POLLEN ANALYSIS FROM THE KAMALAPURA KERE

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The sedimentary record of Vijayanagara reservoirs constitutes a potentially important source of information on past agriculture and landuse in the area in and around the city of Vijayanagara. In any region, the vegetation record is an artefact of both ecological and human forces, but the Vijayanagara vegetation record, in particular, must be viewed as the record of a transformed landscape, the consequence of years of human manipulation of the environment. In this paper I will present some preliminary findings of an analysis of fossil pollen from the sediments of the Kamalapura *kere*, a large reservoir or tank located to the southwest of the city of Vijayanagara. In the pollen record from the Kamalapura core, it is possible to view the rather dramatic impact of patterns of agricultural land use on the regional vegetation and on the more local history of the Kamalapura *kere* itself.

Pollen Analysis: Basis

Pollen analysis, the study of "fossil" (that is, non-contemporary, although the material is not truly fossilized) pollen for the purposes of environmental reconstruction, is one way of detecting and analysing past agriculture. Environment, in this sense, may include factors such as soil, temperature and rainfall as well as the activities of human beings. Human impact on vegetation is variable at different scales, and diverse agricultural strategies might be expected to shape local and regional vegetation in fairly complex ways.

Pollen grains, the "microscopic single-celled (multinucleate) gametophyte generation produced by vascular plants that are responsible for the exchange of genetic information during plant reproductive processes" (Bryant and Holloway 1983: 194), consist of two layers. The inner, or iintine, is composed mostly of cellulose (Moore and Webb 1978: 31), and is not particularly resistant to decay. The outer layer, or exine, is composed of cellulose, hemicellulose, lignin, pectic substances, and sporopollenin (Bryant and Holloway 1983: 194). The sporopollenin is highly resistant to decay. Identification of pollen and spores rests on the observation that each family or genus (and sometimes species) produces a morphologically distinctive product, with a specifiable size range, number and arrangement of pores and apertures, and exine characteristics.

Understanding Pollen

Pollen produced by plants in a region continuously accumulates in soils, lakes, bogs and other bodies of water, creating a temporally stratified record of vegetation. The methodological bases for interpretation of fossil pollen profiles consist of bodies of information drawn from the operation of contemporary processes in plant biology and ecology, hydrology and sedimentology. Differential pollen production, dispersal and preservation, as well as specificity of identification, sampling, and even forms of data presentation all affect the nature of the relationship between observed pollen distributions and past vegetation (Morrison 1992).

The ecological interpretation of pollen profiles ultimately depends on studies of contemporary vegetation dynamics, and on studies of the relationships between contemporary vegetation and pollen in specific environments.

Unfortunately, there are few analyses of contemporary pollen spectra and their relationship to vegetation in South India, apart from some studies from the Ghat forests (e.g. Blasco and Thanikaimoni 1974) and none at all for dry interior Karnataka. Thus, only very general statements about vegetation can be made on the basis of the pollen record from the Kamalapura *kere*.

The results of pollen analyses are commonly presented as percentage diagrams, with taxa values calculated as a proportion of the number of terrestrial pollen grains. However, absolute pollen diagrams, which employ pollen concentration values (calculated with reference to some known volume of a "marker" species such as Lycopodium or Eucalyptus added to the sample), also display significant information. Minor vegetation changes may be discernible only with absolute diagrams, since the values of a dominant species in a percentage diagram may mask trends in rarer species. For this reason, both percentage and absolute diagrams of grouped taxa from the Kamalapura core are provided.

Pollen Analysis from the Vijayanagara Region

Pollen analyses were made from an 57-cm long core extracted from the sediments of the Kamalapura *kere*. The Kamalapura *kere* (VMS-231) is a large reservoir which contains water year-round. Water is retained by a masonry-faced earthen dam nearly 2 km long (Figure 1). Approximately 1,700 m of the embankment appear to belong to the Vijayanagara period reservoir; recent additions in concrete have extended the embankment on either end. Three sluices date to the Vijayanagara period.

The Kamalapura *kere* is one of the few reservoirs in the Vijayanagara Metropolitan Region which is not solely dependent on runoff from seasonal or semi-permanent water sources. instead, its holdings are supplemented by the Raya canal, which itself is supplied by an *anicut* from the Tungabhadra River. Thus, the Kamalapura *kere* contains a much more certain water supply than other reservoirs in the region. In addition to water from the Raya canal, the Kamalapura *kere* was also supplied by seasonal runoff and the overflow from several Vijayanagara period reservoirs upstream. This constancy of water supply has important implications not only for agricultural production, but also for pollen preservation. Pollen grains are more likely to be preserved where conditions are either uniformly wet or dry; pollen degrades rapidly under conditions of alternate wetting and drying. Samples taken from the fill of several seasonal reservoirs in Block O (see Sinopoli and Morrison 1991), for example, did not contain any pollen.

The Kamalapura reservoir was probably constructed in the early Vijayanagara period (Morrison 1992; an inscription of 1518 also appears to refer to the Kamalapura *kere*; Gopal 1990: 180), giving this body of water the potential to provide information on the entire span of Vijayanagara, Colonial and Post-Independence vegetational history.

The Raya canal *anicut* was submerged by the Tungabhadra reservoir (Kotraiah 1959), and the flow through the canal is now regulated by the irrigation authorities at the Tungabhadra dam. Because of the submergence of the Raya *anicut*, it is not possible to study it in detail or to assess its reliability.

It is assumed that the Raya, like other Vijayanagara canals, provided a fairly secure, year-round flow of water. The date of the Raya canal is not entirely clear. Davison-Jenkins (1988: 97) argues that the *anicut* and canal mentioned by Nuniz in his recap of Vijayanagara history is the Raya canal, dating it to the fifteenth century. However, this argument is unconvincing. Even if Nuniz' account is treated as a simple, factual historical account, he mentions a canal which was "brought inside the city" (Sewell 1992: 301), a description which matches the route of the Turtha (Hiriya *kaluve*; Filliozat and Filliozat 1988: 11) and not the Raya canal. It may be that the Raya canal and the reservoir are contemporaneous, but the occurrence of an inscription from Penukonda (Gopal 1990: 42) referring to the construction of a canal in order to supplement a reservoir's supply should indicate that this contemporeneity cannot be assumed.

Vegetation

The Vijayanagara region is characterized by vegetation of the xeric Albizia amara Acacia series. The slopes of the Sandur Hills support vegetation of the Hardwickia Anogeissus series, while the hilltops contain plants of the

Anogeissus-Terrninalia-Tectona series (Gaussen et al. 1966). The vegetation in the area has, however, been greatly modified by human activity and cultivated species today constitute a significant proportion of the regional flora (Singh 1988). The Kamalapura *kere* receives input from a wide catchment area, particularly since the water of the Raya canal is ultimately derived from the Tungabhadra River. The runoff catchment of the Kamalapura *kere* is also large. Overflow from the smaller reservoirs VMS-241 and VMS-242 upstream was channeled into the Kamalapura *kere*; the watershed of these reservoirs included the Sandur Hills. Thus, the pollen source area for the Kamalapura reservoir is likely to have been quite large, including all three of the vegetation series found in the region, and the pollen record from this reservoir ought to provide a large-scale, regional record of past vegetation.

Sampling Programme

Three sediment cores were extracted from the Kamalapura *kere*; only one of these (1KP) is discussed here. The reservoir was cored in early June 1990, at the height of the dry season. In spite of this and despite several years of drought in northern Karnataka, the water level was only slightly below the average, perhaps 1 m less, judging from water staining on the masonry embankment. The reservoir was not very deep, ranging from less than one metre at its marshy edges, to the deepest area near the sluice, where the water depth was about 4 m. Water depths and core locations are indicated in Figure 1. All cores were taken from a raft, using a modified version of the "UNAM" core developed by Roger Byrne of the University of California, Berkeley. The core used on the Kamalapura sediments was constructed under the direction of Dr Phadke at the Department of Instrumentation Science, University of Poona, and was christened "UNAM Dho". (Core descriptions and pollen processing procedures can be found in Morrison 1992.)

Core Chronology

The stratigraphy of the core provides a broad framework for chronological assessment. The reservoir was probably constructed early in the fourteenth century, and the recovered core almost certainly did not reach the original land surface (or the base surface, since the reservoir was likely to have been excavated into the original soil), so that the basal levels are thought to post-date the early fourteenth century, but perhaps not by much. The Kamalapura reservoir is still in operation, so that the uppermost levels date to the twentieth century. Thus, if there are no gaps in the core – and none could be discerned stratigraphically through visual inspection or by X-ray of the core – the pollen record should extend from approximately the fourteenth to the twentieth centuries. The lowest portions are suggested to date to the Vijayanagara period, and the higher portions to the Colonial and Post-Independence periods. It cannot be assumed that the length of core represented by each century is of equivalent length, since that would require that the sedimentation rate of the reservoir be constant through time. This assumption cannot be supported, and in fact, the archaeological and historical evidence suggests, quite to the contrary, that erosion was more of a problem at some times than at others, as differential grain sizes of the sediment also suggest.

In addition to stratigraphy, the presence of plants introduced into India from other parts of the world provides an additional temporal control. New World plants provide a fairly precise marker of time, since they all post-date AD 1500. Afemanthera, a New World weed, appears in the core at 28 cm. Thus, the portion of the core above 28 cm should date to the sixteenth century or later. Casuarina was introduced into India in the 1780s (Tissot, personal communication 1992); it appears first at 18 cm, and occurs consistently in the upper portions of the core. Thus, if there are no gaps in the sequence, the portion of the core between 18 and 0 cm should represent the eighteenth, nineteenth and twentieth centuries. As noted, a constant sedimentation rate cannot be assumed, so this sequence cannot be retrodicted.

Vegetation Groups: Identification

The identification of pollen grains and spores from 1KP was facilitated by use of the excellent pollen reference collection of the French Institute, Pondicherry, India. Much of the pollen from the Kamalapura core could only be identified to family, although some genus and species-level identifications were possible. Families characterized by a single form of vegetation such as herbs, shrubs, or trees are grouped together in Figures 2 and 3. A few families are quite variable in form; these were not included in the overall groupings. The most serious difficulty is presented by the grasses, which dominate the pollen assemblage. The most important agricultural crops of the Vijayanagara period: rice, sorghum, millets, and possibly sugarcane, are all grasses, and in Bellary and Raichur Districts alone, 97 species in 63 genera of non-cultivated Gramineae were reported by N.P. Singh (1988). Most of these occur in disturbed zones such as cleared areas and cultivated fields, and as weeds around habitations and along roads. The great diversity of grasses defies precise ecological cate-gorization, however. General trends can be discerned in both the proportion of grasses to other types of vegetation and in the absolute amount of grass pollen deposited in the reservoir through time (see below).

Vegetation Groups: Results

The overall results of the Kamalapura pollen core are presented in Figure 2, which indicates relative abundance of taxa, and Figure 3, indicating pollen concentrations. It can be seen that grasses dominate the assemblage, followed by herbs and trees. The category of cultivated species refers to non-grass cultigens. On the far right of the diagram are species introduced into India from the New World. Figure 3 indicates a decline in overall pollen concentration in the middle portion of the core, between approximately 28 and 14 cm. This decline can be seen quite clearly in the grass curve (Gramineae), the dominant pollen type, but it is a general feature of this portion of the core. The declining concentration of pollen in the core could have been caused by an increased sedimentation rate at this time. At the 24 cm level, the core contains almost no pollen, and counts from this level were not included in the diagram. There is no visually apparent stratigraphic break at this level. There are several possible explanations for this lack of pollen. One may be that the reservoir actually dried out during this period, and the consequent wetting and drying destroyed pollen in sediments near the surface. Alternately, the low pollen concentration could be seen as an extreme example of the low concentrations in nearby levels.

What can be seen in the grass curve is a marked peak near the base of the core which rises to a very high proportion of the total assemblage, approximately 90 per cent. This peak undergoes a long and sustained decline, until it reaches a minimum at about 40 cm. Following this low point, grasses rebound somewhat between 40 and 28 cm, after which they again undergo a slow and sustained decline. Because of the composite nature of the grass curve, it is difficult to interpret this pattern. It is tempting to suggest that the dramatic increase in grass pollen between 56 and 52 cm is a consequence of agricultural intensification, caused by the expansion of cultivated fields and the concomitant growth of both weeds and crops, and by the clearing of non-grass vegetation. Figure 3 indicates, however, that grass was dominant in the pollen record from the very beginning of the sequence, and in fact, the relative increase of grass at 52 cm is largely a product of a relative decrease in unidentified grains. However, these unknown types are quite unlikely to be grasses, which are easily identified. Thus, the proportional rise in grass pollen actually relates to a decrease in other taxa. The preponderance of grass at the base of the core is significant. At no other level does the relative or absolute abundance of grass pollen reach the levels it attains near the base. It is not possible to assess the proportion of vegetation types directly from the proportion of pollen types, but it is very striking that the contemporary landscape – deforested, overgrazed, virtually denuded of natural vegetation and covered by agricultural fields – does not create as strong a grass signal.

The basal grass maximum declines between 52 and 40 cm, with only a slight rebound at 42 cm. This decline is evident in both relative and absolute pollen counts, and represents a change in environment conducive to grass growth. The cause of that change is open to interpretation; it may represent a decrease in cultivated grasses, or in open habitats favoured by wild grasses, some combination of factors. Between 14 cm and the top of the core, grass pollen increases in absolute terms, but continues to decrease as a percentage, largely due to the increase in Compositae (see Morrison 1992 for more details).

Herbaceous plants exhibit a very clear pattern of growth in the upper portion of the core. Proportionally, they experience two growth peaks, at approximately 10 and 28 cm. The initial peak actually seems to reflect the striking decline in numbers of grass pollen grains deposited, however, and the concentration of herbaceous plants in the core is very consistent before the upper 10 cm, with only a slight increase between 48 and 44 cm.

Shrubs constitute only a very small proportion of the pollen record, and in several levels no shrub pollen at all was counted. For this reason, it is difficult to assign much significance to the distribution of shrub pollen. There are three periods during which shrubs appear in the record. The first two of these correspond with periods of increase in arboreal pollen, and it is probable that both trees and shrubs were responding to similar conditions at these times. Both the tree and shrub curves exhibit a decline between approximately 52 and 44 cm, during the period of most significant change in the grass curve. The loss of trees and shrubs is not precisely aligned with a growth in grass pollen, although there is a slight increase in herbaceous plants. At the base of the core, grasses already dominate the record and trees and shrubs are already undergoing a precipitous decline. The proportion of trees and shrubs remains low until about 40 cm, when it begins to increase. This pattern may indicate pressure on the woody vegetation in the study area from the beginning of the record, followed by a period of more open vegetation, with a later (and limited) regeneration of trees and shrubs.

The curve representing cultivated plants does not include any cultigens belonging to the family Gramineae. Only pollen grains which could be securely identified to genus, and which are known to have been cultivated (that is, they do not occur naturally in the area and are cultivated today) are included in this category.

Grasses and Aquatic Plants

Figure 4 indicates the concentration of three taxa of aquatic plants in the core, which exhibit a very striking pattern. There is a well-defined peak in aquatic vegetation (with a slight decline at 40 cm) between about 44 and 32 cm. The rapid growth in aquatic plants corresponds with a decline in grasses, and begins somewhat before the period in which trees and shrubs begin to reappear in the record. Normal maintenance of reservoirs includes cleaning out aquatic plants, so that the rapid growth in aquatic vegetation almost certainly indicates a period during which the reservoir was not well maintained. By the time trees and shrubs began to regenerate, the reservoir had become choked with aquatic vegetation. The rapid decline in the concentration of pollen of aquatic plants (at about 28 cm) occurs at the same time as the first introduced species appear in the record, and shortly before the possible drying out of the reservoir at the 24-cm level. Thus, the postulated drying out period follows the beginning of renewed maintenance of the reservoir. Because the Kamalapura *kere* is supplied by both seasonal runoff and the river fed Raya canal, virtually the only way the reservoir could dry out (seasonally) would be to block, divert, or otherwise stop the flow from the canal. Today, canals are periodically blocked in order to clean out silt and vegetation. Perhaps the potential drying out actually represents maintenance of the reservoir, including the removal of aquatic plants.

Most of the aquatic plants are represented by plants belonging to just three families: Typhaceae, Cyperaceae and Potomagetonaceae. Typha angustata is an aquatic or marshy-habitat herb which grows in shallow water around the edges of reservoirs and other bodies of water. Similarly, the five genera of Cyperaceae that are found in the study area grow in shallow water. In contrast, Potomageton nodosus, although it also grows in shallow water, can grow partially or almost completely submerged, so that it has the potential to invade more of a reservoir than simply its edges. The strong pattern in aquatic plants is created almost entirely by Potomageton, with some contribution by Cyperaceae.

Typha concentrations are remarkably consistent throughout the core, with a slight increase near the top and a decrease in the lowest levels.

The strong pattern exhibited by the aquatic plant concentrations in the core also raises questions about the pattern of the grass curve. Below 48 cm, there appears to be no relationship between the concentration of Gramineae and of aquatic plants in the core. During the period of maximum aquatic plant growth, however, smaller peaks in the grass curve co-occur with those of aquatic plants. It is not possible to discount the possibility that some of the grasses making up the overall curve may be aquatic species, and in the areas where grass pollen patterns echo those of aquatic plants, the possibility is even stronger. If this were the case, then the pattern of non-aquatic grass decline above 52 cm would be even more marked.

Non-Gramineae Cultivated Plants

The combined pattern of non-grass cultivated plants shows little significant patterning through time except for a slight increase in the upper levels of the core. However, some interesting patterns do emerge when this composite curve is separated into its component species (Morrison 1992). *Arenga pinnata* (gomuti palm) and *Jasminum auriculatum* (jasmine) are very rare in the sample. More common are *Cocos nucifera* (coconut) and *Ricinus communis* (castor oil plant). *Cocos* is an important cash crop on the area today, and this dominance is reflected in the larger amounts of coconut pollen between 10 cm and the top of the core. *Cocos* has its second highest concentration at the base of the core, but it quickly declines in importance before reaching a small peak between 44 and 40 cm. This pattern may simply be a product of the small sample size of coconut pollen at the base of the core, but it is at least qualitatively interesting as it indicates the production of coconuts in the Vijayanagara period (also noted in historical sources). Whether or not the apparent decline in *Cocos* in the lower third of the core is a "real" phenomenon or just a sampling fluctuation, it is apparent that overall, the earlier record of coconuts indicates that they were of lesser importance than in the later record. The more recent focus on *Cocos* production occurs at the time of the first New World species and during the period in which it was suggested that renewed maintenance of the reservoir was taking place. *Ricinus* may originally have been a native of Africa, as are many other Indian cultigens, although some botanists feel that *Ricinus* may be indigenous to India (see discussion in Narain 1974). The distribution of *Ricinus*, which may be grown as either a dry or an irrigated crop, is strikingly different from that of *Cocos*, occurring neither in the earliest nor in the latest portions of the core. The context of *Ricinus* cultivation thus appears to have been quite different from that of coconut cultivation.

Discussion

Only a very general discussion of the Kamalapura pollen record could be presented here. Interpretation of the pollen analysis from the Kamalapura core is hampered by the imprecision of dates from the core and by the lack of detailed studies relating modern vegetation dynamics in dry interior south India to the pollen record. Nevertheless, several strong patterns have emerged from the pollen analysis. These patterns include very high values for grass pollen at the very beginning of the record and a concurrent sharp decrease in the pollen of trees and shrubs. The quantities of tree and shrub pollen were reduced significantly in what is suggested to be the Middle or Late Vijayanagara period, only to undergo a rebound, probably at the end of the Vijayanagara period. In the post-Vijayanagara period, the reservoir became choked with aquatic vegetation. About the time the reservoir was cleared of swampy vegetation, the first introduced New World species appear in the record, and the concentrations of pollen also decreased, possibly as a result of increased erosion (associated with renewed clearance of vegetation?). At 24 cm, the reservoir may have dried out completely for a time.

Toward the top of the record, probably the later Colonial or the Post-Independence periods, agricultural production seems to be of renewed importance, but this agricultural landscape appears different form the

Vijayanagara period landscape in several important respects. First of all, the grass-dominated Vijayanagara record is not duplicated in the record of modern, commercial agriculture. Instead, herbaceous plants appear much more important, and specifically, Compositae come to constitute a significant proportion of the pollen flora. Coconut pollen also appears in greater quantities. While coconuts did appear in the Vijayanagara period record, their numerical importance in more recent sediments is striking, and is consistent with their current value as commercial crops. Thus, the impression of Vijayanagara agriculture is one of a pattern of land use that was already intensive from the beginning of the pollen record. Grasses did increase proportionally at the beginning of the record, but the concentration of grass pollen at the base of the core was consistently high.

Pollen analysis of Vijayanagara area sediments is still at a preliminary stage, and significant problems of chronology and interpretation remain to be addressed. Future research will include analyses of the pollen and charcoal records from additional cores and from additional sampling locations in order to place the record from this single Kamalapura core in context.

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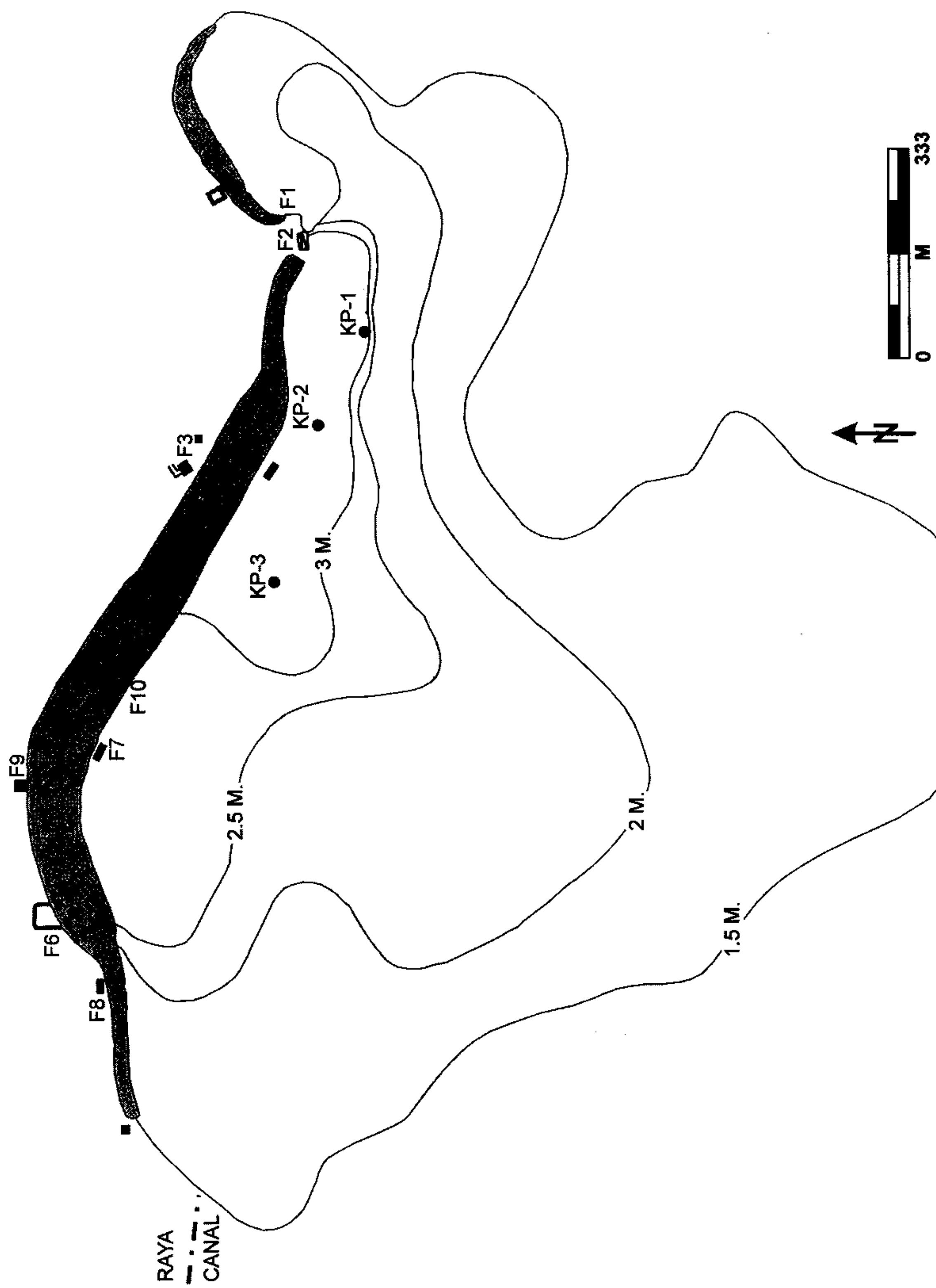

Figure 1. VMS-231, The Kamalapura Kere.

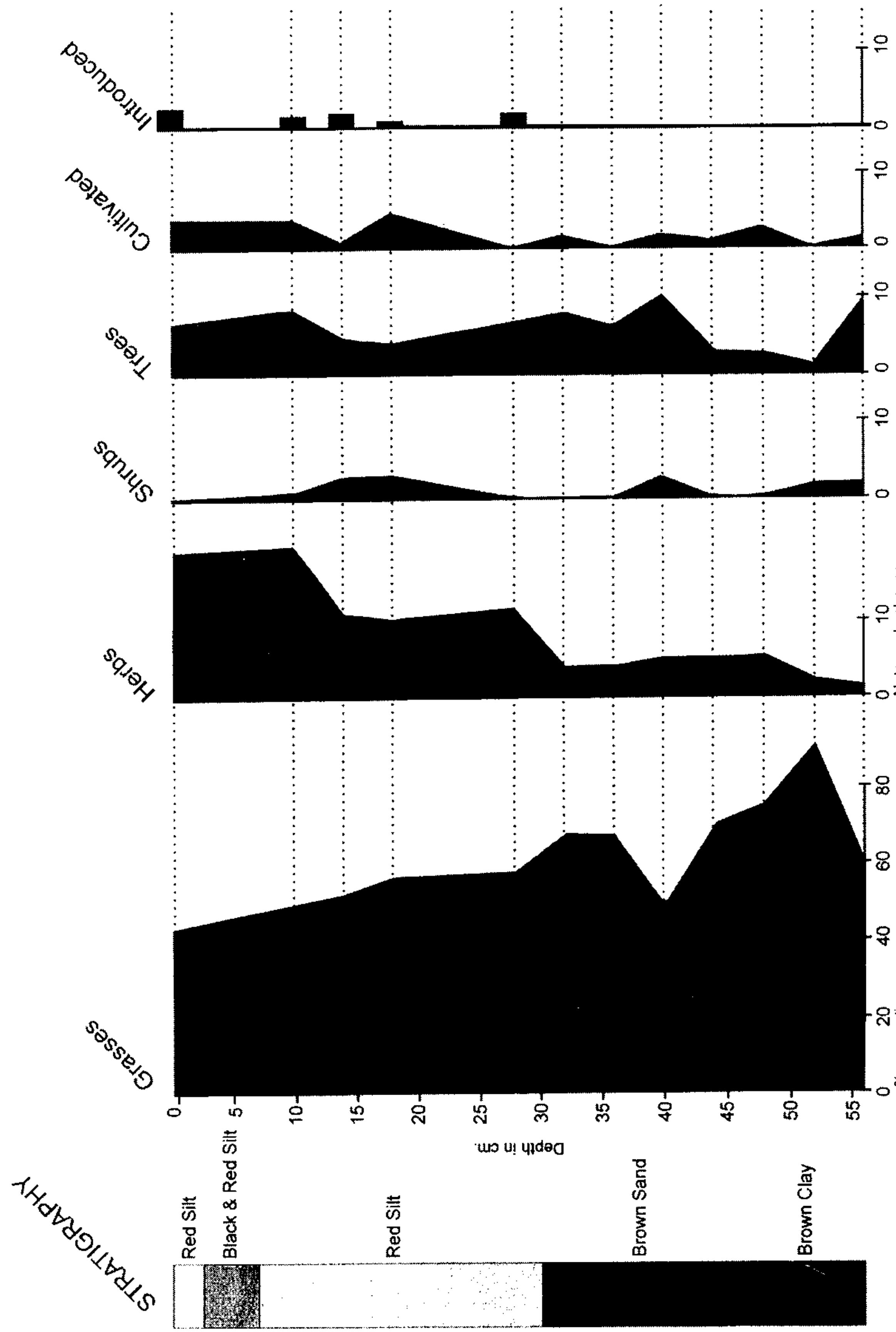

Figure 2. VMS-231, Kamalapura Kere, core 1: Percentage diagram of vegetation groups.

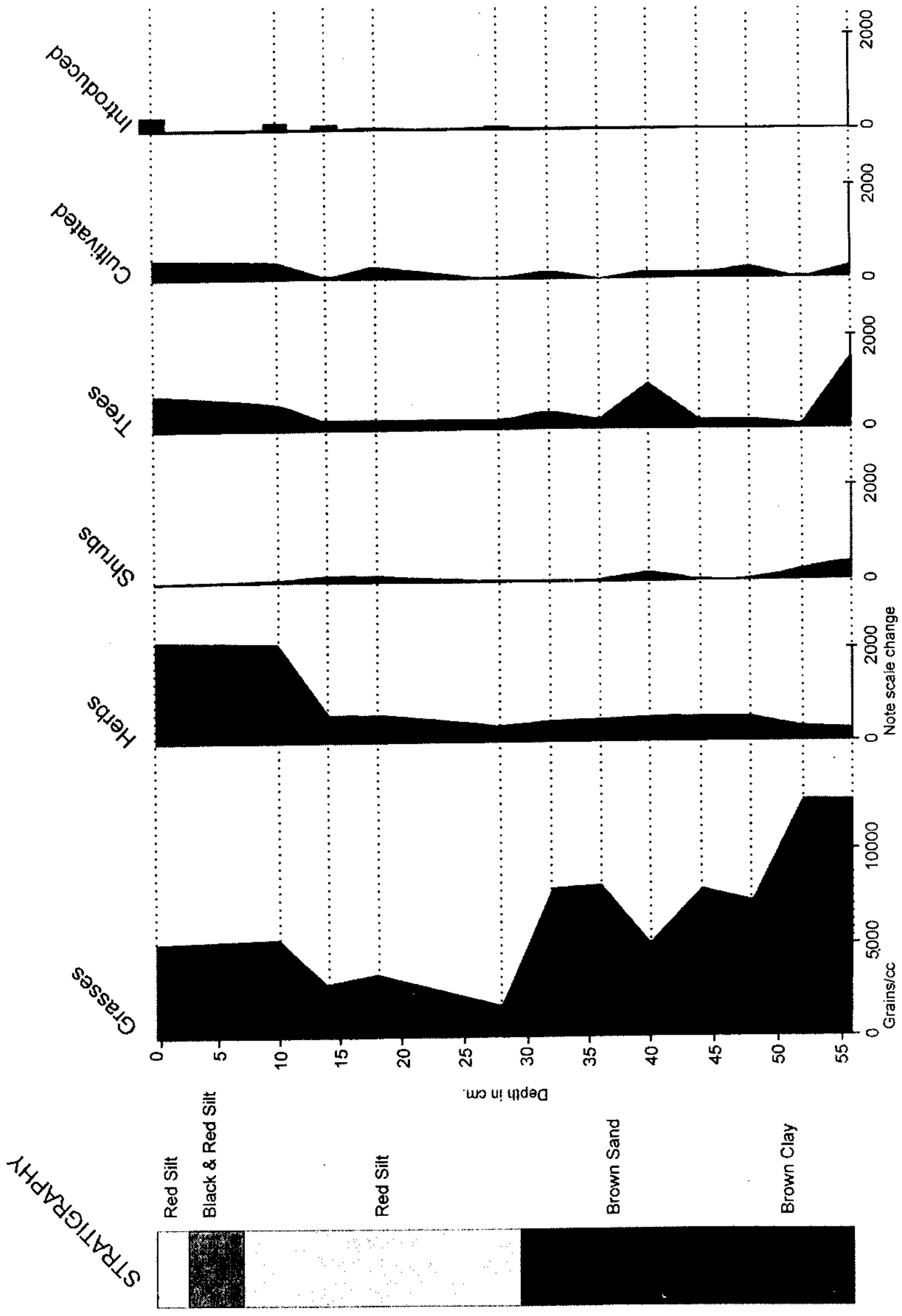

Figure 3. VMS-231, Kamalapura Kere, core 1: Concertration of vegetation groups.

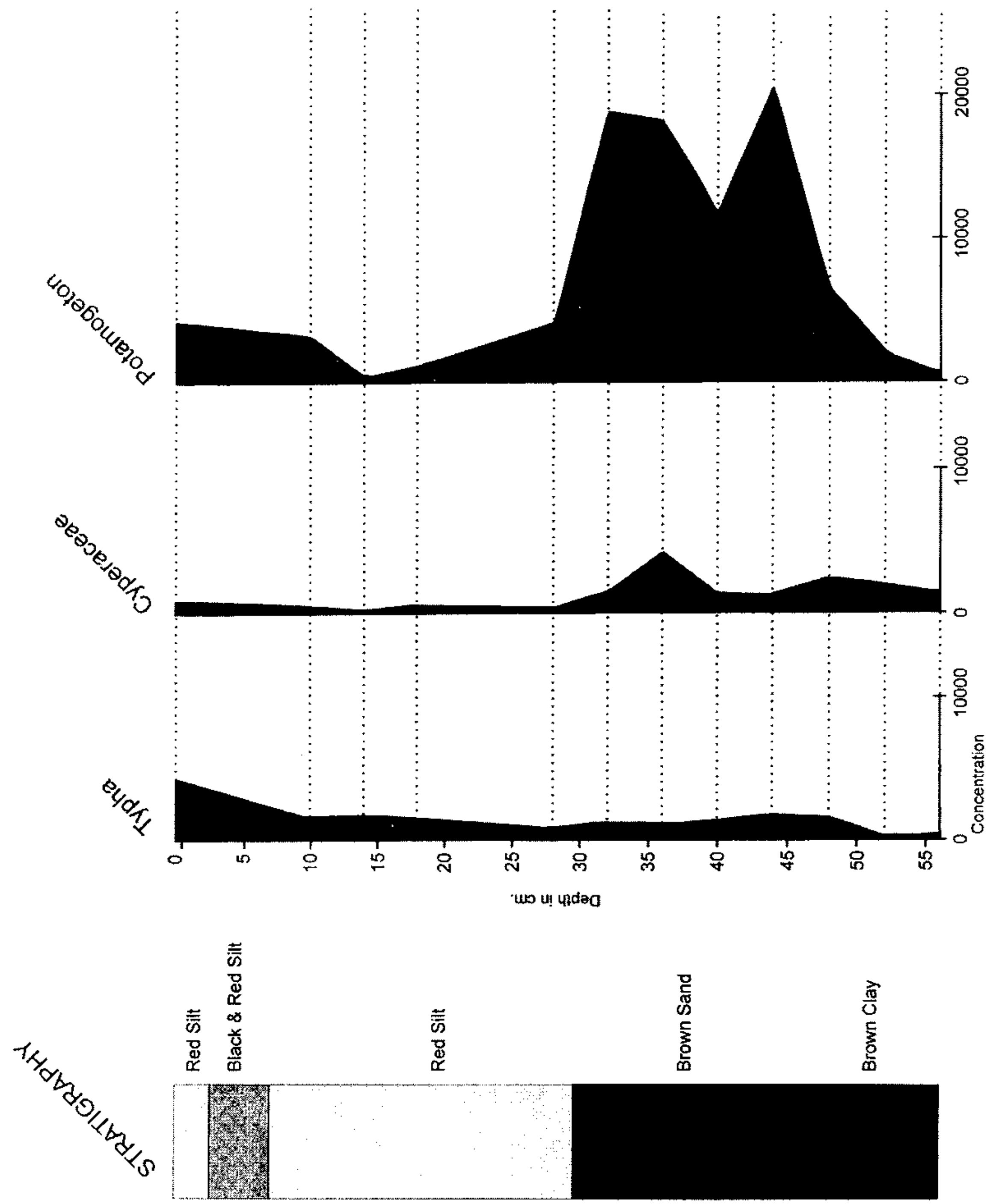

Figure 4. VMS-231, Kamalapura Kere, core 1: Concentration of aquatic plants.