases—an earlier cold/wet phase and a later cold/dry one (Grichuk 1972). In Upper Pleniglacial (Late Valdai) sections of the northern and central part of the Russian Plain, the beginning of the maximum increase of *Artemisia* is dated to around 15 kyr BP (Bolikhovskaya 1995). A tentative correlation of the upper part of Level 6-1 and Layer 5 with the date 15–13 kyr is therefore suggested.

Pollen in the base of Level 6-1 indicates a cool and wet interphasial. The underlying Level 6-2 is $^{14}C$ dated to 30,740 ± 460, but contains a Gravettian cultural layer (Chabai et al. 2000). This archeological culture is usually regarded as younger than the Last Glacial Maximum, which occurred around 18 kyr BP (A. Yanevich, personal communication). The interphasial seen in this zone, bracketed within 18 and 15 kyr BP, can tentatively be correlated therefore with the Western European Lascaux interstadial, dated 17–16 kyr BP, or the Plyussky interstadial of the Central Russian Plain of 16.5–15 kyr BP (Bolikhovskaya 1995). It is interesting that the arcto-boreal species of Lycopodiaceae and *Botrychium boreale* Milde. disappeared during the Plyussky interstadial on the Central Russian Plain (Bolikhovskaya 1995), whereas a decrease in club mosses and grape ferns (and their eventual disappearance) was also observed in the lower part of Level 6-1 and in Level 6-3. Unfortunately, gaps in the pollen records of Buran-Kaya III occur in Levels 6-2 and 6-4, but, judging from the pollen content of Level 6-3, the climate during this part of the Pleniglacial was somewhat wetter than during the formation of the upper part of Levels 6-5 and 6-1 and Layer 5. The interval with the most xeric vegetation within the first half of the Late Pleniglacial (the upper part of Level 6-1) can tentatively be correlated with the arid interval at the beginning of the Late Pleniglacial of Western Europe, between 27 and 23 kyr BP (Hammen 1995).

Level 4 overlies the dated Younger Dryas deposits and should belong to the Holocene. It displays a continuing cool boreal climate, first very humid, then continental. Correlation of the wet interval with the beginning of Preboreal (10.3–9.6 kyr BP) is suggested, whereas the following arid spell may correspond to the cold second half of Preboreal (9.6–9.0 kyr BP). The Pereslav cooling of this time (established by Khotinsky 1982), indicates a retreat of Late Glacial flora and aridification of the climate.

Layer 3A is $^{14}C$-dated to 5,070 ± 40 and 5,180 ± 50 and includes the Neolithic cultural horizons (A. Yanevich, personal communication). It represents the second half of the Atlantic period, with an interglacial type of vegetation. The forest-steppe vegetation of the period generally corresponds to the modern vegetation of the area. Judging from the complete afforestation of the lower part of the Burulcha River Valley nowadays, however, it seems that the climate was somewhat drier during the Late Atlantic. This is regarded as a more arid stage than the preceding Atlantic climatic optimum at 5.5 kyr BP and also drier than the beginning of the Subboreal, 4.5 kyr BP (Khotinsky 1982).

## Conclusion

Pollen analysis of Buran-Kaya III demonstrates the absolute predominance of steppe landscape through the Late Pleniglacial and Late Glacial history of the site. South-boreal forest-steppe existed at the beginning of the Buran-Kaya III sedimentary sequence formation. This time span (Level E) is tentatively correlated with the end of the Hengelo interstadial. The Denekamp (Arcy) interstadial had drier environments,

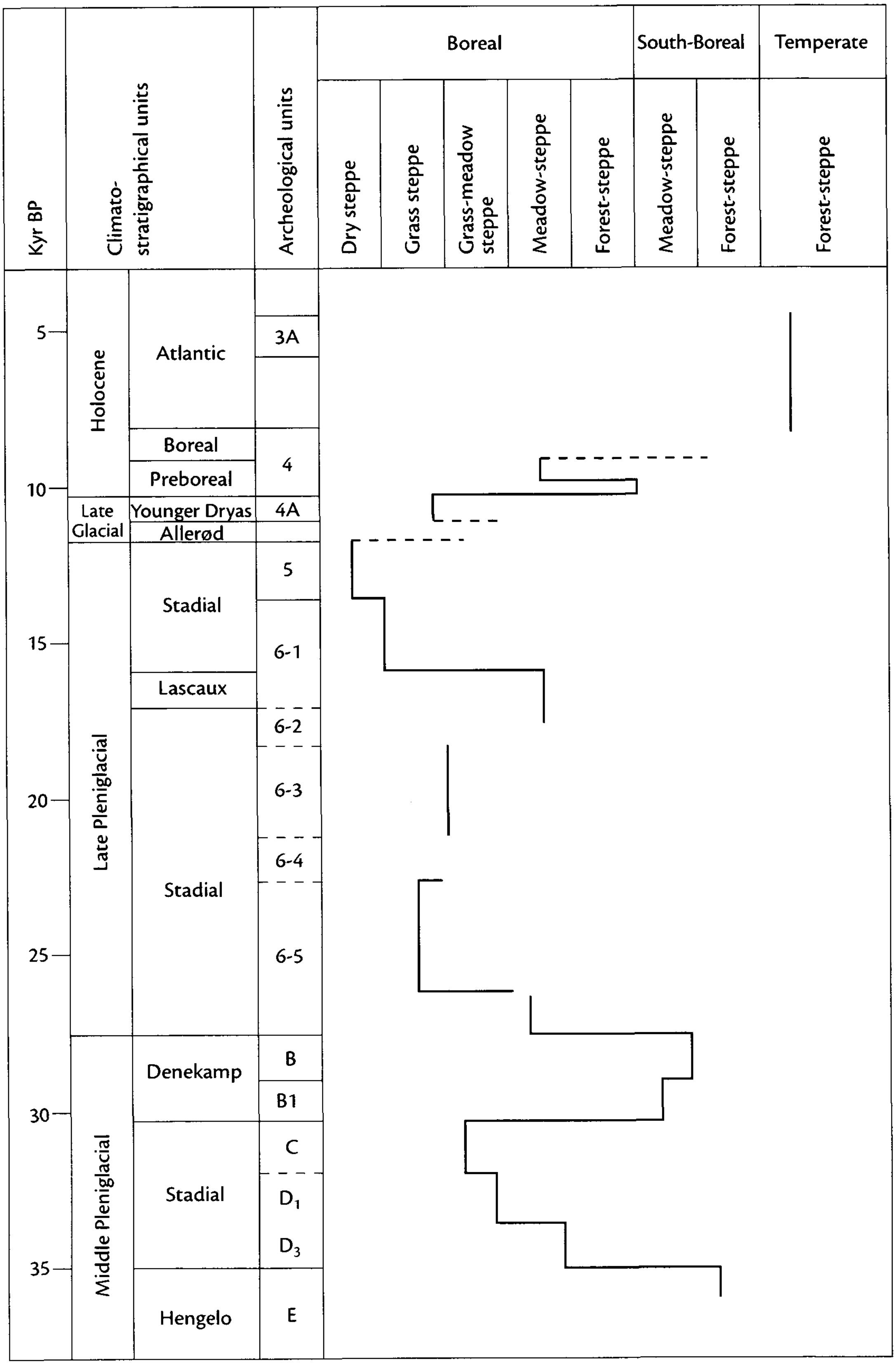


Figure 2-2—Vegetational dynamics of Buran-Kaya III.

represented by south-boreal meadow-steppe. This interstadial corresponds to the last Middle Paleolithic culture in the site (Layer B). The stadial that separates the two Middle Pleniglacial interstadials (Level D) was characterized by boreal steppe vegetation, which continued to have a considerable proportion of meso-hydrophytic coenoses.

The Late Pleniglacial interval obviously began in Level 6-5, although the transition from the Middle to Late Pleniglacial is recorded in the Buran-Kaya III sequence as a gradual one. The Late Pleniglacial steppes were generally more xeric than the Middle Pleniglacial ones. A trend towards xerophytization of the vegetation from the beginning to the end of Late Pleniglacial is observed. The landscapes of first half of the Late Pleniglacial (Levels 6-5–6-3) were dominated by Gramineae (grass) and Herbetum mixtum-Gramineae steppes. During the second half of Late Pleniglacial (Layer 5, the upper part of Level 6-1), dry steppes were extensively distributed in the area, especially during the Layer 5 interval. The area periodically became treeless. This dry climatic spell is correlated with the Late Valdai cryo-xerophytic phase (13–15 kyr BP).

A cool and wet interphasial occurred in the interval following the appearance of the Gravettian and prior to the cryo-xerophytic phase. In this context, the interphasial (the lower part of Level 6-1) is tentatively correlated with the Lascaux (Plyussky) Interstadial (16–17 kyr BP). Meadow steppes occupied the area during this period.

During the Younger Dryas (Level 4A), the xeric steppes of the end of the Late Pleniglacial were replaced by a typical grass steppe. This shows a decrease of climatic aridity during the Late Glacial, though the climate was still cold and continental. The last occurrence of Upper Paleolithic culture was associated with the last xeric phase of the Upper Pleniglacial, and the Final Paleolithic occurred in the area during the Younger Dryas and Preboreal.

At the beginning of Preboreal (the lower part of Level 4), a re-establishment of forest-steppe environments occurred for the first time since the Hengelo interstadial. The humid climate favored the extensive distribution of meadow steppe, alder forest, and an abundance of Polypodiaceae ferns. The later dry spell with the reappearance of boreal steppe (the upper part of Level 4) is correlated with the Late Preboreal (Pereslav) cooling (9.6–9.0 kyr BP). The climate was less continental than during the Late Pleniglacial and Late Glacial stadials, and meadow steppes spread in the area.

From the Denekamp Interstadial up to Late Preboreal, there was a boreal type of vegetation and climate in the area. The beginning of Preboreal could be similar to the south-boreal conditions (appearance of Rhamnaceae and Caprifoliaceae, Polypodiaceae maximum). Subboreal (temperate) forest-steppe existed in the area during the Late Atlantic. The Neolithic population of the site lived during a climate similar to the modern one, or slightly drier.

The vegetational dynamics recorded in the Buran-Kaya III pollen sequence are shown in Figure 2-2. The environmental changes in the site are generally well correlated with the main events of the period from the end of Middle Pleniglacial to the end of Late Pleniglacial. The Late Glacial interstadials are not represented in Buran-Kaya III, and some Late Pleniglacial phases were possibly overlooked because of low pollen frequencies in the samples. In the Middle Pleniglacial records, the amplitudes of stadial/interstadial changes are less pronounced than in the western Crimean site Kabazi II. This can be explained by the greater aridity of eastern Crimea (*in re* arboreal pollen), as well as by the stronger impact of floodplain vegetation in Buran-Kaya III (*in re* herbaceous pollen). The site's position in the lower part of the mountain river valley also controlled the Late Pleniglacial records of the site. Xerophyte pollen was never as abundant in Buran-Kaya III as it was in the Upper Pleniglacial pollen spectra in the Ukraine plain, including its northern part (Sirenko and Turlo 1986; Bolikhovskaya 1995; Gerasimenko 2001). From the Middle Pleniglacial to the Middle Holocene, grass steppes and meadow steppes were the dominant vegetational type in the site vicinity. Dry steppes extended over large areas only during the 13–15 kyr BP interval.